Proposed Low Power Consumption of Power Monitoring and Management System Embedded RFID with WSN and IoT Technologies

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ABSTRACT

Currently, electrical power consumption especially in homes is an important issue that is being given serious attention. Since the electrical energy resource is valuable and not unlimited, it should be conserved with the aid of energy saving devices. Therefore, a concept of power consumption monitoring and management system (MMS) is designed to solve the problem of inefficient electric power usage through notification from the substation to the consumer. The proposed power consumption monitoring and management system using embedded radio frequency identification (RFID) with Wireless Sensor Network (WSN) and Internet of Things (IoT) technologies is designed to monitor and manage the power consumption in the house with wireless automation monitoring and identification. This proposed system is developed using the IEEE 802.15.4 based ZigBee-Pro

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application at 2.4 GHz. In addition, the administration section is also allocated with effectively function used for communication and notification of the client's power consumption details such as the amount of units of their electricity use, the expenditures that to be paid at present or even for warning the excessive consume of their electricity with real-time supervisory system with low load power consumption about of 1.67 W.

Keywords: *MMS, RFID, WSN, IoT, ZigBee-Pro.*

Introduction

Governments of so many countries are increasingly becoming aware of the urgent need to make the world's energy resource more efficient [1], because of the trend in world energy consumption which is gradually increasing. Therefore, improving energy efficiency is often the most economic and readily available means of improving energy security and reduction of household power consumption and in order to support better energy efficiency policy-making and evaluation. This is especially for the residential energy consumption, since many organizations have tried to observe the household energy consumption and have found that the consumed energy from 1970 to 2000 has grown [2] and this power consumption has been continuously increasing until today [3]. The International Energy Agency (IEA) also has observed and posited that agricultural, commercial, public services and residential sectors together account for most of the energy consumption, which is about 57% on a global scale. Furthermore, according to the same agency, the energy demand is projected to grow at an average annual rate of 2% between the year 2015 and 2030 [4, 5].

A study of the European Union stated that the energy efficiency of household facilitiy section can be improved by as much as 13% [6]. This can be achieved by responding to the challenge of reducing the energy consumption with provided monitoring and management system and made more efficient through the development of smart, reliable and efficient solutions that assist consumers in reducing their power consumption and leading also to a competitive market pricing.

The starting point is to be aware of how much power is to be consumed and how it is to be consumed. The proposed monitoring and management system is a feasible solution developed to monitor and report to the customer the entire energy consumption history using embedded RFID with WSN and IoT technologies. These measurements are usually made by distribution network companies using different technologies, such as electrical power meter with an embedded RFID module [7], ZigBee-Pro, WSN and IoT technologies. Likewise, the energy management used for a residential consumer is increasing as result of advances in electrical power grid technologies [8].

The objectives of this research are thus as follows: to develop a wireless automated data monitoring instead of the human to human (H2H) communication with the concept of Machine-to-Machine (M2M) communication using active RFID technology based on WSN with IoT technologies, to characterize the proposed system with green technology realization with low power consumption about of 1.67 W and to analyze the real-time consumption during its transmission and receiving conditions.

The remainder of this paper is organized as follows: Section 2 contains the Research Methodology, which basically is for the architectural design of the proposed system while Section 3 contains the Experimental Results and Discussion which is subdivided into Current Calibration and Current Consumption during transmission and reception of data. Lastly Section 4 concludes the paper.

Research Methodology

This section is involved with the research methodology of the proposed power consumption monitoring and management system. All details are explained in the following subsections.

The proposed MMS using embedded active RFID consists of two main parts, namely the data monitoring end device and the RFID reader tag module which are normally together with a work station. Its details are described as follows:

Architectural Design of the Data Monitoring End Device

The proposed MMS end device is supplied by using the power source which is taken from the household electrical power meter. By this way, it is free from the problem of battery life time limitation because of the smart design of power management circuit. It consisted of a Microcontroller unit which is the main part to organize and drive each section effectively. The Arduino Uno is chosen to be a main board because it can support an internal flash memory unit and 32-8 bit registers with assorted programmable I/O lines. Moreover, it readily functions as the analog and digital ports [9].

In the design, the external memory and real-time clock (RTC) are added to the proposed MMS end device system to support and stand-by the capability of information logging and also in case of an electricity outage, the module still records the last information of accumulated power consumption without data loss.

Moreover, the power sensor which contains the current and voltage sensors functions to sense the power consumption from the AC appliance loads. On the other hand, the control and alarm unit is intended to facilitate the setting up of an amount of Kilowatt-hour usage for the consumer. This means that the power consumption requirement by a consumer can be controlled and fed into the system. In case of a consumed power value being higher than a set up power level, the control and alarm unit will immediately send alarm and alarm to the consumer through a display module in terms of current and accumulated power consumption and report to the nearest base station.

The last section to be discussed is the wireless RF sensor. The ZigBee-Pro was adopted and embedded into the proposed MMS to work as wireless personal area network (WPAN) at 2.4 GHz with communication data rate of 250 Kbps [10]. The completed proposed MMS diagram is shown in Figure 1.

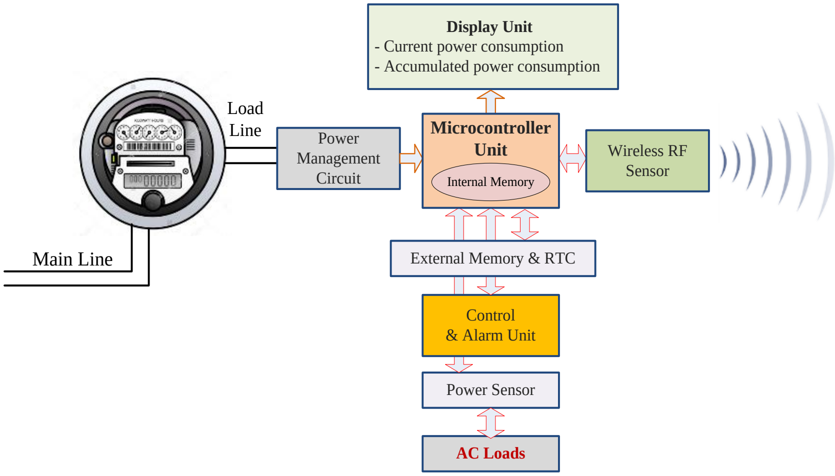

Figure 1: The proposed MMS end device block diagram

Fundamental Programmable of the Proposed MMS module

The proposed MMS is embedded and programmed with multiple-functions as mentioned in Fig 1. In this subsection the principle of power sensing is displayed. It is an energy sensing from a load in a unit time based on alternating voltage $v(t)$ with amplitude $v(o)$ and applied to a load with current $i(t)$ calculating through the load with an amplitude $I(o)$ and phase φ between them [7]. Moreover, the whole functions of the proposed MMS will be demonstrated by the flowchart in Figure 2.

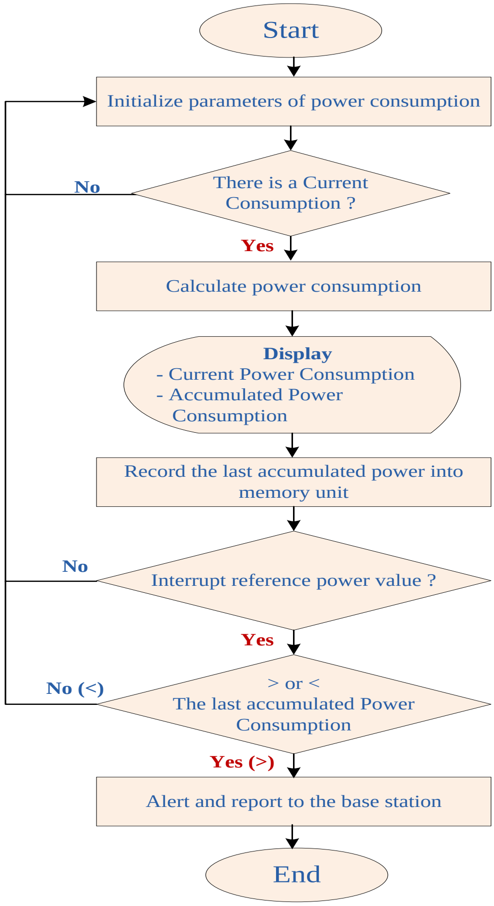

Figure 2: Flowchart of the proposed MMS end device

Architecture Design of the Reader

The proposed MMS employs three technologies to monitor the power consumption information data from a household electrical power meter which are RFID, WSN and IoT platforms. The tag-reader communicates by using the RFID protocol based on IEEE 802.15.4 LR-WPAN standard. The universal electrical power meter with embedded active RFID tag communicates with the reader RFID tag while the RFID reader tag is designed to communicate with the base station through the Microcontroller main board embedded with WiFi shield module based on the IEEE 802.11b standard. The components are integrated into the reader module as shown in Figure 3.

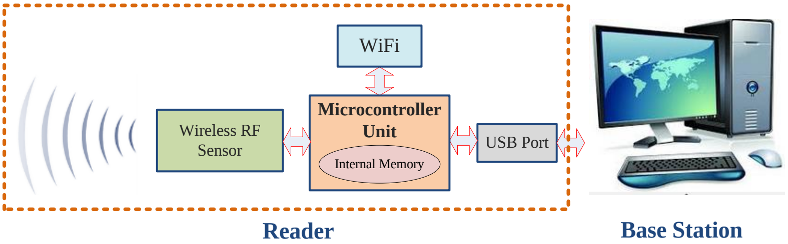

Figure 3: Architectural design of the proposed reader module connected with the base station

Proposed MMS Framework

In this section, the framework is presented to show the effective use of three technologyintegrations, which are RFID, WSN and IoT platforms to monitor the energy data of the residential electrical power meter.

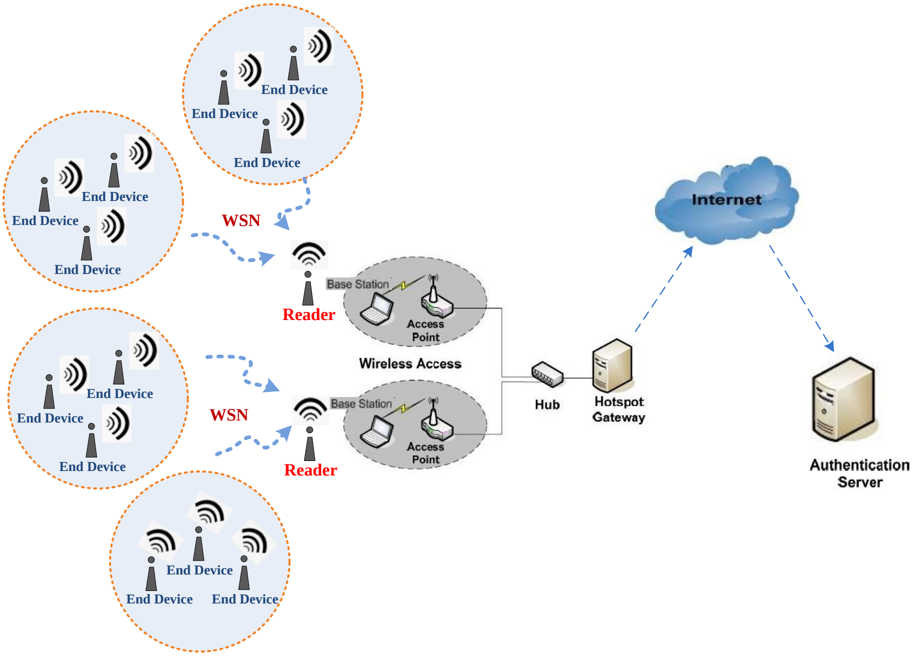

Figure 4: Proposed MMS framework with multiple technologies (RFID, WSN and IoT)

The proposed system can fulfill the requirements of clients and utilities to reduce manpower source, save time in the billing process, remove errors that sometimes happen from human and non-human factors. It is useful and import in our daily lives and more manageable due to their low cost. The growing development in wireless sensor application has created the needs for protocols and algorithms for large-scale self-organizing ad-hoc network that consists of hundreds or thousands of nodes applied with IoT technology which more serve to facilitate the clients to acknowledge the information on their power consumption with proposed real-time monitoring MMS system. The framework structure is as shown in Figure 4.

Experimental Results and Discussions

The experiment performed in this paper is to exhibit the performance of the proposed MMS in terms of current consumption during its transmission and receiving processes. The MMS embedded active RFID end tag is set to communicate with the MMS reader within a suitable distance of 3 m [11]. The measurement and analysis of the current consumption were conducted by transmitting the packet samples of data during the operation mode. The experimental results were obtained based on the performance of transmission data followed by a comparison with the receiving condition. The test analyzed the characteristics of the MMS end tag by examining its current consumption as shown in Figure 5.

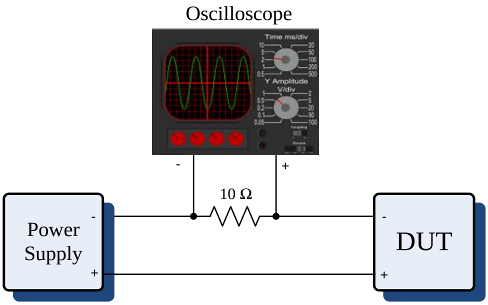

Figure 5: Current consumption measurement of the proposed device under test (DUT)

The current tracking in each component module that is contained in the proposed MMS module is calibrated and clarified in this section to show that the module is work with low power consumption and complies with green technology policy [12, 13]. The consumed current of each mode is declared as in Table 1 below.

Table 1: Power consumption in each operation mode

Operation Mode	Current Consumption(A)		Power Consumption(W)	
	ZigBee	WiFi	ZigBee	WiFi
Transmission	0.1375	0.6684	1.6500	8.0208
Reception	0.1187	0.1272	1.4244	1.5274
Idle	0.0869	0.0923	1.0428	1.1076
Sleep	0.0625	0.0762	0.7500	0.9144

By the results, it was discovered that the electric current consumed by the proposed MMS at low rate is about 137.50 mA during its transmission mode. Thus, the power consumption can be calculated by the obtained current multiplied by the voltage source 12.0 V, hence the total power consumption is exactly about 1.6500 W. The energy consumption of each prototype system design is the critical issue that should be considered and realized as such as Wang, Fang and Zhang (2012) [14], in which have analyzed the power consumption during transmission for multiple hop communication under water acoustic networks. The power saving issue is realized to reduce energy use, which becomes significant at longer distances of network communication as well.

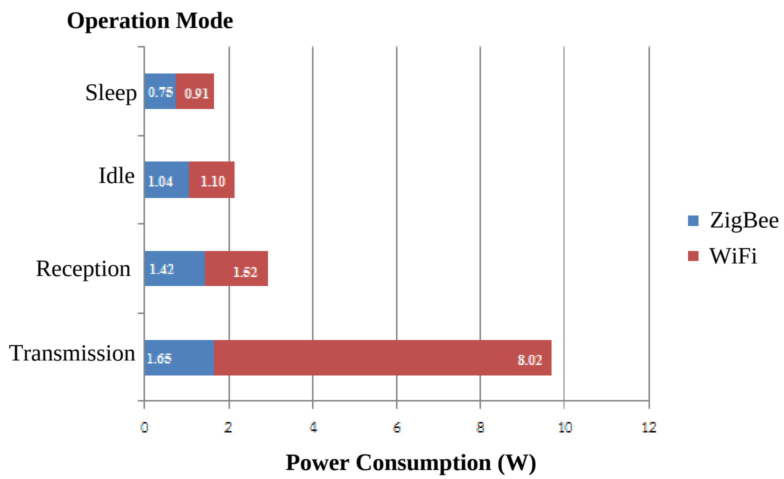

Figure 6: Comparison of MMS's power consumption in each operation mode between ZigBee and WiFi technologies

Figure 6 shows the comparison of power consumption in each operation mode of the proposed MMS between ZigBee and WiFi technologies. It was found that the transmission mode consumed highest power which was about 1.650 W, followed by the reception mode which consumed power of about 1.4244 W and idle mode 1.0428 W, and minimum power consumed was the sleeping mode, which was about of 0.75 W to maintain the circuit module during its energy saving process. These obtained results are valuable to present that the proposed system has responded to the green technology trend to save energy in the realization of low power consumption compared with WiFi technology [15]. Although, there is a research area similar to the proposed system such as Kazi, R. & Tiwari, G (2015) [16], in which the authors worked on the IoT based industrial home wireless system, energy management system and embedded data acquisition system to display on web page using GPRS, SMS and E-mail alert, but did not consider the power consumption issue which is one of the most important issues to consider in terms of load system design because this is part of an end device for the consumed power of an householder.

Consideration of Current Consumption Signal

In this section, the captured signals during its receiving and transmitting modes are proposed by repeating for 10 times using a digital oscilloscope to get an average value obtained, Selvig [12]. The average current consumptions during its transmission and reception conditions were 136.50 mA and 118.01 mA respectively as shown in Figure 7.

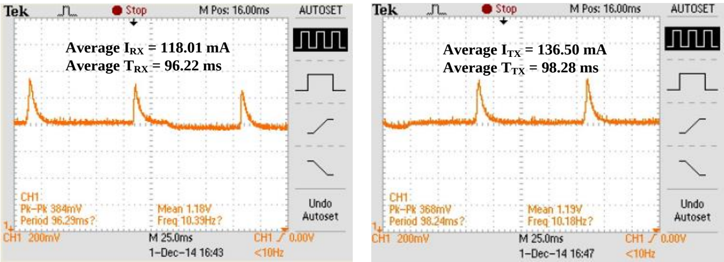

Figure 7: Current consumption during cycle of the (a) receiving and (b) transmission conditions for the proposed MMS module

The differences in terms of current consumption, period and pulse width during the receiving and transmission are observed to be slightly small. The obtained results are consistent with the theoretical as mentioned in the data sheet [10]. Namely, the transmission current should be higher than the receiving current for ZigBee-Pro S2 module. However, both the transmission or receiving condition consuming energy much or less depends on the individual block diagram design. On the other hand the research of Karel Povalac and Peter Ligertwood (2012) [17] stated that the supply current of their application during the receiving mode consumed a higher current than the transmission condition, which is opposite of the system proposed. Therefore, it is recommended that the researchers should analyze their obtained results with the data sheet appropriately.

The Measured Current Consumption versus Distance Range Analysis

In this section, the measured current consumption during its transmission and receiving conditions versus several distance ranges is demonstrated. It was carried out to analyze the stability and performance in terms of current consumption when the distance range between the end device tag and the reader tag increased. The current consumption was measured using an ammeter with the distance range from 1 m to 60 m at indoor environment. The measured obtained results are plotted in Figure 8.

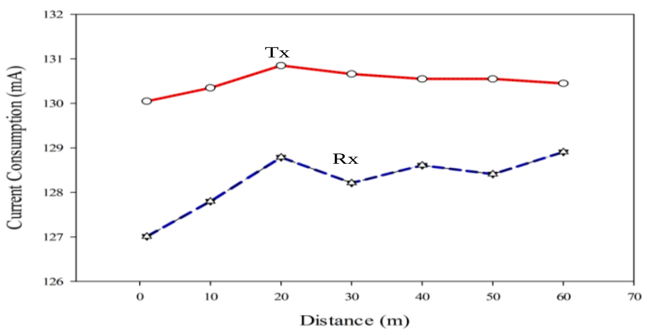

Figure 8: Current consumption during transmission and receivingof the proposed MMS

The average measured currents of the proposed MMS during the data transmission and receiving conditions were 130.49 mA and 128.14 mA respectively. The results found that the current consumption during the transmission was higher than the receiving condition by 1.80 % which is consistent to the theory that is referred to in the data sheet [10]. In addition, it was found that the measured current during transmission is lower than the theoretical value which obtained by the calculation. On the one hand, its receiving condition is higher than the theoretical which also obtained by the summation of current in each module involved.

Firstly the issue of the current consumption during the transmission process is hereby discussed. The measured current consumption of the proposed MMS was lower than the calculated one which is mainly referred to by data sheet. Actually, in the real use of ZigBee-Pro, it consumed the current to maintain its module at about 50.0 mA only which differs from what the data sheet refers to at 170.0 mA. So, the difference in current between them is 120.0 mA which caused the measured current consumption during the transmission mode of the proposed MMS to be lower than the theoretical value explicitly. The second issue, the receiving condition of the proposed system is also discussed. It indicated that the measured current consumption during the receiving mode was higher than the calculated current due to the real use of the wireless ZigBee-Pro module, it consumed current during the receiving mode and was less than the referred current (45.0 mA). Furthermore, it was found that the variation of distance did not much impact the current consumption during the data transmission or receiving processes, it worked with the stable current consumption with the fluctuation was within 0.80 mA and 1.90 mA respectively. The results show that the proposed MMS could work effectively with low current consumption, meaning that it also consumes low power according to the user's requirement.

The power consumption value was taken by MMS and sent to the central office via a reader. As long as the accumulated power consumption from the household appliances was able to be detected by the smart MMS module acting as a terminal node, the information would be transmitted back to the RFID reader via the wireless RF transceiver (ZigBee-Pro Module). To achieve remote control, the terminal device invented was added to the network terminals and microcontroller. A household electrical power meter interfaced with the smart MMS module is able to receive commands from the work station and operate together with the RFID reader as well.

The combination of alternative and pervasive technologies with low current consumption is a powerful invention to be applied for monitoring and controlling energy consumption to reduce energy demand. With an effective feedback about energy consumption and control of household appliances, users can be motivated and encouraged to change their behaviors on energy consumption such as turning of lights or reducing heat in their residence. These small changes in behavior can further lead to significant energy savings.

Conclusion

In this paper, the wireless data monitoring of an electrical power meter using the MMS focused on dual current tracking of transmission and receiving conditions is proposed. This kind of tracking is important in investigating the actual performance of an individual MMS end device with stable function and low current consumption based on the defined distance ranges of 1 m to 60 m at an indoor environment. This study is useful for the electrical power utility station and consumers as an alternative way in future's electrical consumption monitoring and billing. Furthermore, an awareness of electricity consumption in the home or building is a first step towards an efficient energy usage.

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