Design Automatic Meter Reading (AMR) Data Logger with Xbee

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***Abstract* — This paper presents a low cost embedded Automatic Meter Reading (AMR) prototype system using Arduino and wireless communication based on an IEEE 802.15.4/Zigbee standard. The function is to read, monitor and record all the consumer power usage in kilo Watt Hour (kWh) using wireless communication for application in electricity usage billing without involve human interaction. Furthermore, the design was carried out in two main stages; overview, design and development, architecture and specification and component testing. The complete architecture of the proposed system in real environment requires several stage of data transmission station while the detail proposed system function is very important in design and development. A mesh protocol is selected after the protocol is proven as the best protocol in Zigbee. The 5mm photodiode has been identified as the suitable sensor for electricity meter while 30 meter is the best range for Xbee data transmission. In addition, the proposed project was successful develop and tested on the real electricity meter with Xbee data range setting at 20 meter for duration of 8 hours. The recorded data was verified and produce the same result as electricity meter recorded manually. Therefore, the proposed low cost AMR is capable to reduce the existing system complexity at the same time reduce the cost of operational and maintenance using Zigbee technology.**

Keywords - Automatic Meter Reading (AMR), Xbee, Arduino

I. INTRODUCTION

Electricity is the driving force behind the rapid development of the country in all sectors. With the rapidly increasing population, residential, commercial, and industrial area, the consumption of electricity or utilization of power increases much rapid than the user numbers due to technologies and power dependent equipment and systems. It has now become imperative for utility companies to devise better, non-intrusive, environmentally-safe techniques of gauging utilities' consumption so that the correct bills can be generated and invoices. The benefit goes beyond the power consumption. It will also be the basis for power generation and more accurate demand forecasts which will lead to more efficient usage power distribution, power generation and minimizing raw material waste.

Over the past years, metering devices have gone through many improvements and expected to become more sophisticated with more features and functions. Meters from the past and today in a few countries are electromechanical devices with very low accuracy and lack of configurability. There are so many problems require utilities companies to overcome such as electricity theft, meter modifications and more. Furthermore, meters are limited to provide the amount of energy consumption on consumer's premises.

An electricity meter or energy meter is a device that measures the amount of electric energy consumed. In Malaysia, there are two types of Domestic Ordinary Power Consumers meters: I) Single Phase, II) Three Phases [1]. Most of the newer meters are electronic meters and these meters are identifiable through the LCD panels. The billing process that is currently being practiced in Malaysia is by calculating the recorded energy consumption reading in kilowatt hour (kWh). The readings are available on the LCD display of the meter and the number display denotes the accumulated energy used in kWh [1].

Traditionally, electric meters are installed on the consumer's premises outside the premises and the consumption information or electricity usage is collected by meter readers on their fortnightly or monthly visits to the premises [2]. This method of has some disadvantages: i) Sometimes the meters are installed inside user's premises and if the consumer is not at home, the meter reader cannot read and record monthly consumption or monthly usage of electricity and then the utility company must consider an average bill-amounts of the previous months as an indicator of consumption for the current month. The estimated billing and usage of electricity are both unfair to the company and consumer. On the consumer part, if electricity has not been consumed it may cause additional financial hardship or it will become a complaint from the consumer. On the provider, this method of billing is also not suitable because it will give an inaccurate account of the overall electricity consumption in the consumer's area and may ultimately result in errors in future planning by the company. ii) Hiring

the number of meter-readers by utility company. iii) Logistics and transport costs will also be in accurate and affects the overall budgeting. Not to mention the overall affect from power generation and transportation generates pollution in the air which has a negative impact on the environment and the greenhouse effects.

In order to overcome these disadvantages of the traditional meter reading system, efforts are underway around the world to automate meter reading and to provide comprehensive information to the consumer for efficient use of the utilities [3-11]. Today most of utilities provider are looking for solutions to overcome these disadvantages until they found the solution which are Automated Meter Reading (AMR). AMR incorporates a built in transmitter in each meter and sends the data usage of electricity via Xbee module. The transmitter is built into the meter that's installed in the consumer's premises.

Furthermore, for this system, the combination of embedded system and wireless communication where it allows data transmission among the consumer's house over the ad-hoc wireless networks as shown as Fig. 1. The ad-hoc network requires no existing infrastructures unlike those WLAN or cellular networks. Each AMR node has a brain where the microcontroller will process all meter readings from its own and can be accessed in the client computer.

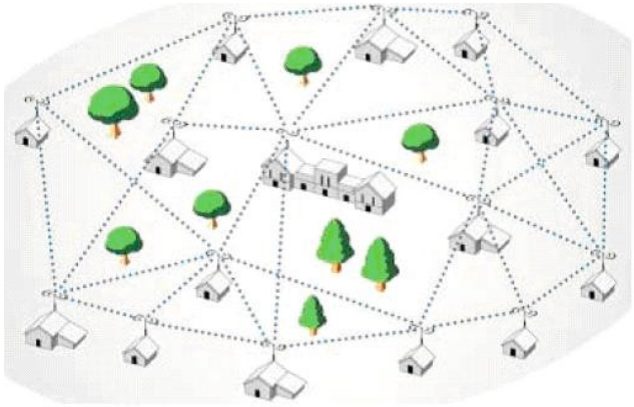

Figure 1. Ad Hoc System

This prototype has been tested in one house in site testing to make sure it can run properly and follow the standard of the meter in measuring the unit of usages of electricity in kilowatt hour (kWh). This prototype also has been monitored and tested for all functionalities in measuring the pulse from the electric meter that is installed in the consumer's premise.

In this prototype, an Xbee module based on the IEEE 802.15.4/Zigbee Wireless Personal Area Network (WPAN) has been used. The standard help to build a low-power, low maintenance and self-organizing as mentioned in [13]-[14]. Besides that, the small size and low power consumption are the other choosing factors. On the other hand, Arduino ATmega1280 has been used as microcontroller for interfaced with Zigbee using Arduino C language code in this prototype. The Arduino ATmega1280 consists of 54 digital input/output pin [15] for interface with Xbee module and other devices such as data logger, Light Emitting Diode (LED), Real Time Clock (RTC) module and Liquid Crystal Display (LCD).

In section II, the related and current practice will be detailed discussed. The details methodology will be detailed outlined in Section III. While, Section IV explained the details testing conducting on this project for verified the system functionality. The result is tabulated and discussed in Section V. The conclusion has been outlined under Section VI.

II. RELATED WORKS

Automatic power Meter Reading system using GSM network has been proposed before by [3], [10] and [11]. In this system, the AMR uses the GSM network to send the data through the GSM modem which is utilizing the GSM network to send the total power usage reading using Short Messaging System (SMS) [2]. The operational cost for SMS increased the operational cost for every meter reading. Therefore, it will limit the monitoring for once a month for reducing the additional cost due to the SMS. On the other hand, the GSM coverage is depend on the service provider. Some of the rural area is not covered by the service due the service provider facility limitation. Therefore, a not bounding communication system is required to solve the AMR issue when running in rural area or developing country.

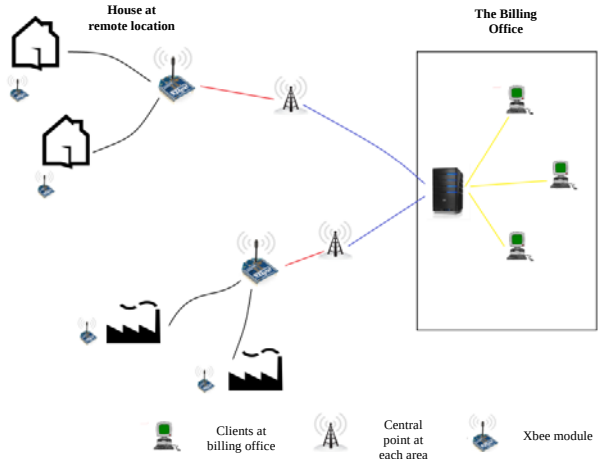

Figure 2. Overall Global AMR

III. METHODOLOGY

A. *Overview*

The architecture of the proposed system is shown in Fig. 2. The AMR system will be installed in all consumers' premises. While, the billing issues are directly sent to the billing office using the repeater facility based on the same communication protocol. This system was designed to operate by using mesh network. All the data will be sending through the Xbee module wirelessly from the consumer's premise to the coordinator Xbee. The coordinator function is

to collated the data before the will be sending to the central point in each area. The central point will be boosted and sending the signal to the database server at the billing office.

The system diagram of proposed prototype is exhibited in Fig. 3. Arduino Mega ATmega1280 has been utilized as a controller in this prototype. The LCD 16x2 has been used to display the electricity usage unit counting by the pulse sensor. All the electricity usage counting by the pulse sensor will be stored in micro SD card data logger. The recorded time list is used to obtain the accurate recorded time controlled by RTC. The Xbee module will be sent the recorded data to the coordinator attached to client computer via USB.

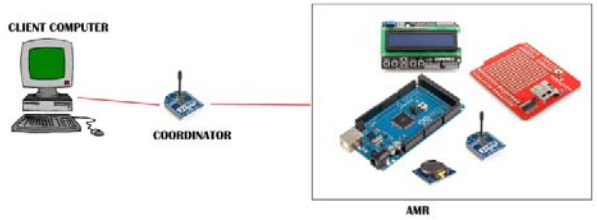

Figure 3. AMR System

B. Design and Development

The system is divided in three main parts: I) User Interfaces II) Coordinator, III) End Device (AMR)

1) User Interfaces: The user interface communicates to the user via COM port of the computer as shown in Fig. 4. The user has the acces over the sending data to the computer. The transmitted data will be recived by the coordinator and displayed in COM port via X-CTU software. Meanwhile, the X-CTU software can directly access the Xbee Module and will display the total unit in kWh of cunsumer usage in every interval hour, daily, weekly and monthly. On the other hand, the users can access the database for information about their usage. The recorded data in AMR memeory will be transfer to coordinator as per request.

2) Coordinator: The coordinator is the centre of the system, which received the data before displayed on the computer. On top of that, the total usage in kWh will be collected by the coordinator. In this prototype, three intervals setting have been used; every 5 minutes, 1 hour and weekly. The coordinator will receive the data from AMR directly at this interval of time. The setting for the coordinator is shown in Figure 4.

3) End Device: The End Device for the prototype is AMR. AMR contains a pulse sensor to detect the meter reading pulse. The pulse reading will be sending to microcontroller as a interrupt signal and connected directly to the interrupt port of the microcontroller. While, the microcontroler is using this interupt signal to count the total number of electrical usage. The pulse counting is continuing until the AMR reach the interval setting time to send the data to Coordinator. The setting for the Xbee module on the AMR is shown in Fig.5.

The total unit in kWh will be diplayed on AMR using LCD 16x2 display while micro SD has been used to record the total unit usage in every 1 hour, daily and monthly. Meanwhile, 1 Giga Byte (GB) micro SD has been choosed and it capable and consist enough storage for duration of 5 years.

The Arduino Mega microcontroller board with ATmega1280 microcontroller has been used. It consists of 54 input/output pins with 16 analog input pins while the operation voltage at 5V as details out in [15]. In this design, the accurate time on every data recorded is required. Therefore, the RTC module has been installed in this system for obtain the accurate data on specific time. Meanwhile, the generate time for sent the data through the Xbee module is also produced and generated by RTC.

The flow chart of the AMR operation is shown as Figure 6. Based on this flow chart, the AMR will display the status on LCD while the timer is start to count after the system was operated. The pulse sensor will start to send interrupt signal to the microcontroller at the same rate of the pulse from electric meter while every pulse received by microcontroller will be idicate by the blinking blue LED. The total counted unit will be displayed by LCD in kWh reading. All counted unit will be stored in data logger according to the interval 30 minutes, day, week and month while the recorded data will be trasmitted to Coordinator based on the request. The blinking yellow LED on AMR has been used to indicate the failure in data logger and data transmission between AMR and coordinator. One warning will be send to coordinator to notify the error.

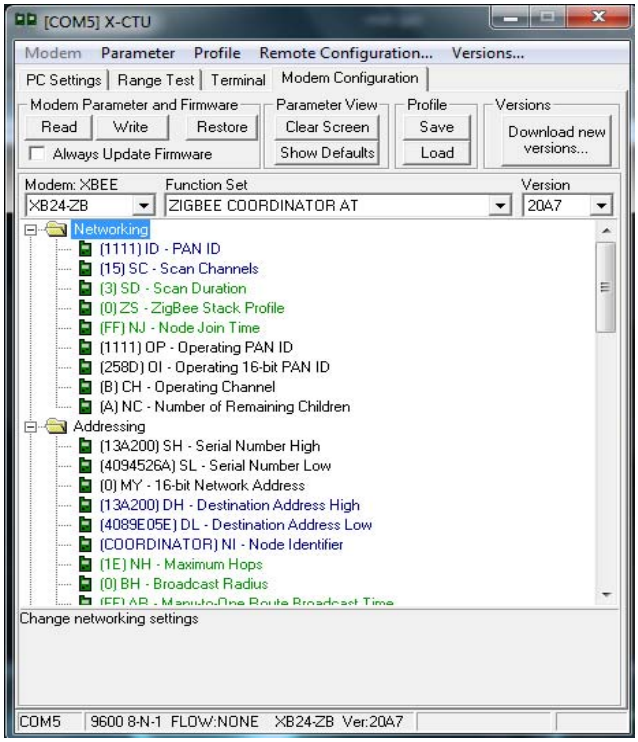

Figure 4. XCTU Setting for Coordinator

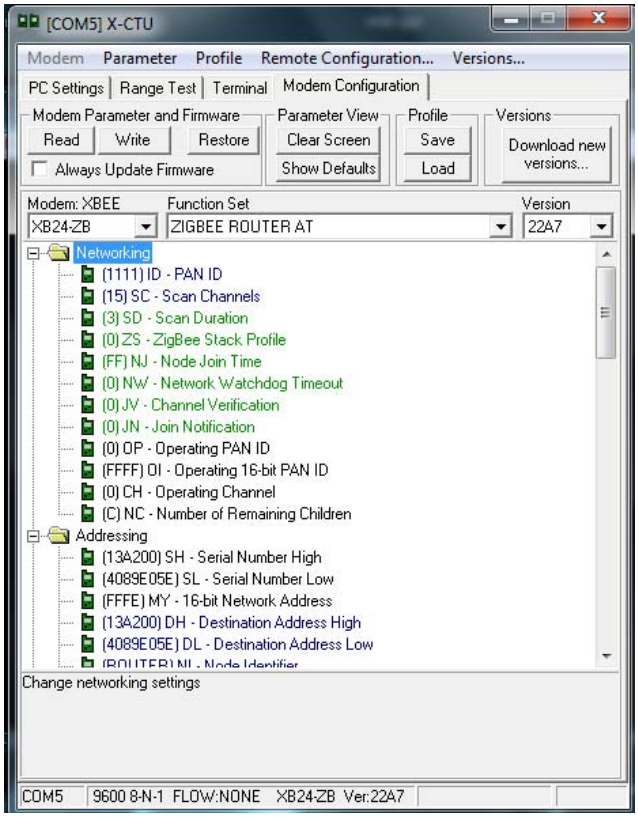

Figure 5. XCTU Setting for End Device (AMR)

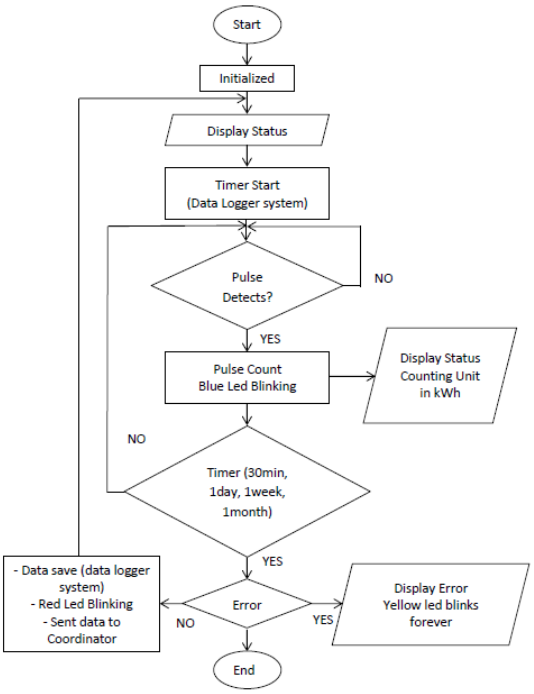

Figure 6. End Device (AMR) Flowcharts

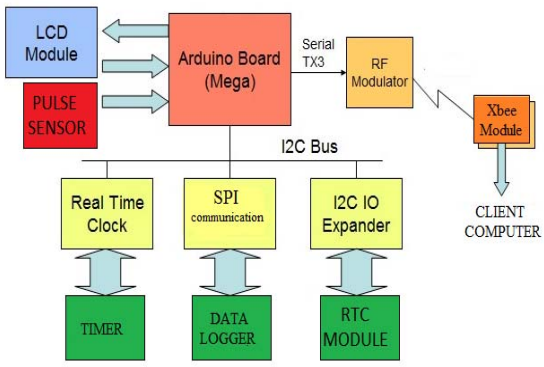

Figure 7. End Device (AMR) Block Diagram

C. Architecture and Specification

1) Network Specification:

a) Pair: This is the simplest node used in this prototype to test the functionality of this project. It has been choose due to the basic function of communication and only communicates with two radios or nodes. It required one node as a coordinator and the other node as a router or end device for complete the network [12].

b) Mesh: The mesh configuration uses a router node in addition to the coordinator radio. These radios can transmit messages to the other routers and end devices as needed.

The coordinator acting as a manager in this network and capable to route the messages [13]. More than one AMR can be attached to any router or to the coordinator using this configuration. This network is most suitable configuration for a large AMR network since it can directly sending the usage unit to the client computer or billing office.

2) Hardware specification: The AMR consists of a microcontroller, pulse sensor, 16x2LCD display, data logger system, RTC module, communication module and indicator LED for mode display. The architecture block diagram for AMR is shown in Fig.7.

3) System Limitation: The distance between Coordinator with End Devices (AMR) should not exceed 140m from the specification. On the other hand, if there are some blocked or indoor/urban areas, the networking the distance between each other should not exceed or the maximum distance of 40m.

IV. COMPONENT TESTING

A. Sensor Testing

The selection of pulse sensor required several external tests over several option for identify the suitable sensor before it can be attached to usage counting indicator LED on the electricity meter. Four different model of sensor has been chosen and tested for determine the suitable sensor which capable to read the generated blinking from the usage counting indicator LED. Photodiode sensor TLS252 and TLS257 with high sensitivity light to voltage converter is not suitable in this application due to the high sensitivity while the Photoresistor is rejected due to the accuracy in detecting the blinking usage indicator LED signal. The 5mm Photodiode connected in series with resistor is capable to sense the signal accurately including sending the interrupt to the microcontroller. Therefore, the 5mm Photodiode has been chosen as a pulse sensor in this research.

B. Xbee module range test

Several distance tests have been done to identify the suitable range for data transmission between Xbee module and coordinator. The X-CTU software has been used to perform this test using two computers complete equipped with Xbee module. The test conducted by sending initialize signal to both transmitter and receiver. In this test, the total data loss and received can be obtained from Coordinator as shown in Figure 8.

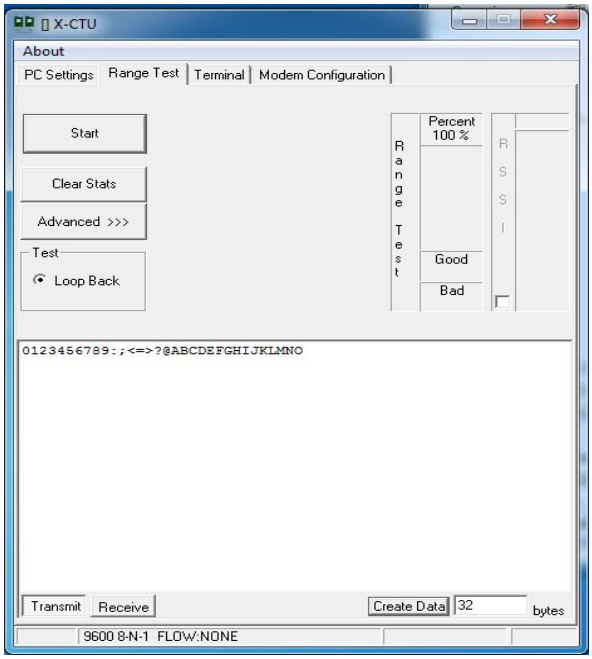

Figure 8. XCTU Rabge Test

The test was conducted at blocked and open area since some of the consumer meter located at these two scenarios. The blocked area test result is shown in Table I while the open area result is shown in Table II.

TABLE I. TEST IN BLOCKED AREA

Range	Data lost	Data receives
10m	0%	100%
20m	0%	100%
30m	0%	100%
40m	55%	45%
50m	95%	5%

TABLE II. TEST IN OPEN AREA

Range	Data lost	Data receives
30m	0%	100%
50m	0%	100%
70m	0%	100%
80m	0%	100%
90m	30%	70%
100m	75%	25%

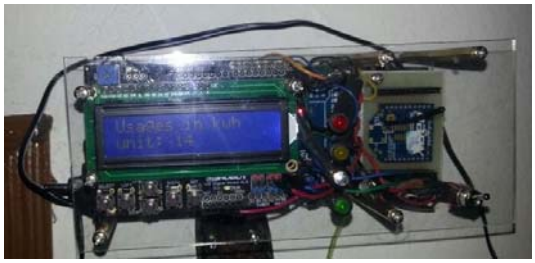

Figure 9. AMR (End Device)

V. RESULTS AND DISCUSSIONS

The project was successful developed and tested over the real digital electricity meter as shown in Figure 9. The operating range for the proposed AMR is depending on the electricity meter location. From the experiment, the best range for open area is 80m while 30m is the best transmitted range for blocked area highlighted in Table I and Table II. The recorded Coordinator data from AMR in every interval 30 minutes is shown in Figure 10. Additionally, the data recorded in Coordinator was copied and transmitted via Xbee from AMR micro SD card which obtained from the generated signal counting by pulse sensor. The duration of the transmitted data is according to the timer setting. On the other hand, the recorded data was measured in kWh with every transmitted reading recorded with date and time together for minimize the error. Apart from that, the distance in this test was set at 20 meter for reduce the error effect after the range was identify to work below than 30 meter. The test was conducted on 6 December 2012 from 0225 to 1025 and the maximum power usage recorded at 17kWh. The power usage was recorded under LOGGER.csv file in AMR data logger.

In this experiment, the recorded data from electricity meter is manually measured for verified and justify the operation and functionality. The manual measurement has been done simultaneously in this test to verify the recorded result in Coordinator. The electricity meter reading during the test at 0925 on 6 December 2012 is shown in Figure 11. Both of the images are shown the meter reading during this test.

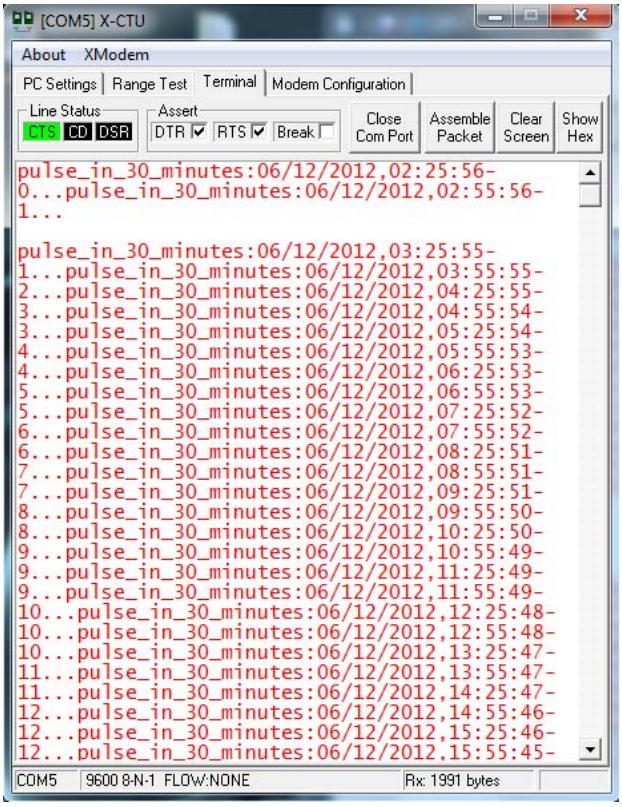

Figure 10. Data on Clients Computer

TABLE III. DATA LOGGER EVERY 30 MINUTES

Date	Time	Total usages	Date	Time	Total usages
12/6/2012	2:25:56	0	12/6/2012	10:55:49	9
12/6/2012	2:55:56	1	12/6/2012	11:25:49	9
12/6/2012	3:25:55	1	12/6/2012	11:55:49	10
12/6/2012	3:55:55	2	12/6/2012	12:25:48	10
12/6/2012	4:25:55	3	12/6/2012	12:55:48	10
12/6/2012	4:55:54	3	12/6/2012	13:25:47	11
12/6/2012	5:25:54	4	12/6/2012	13:55:47	11
12/6/2012	5:55:53	4	12/6/2012	14:25:47	12
12/6/2012	6:25:53	5	12/6/2012	14:55:46	12
12/6/2012	6:55:53	5	12/6/2012	15:25:46	12
12/6/2012	7:25:52	6	12/6/2012	15:55:45	13
12/6/2012	7:55:52	6	12/6/2012	16:25:45	13
12/6/2012	8:25:51	7	12/6/2012	16:55:45	14
12/6/2012	8:55:51	7	12/6/2012	17:25:44	14
12/6/2012	9:25:51	8	12/6/2012	17:55:44	15
12/6/2012	9:55:50	8	12/6/2012	18:25:43	16
12/6/2012	10:25:50	9	12/6/2012	18:55:43	17

Figure 11. Electricity Meter Reading during test

VI. CONCLUSION

In this paper, a prototype of an embedded AMR based on low cost Arduino microcontroller board and Xbee module has been successfully developed and tested. The operation range of the proposed AMR is from 30 meter to 80 meter depending on the building structure has increase the potential to be used in residential and commercial area while the low cost 5mm photodiode has reduce the sensing complexity of in electricity meter circuit since it only attached externally to the electricity meter. A part from that, the free data transmission cost of Zigbee has reduce the operational cost compare to GSM based AMR. Therefore, the proposed low cost AMR is capable to reduce the existing system complexity at the same time reduce the cost of operational and maintenance using Zigbee technology.

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