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Research Article

Wireless Controlling and Monitoring the Consumption Energy Meter based on ZigBee Technology

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Abstract

This paper introduced a proposed system to development the way of controlling, monitoring, and reading the consumer energy meter by remote wireless ZigBee communication network. The ZigBee is advancing global standard in wireless communications with the low cost, low data rate, and low power consumption. The traditional electromechanical energy meter was used in every consumer of the Iraqi house can be adopted by converting it to a pulse production that increase with amount of consumption. The calculates number of units consumed transfer to control circuitry represented by Microcontroller, which providing with real time clock, liquid crystal display to show consumption and time and a memory to keep consumer data when power is cut. This solution of wireless energy meter controlling, monitoring, and automatic reading system is able to send its data via wireless communication to a base station where monitoring and analysis of the data from consumer energy meter for energy management. Also, the system can avoid manual meter reading mistakes, and errors of leakage of metering reading, fast, accurate, economical, flexible and reliable following mode of electrical energy.

Keywords: *Energy meter, ZigBee, and Microcontroller*

1. Introduction

Electrical energy has become a crucial demand for human survival. The automation in the distribution of the energy is also significant to improve people's life. The rapid growth of Wireless communication and the wide use of microcontrollers, lead to large enhancements in automating many industrial sides to reduce the manual efforts. The manual energy Meter Reading was inefficient for operating purposes, which leads to dissipate human effort (O.Homa Kesav *et al*, 2012). Automated Meter controlling, monitoring, and reading systems are going to be the most important technological advancement that can be lead to an enhanced standard of living, due to the fact that metering has become a parcel and part of our lives. Also, It solves several issues of the traditional meter reading system such as the needing for human resources, delayed work, accuracy, efficiency, and unavailability of the customer during metering visit by energy man(S.Palaniappan *et al*, 2015). Billing system for energy consumption is manually done by energy man. Data collected by energy man is used for billing calculation. The manual process of billing system can be considered as a waste of time and may cause human error. Thus billing system may become inefficient and inaccurate (Mahesh Chahare *et al*, 2013).

2. Traditional Energy Meter

One of the most common types of electricity meters is Electromechanical meters that can be shown in Figure (1), has an aluminum disk placed between two coils. One coil is supplied by the voltage and the other carries the current.

The fluxes produced by the voltage and current coils generate a torque thus causing the disc to rotate. Therefore the speed of rotation is directly proportional to the power flowing through the meter as the disk rotates (Dr. Eyad I. Abbas *et al*, 2015). Therefore, the energy determine by the following equation:

$$375\ cycle\ from\ rotory\ disc\ \equiv 1KWh \quad (1)$$

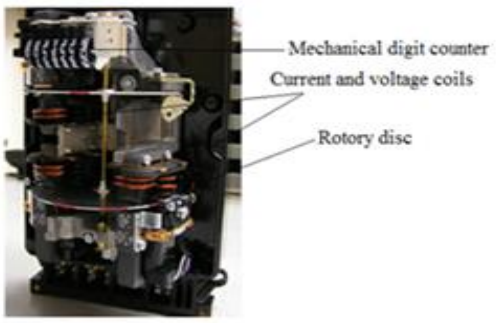

Figure 1: Traditional energy meter

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One commercially available retrofitting device uses, a reflector on the rotating disk of electromechanical meter, and an optical sensor to count the number of rotations of the disk. A device named Meter-Mimic which is fixed close to the existing meter, counts the number of rotations by using a ferromagnetic technology. The number of rotations is used to calculate the energy consumption. Another way is adding optocoupler circuit after making a proper hole in the rotating disk as illustrate in Figure(2).

The pulses produced from holes by optocoupler when the disc rotate is represented the energy consumed. Counting the pulses number by microcontroller used to estimate the energy by the following equation considering 1 pulse for each cycle:

$$375\ pulses \equiv 1KWh \quad (2)$$

The optocoupler is a component that transfers electrical signals between two isolated circuits by using light. A common type of optocoupler consists of an light emitting diode (LED) and a phototransistor in the same package. Optocoupler are usually used for transmission of digital (on/off) signals.

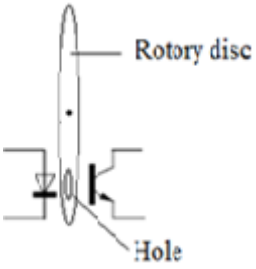

Figure 2: Improved the rotary disc

The time varying voltages and currents, and the power that delivered to the load is also time varying. This time varying power is referred to the instantaneous power. Therefore, The real power is the average value of the instantaneous power.

The Average Power depends on the rms value of voltage and current and the phase angle between them as shown in the following equation (Reza Shahrara, 2011):

$$P = V_{rms} \times I_{rms} \times \cos(\theta_v - \theta_i) \quad (3)$$

3. The Uno Arduino Microcontroller

The uno arduino microcontroller is a powerful single board computer which has a considerable traction in the professional markets. The Arduino programming is based on a simplified version of C/C++ language (http://arduino.cc Access January 2017). As known, C programming of the Arduino will be easy. An important advantage of the Arduino is that anyone can create a control program on the host PC, download the control program to the Arduino and the program will run automatically. And, by removing the USB cable from the PC, the program will keep running. Therefore, the need for a PC to run the program is no longer required and by reconnecting board to the host PC the program can be improved and debugged.

4. ZigBee Technology

With the rapid improvement in communication technology, an electromechanical energy meter can use ZigBee technology to collect the consumption data from the costumers. ZigBee is a two-way wireless communication technology that has advanced features, such as, low power consumption short distance, low data speed, low power consumption, low complexity, and low cost (N.Gokul Raj *et al*, 2013). It is mostly used in exchanging data between low power electronic devices in a short range. The ZigBee network is similar to telecommunication networks such as GSM or CDMA. The technical features include (Hung-Cheng CHEN *et al*, 2012)

1. Reliability: It uses collision prevention mechanism, then it reserves a dedicated time slot to a permanent bandwidth of the communication service, this can be avoided the conflicts and competition when data is transmitted. The MAC layer uses the verification of the transferred data, and then each packet of sends data must wait to receive verification.
2. Security: ZigBee offers data integrity authentication and check. Which use AES-128 security algorithm.
3. Power saving: due to the very short duty cycle, transmitting and receiving data has low power consumption.
4. Short delays: improved communication delays for sensitive applications. Communication time delay is very short.
5. High network capacity: the network of ZigBee can provide accommodations a maximum of 65536 devices.

ZigBee network layer support three topology structure which represent by star, tree and mesh topology. The topology tree structure and the network structure topology is obviously Point to point network. In the star topology structure, there is a device called ZigBee Coordinator, which is used to start up and keep up the devices of the network, and the other devices just to be able to communicate with ZigBee Coordinator (ZigBee Alliance, ZigBee Specification, Access January 2017). The figures (3,5, and 5) below show the topology of connection.

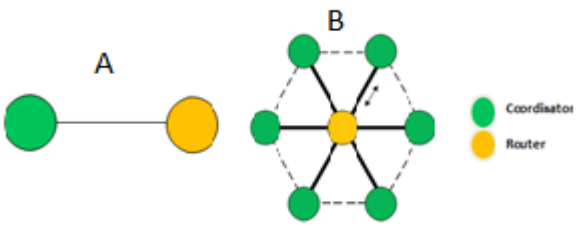

Figure 3: A- point to point diagram, B-point to multipoint diagram

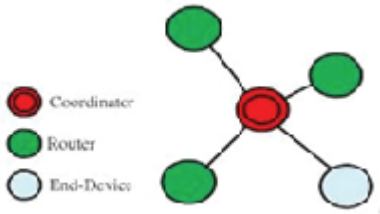

Figure 4: Star topology diagram

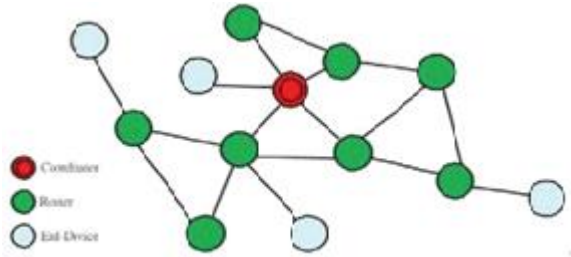

Figure 5: Mesh topology diagram [Hung-Cheng CHEN, Long-Yi CHANG (2012)]

The communication distance and coverage range of ZigBee is relatively small. The coverage range of the network can be extended by ZigBee router. The communication methods of ZigBee technology represented by three models, they are broadcast, unicast and multicast. The unicast data can be transferred to specific single device. The broadcast data can be transferred to all the devices in the network. Multicast data can be transferred to all the devices to various group, Also can be called groupcast. The main applications of ZigBee are data transfer rate among the many electronic equipment within a short range. The transfer data types are intermittent data (such as lighting control), repetitive low latency data (such as a mouse), and periodical data (such as sensor data).

5. The Proposed System

The Traditional meter device used to measure the energy consumption in each house. Interface circuit: It is an intermediate device set between the energy meter, the communication device, and the power supply; in addition, it is in charge of reading the power consumption which passes across the cable then goes to the manual energy meter and controls the power flowing that enters to the energy meter. Therefore, it is necessary to break the power flow that goes to the energy meter.

ZigBee Device: it collects and keeps updated data that is received from interface circuit. Then it passes the data to the immediate router or the concentrator upon request. ZigBee router: it passes the received data from other ZigBee Devices or transmits it to other ZigBee Devices to immediate coordinator or router. Concentrator: it has the capability to collect, store and forward metering information from other meters. The entire system parameters can be shown in the Figure (6).

The system hardware implement consist two parts:

1- Modified energy meter designed using rotation disc with hole to determine the number of revolution in watt-hour. Also, the optocoupler is a component that transfers electrical signals between two isolated circuits by using light. A common type of optocoupler consists of a light emitting diode (LED) and a phototransistor in the same package. In addition, the systems include LCD to appear the result. The Figure (7) shows the modified energy meter.

2- The station part, which consist ZigBee to receive the transmitted data from the other ZigBee device that set on the modified part. The received data will be appear on the LCD as shown in Figure (8).

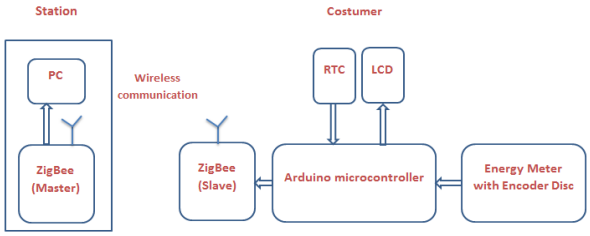

Figure 6: The proposed system

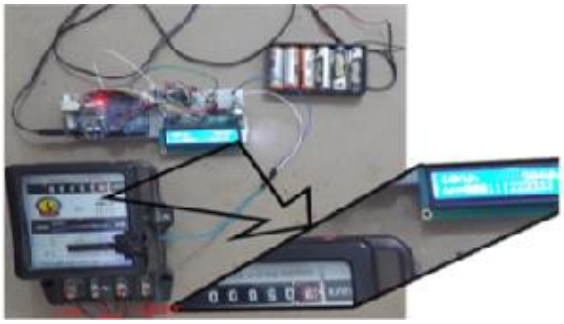

Figure 7: The modified energy meter

6. System Algorithm

This algorithm is based on C language to design the required system of energy meter interface with ZigBee to improve the billing system. The flowchart in figure (9) shows the protocol procedures for ZigBee Devices.

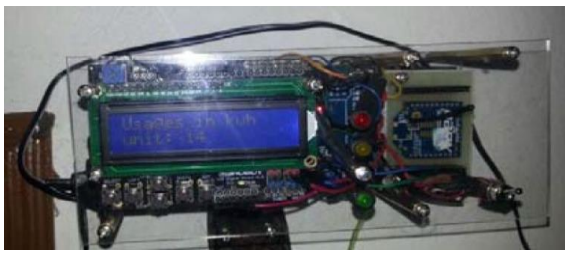

Figure 8: The station part

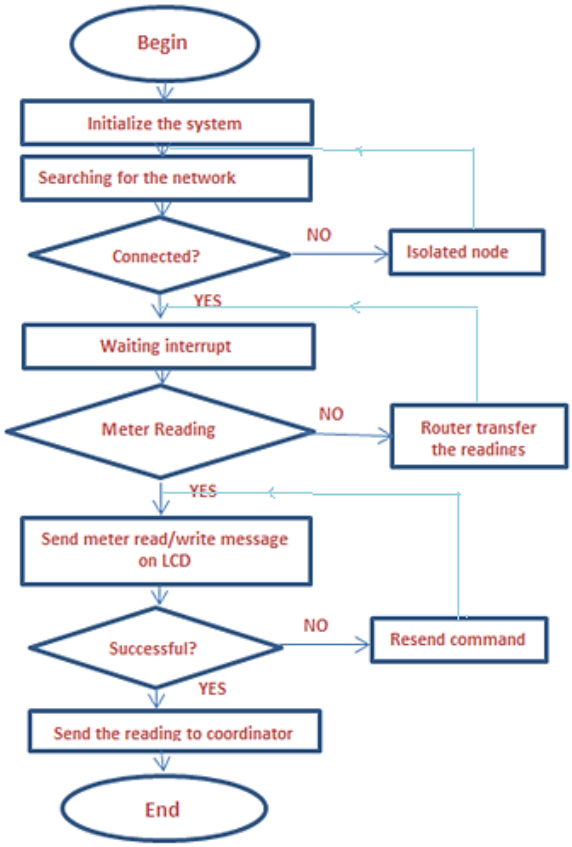

Figure 9: Flowchart of ZigBee protocol

7. Results

According to the experimental work that has been done to test the accuracy of the modified energy meter then compare it with the result of the traditional energy meter by taking five reading to the both meters. The Improved traditional meter reading show close result to the traditional one with 12% error percentage. This error percentage has been appeared due to the weight of hole mass removed in the disc, which will cause increasing in rotate speed. The error percentage can be corrected by tuning the energy meter device. Table (1) shows the energy meter readings after and before improvement. The error percentage calculated using the following equation (4):

$$Error = \frac{|meter\ reading - improved\ meter\ reading|}{meter\ reading} \times 100\% \quad (4)$$

The ZigBee in the consumer's side will send the data of the energy meter, and then the other ZigBee device that existed in station will receive the data from different consumer's meter. After that appeared the readings on LCD. Table (2) shows the readings of three consumer's energy meters at different time.

Conclusion

In this paper, Traditional electromechanical energy meter has been modified based on Arduino microcontroller board and ZigBee technology. This work has been successfully developed and tested due to the fact that the results of developed energy meter were very close to the traditional ones. ZigBee wireless communication to control and monitoring and management for energy meter improve the accuracy access power consumption message. The advantages of this system can be summarized by the cancellation of the energy man job and reduction of the error that occurs in manual billing. Also, it has an economical advantage due to the fact that it can reduce the cost of design and operation.

Table 1: Result of traditional energy meter before and after improvement

Reading	Traditional meter reading KWh	Improved Traditional meter reading KWh	Number of pulses	Error Percentage
1	30.0	30.036	11263	0.12%
2	45.0	45.054	16895	0.12%
3	55.0	55.066	20649	0.12%
4	63.0	63.0756	23653	0.12%
5	100.0	100.12	37545	0.12%

Table 2: The output data of three meters

Reading	Consumer address	KWh	Time
1	11221	67458	25/12/2017 13:23
2	11222	32851	25/12/2017 11:16
3	11223	85791	25/12/2017 10:15

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