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DEVELOPMENT OF IOT BASED SMART ENERGY METER READING AND MONITORING SYSTEM

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ABSTRACT: *In the most of the developing countries, the effort of collecting electricity utility meter reading and detecting illegal usage of electricity is a very difficult and time consuming task which requires a lot of human resources. Energy meter reading and monitoring system using Internet of Things (IoT) present an efficient and cost-effective way to transfer the information of energy consumed by the consumer wirelessly as well as it provides facilities to detect the illegal usage of the electricity. Aim of this study is to measure electricity consumption in the household and generate its bill automatically using IoT and telemetric communication techniques. Also this study aims to detect and control the energy theft. The Arduino microcontroller is employed to coordinate the activities with digital energy meter system and to connect the system to a WiFi network and subsequently to the Internet and Server. A passive infrared sensor is engaged with the system to detect when any illegal alteration happen in the metering system. In such case, system will send an alert to the server as well as it has the facility to disconnect and re-connect the electricity supply automatically. The proposed system is capable of continuously monitor and being notified about the number of units consumed to the energy provider and consumer. The energy consumptions are calculated automatically and the bill is updated on the internet by using a network of Internet of Things. This automation can reduce the needs of the manual labours.*

Keywords: Internet of Things (IoT), Microcontroller, Electricity theft, AMR

1. INTRODUCTION

Electricity is one of the essential necessities of human being for their life. It is a non-renewable energy source therefore we must use it judiciously for its sustainable utilization (Tan, Lee, & Mok, 2007). In a country like Sri Lanka, the most of the consumers are not happy and satisfied with the services of electricity suppliers; because of traditional meter reading methods which requires huge number of man power and long working hours to collect metering data for billing process. Manual billing process is sometimes slow by various reasons. Human operative traditional metering method can lead to be inaccurate (Mohamed Mufassirin & Hanees, 2018) and (Mufassirin & Hanees, 2014).

Electricity theft is also a challenging problem to the electricity board in Sri Lanka. Sri Lanka electricity board reported that near 30% of its total supply of electricity was lost due to electricity theft (Mohamed Mufassirin, Hanees, & Shafana, 2016). During the year 2011, officials from electricity board have caught 2935 offenders who used electricity illegally and earned about 199 million LKR by imposing penalties on them (News, 2014). Therefore, the Electricity Board officials are forecasting to take tough laws such as

withdrawing electricity supplies to houses or industries who have engaged in electricity theft. The economic impacts of theft reduce the income from the sale of electricity and increase the necessity of overcharging to consumers. Only generating more power is not enough to meet present day electricity requirements. Electricity consumption and losses have to be closely monitored and managed to efficiently utilize the generated power (Mohamed Mufassirin & Hanees, 2018).

The Internet of Things (IoT) permits object to be controlled and sensed remotely through existing communication network that creates chances for more direct integration between the physical world and computer based systems. These activities are resulting in improved efficiency, accuracy and economic benefit (Pooja & Kulkarni, 2016) and (Muhammed & Hanees, IOT Based Waste Collection Monitoring System, 2017). This proposed IoT based smart energy meter reading and monitoring system in this study, measures electricity consumption of each household and generate its bill automatically using IoT and telemetric communication techniques like microcontroller. Also this study provides an effective mechanism for detecting and controlling electricity theft in household site based on infrared sensor and IoT.

The remainder of this paper is organized as follow: Section 2 discusses the objectives of the study. Section 3 discusses the existing works related to the study and Section 4 is dedicated for research methodology. Finally, section 5 concludes the paper.

2. OBJECTIVES

The main aim of this study is to design and develop a fully functional “Automated Energy Metering and Monitoring System” having innovative capabilities like remote metering, theft detection and controlling the electricity supply to the consumer. The research is about to handle all the information of the consumer regarding energy consumption using a software system.

3. EXISTING WORKS

In this study, authors investigated the existing traditional meter reading system associated with energy provider of Sri Lanka and discovered various drawbacks and difficulties. Here authors have studied different technologies and methods available to reduce the meter reading problems. Finally authors modeled out a worthy and feasible solution after analyzing the number of research papers and studies. Some of the important papers are summarized and evaluated in this section.

Tan, Lee, & Mok, (2007) suggest a development of a GSM based automatic power meter reading (GAPMR) system to solve this traditional meter reading

problems. The GAPMR system contains GSM digital power meters installed in every consumer unit and an electricity e-billing system at the electricity provider side. In this study, it is failed to classify the area in which nonexistence of trusted third party GSM network coverage.

An IoT based system that consists of Power Line Communication (PLC) modem, a theft detection unit and a WI-FI unit was proposed by (Darshan & Radhakrishna, 2015). Two separate sub systems were employed to build up the system. One of the systems is to be installed at the consumer's energy meter point while the other unit is to be installed at the utility supplier company. Generally, three microcontrollers were proposed to be used in the project; two of such will be used in the system installed at the consumers end for IoT and theft detection capabilities. The remaining microcontroller will be used in the system located at the utility office (Darshan & Radhakrishna, 2015). However, the proposed system is not cost effective as it involves the operation of two separate systems to form a functional system.

Jain & Bagree, (2011) suggest Electromechanical Energy meters are being replaced by more accurate prepaid digital energy meters. They also claim that a huge percentage of electricity income was lost due to inappropriate meter reading and monitoring. Considerable amount of revenue losses can be minimized by using Prepaid Energy Meters and prepaid cards. The prepaid card system communicates with the power service provider using mobile communication medium. In this research, the proposed prepaid meter was a good solution for revenue collection from consumer, but it increases the effort of the billing process which is very problematic to consumers. In the meantime the authors put forward about communication between prepaid energy meter and power utility using mobile communication infrastructure but the communication module and infrastructure are not clearly exposed in the proposed work.

Authors found most of the systems analysed in the literature require high cost for implementation. Therefore, there is need to develop a cost effective system as a single solution that will read the meter remotely and prevent meter tampering.

4. METHODOLOGY

4.1 IoT- Based Energy Management Technology

The need for proper energy consumption and monitoring awareness has motivated several researchers to provide innovative controlling and monitoring solutions for the energy sectors. Similarly, several companies provide Enterprise Energy Management (EEM) software applications to analyze the collected data. By generalizing those practices, a general

system architecture for energy monitoring using IoT can be resultant, as shown in Figure 1.

At the bottom layer of this architecture, there are smart meters and sensors, which may be connected through wired or wireless networks. Smart energy meters available on the market can attain several parameters (e.g. power consumption, max/min of peak voltage and power factor), hence they provide a high level of flexibility in monitoring and analyzing energy consumption.

At the mid layer, collected data are sent to a gateway, and then transferred to a local computer or to the internet via standard communications protocols, such as the ZigBee wireless technology. If wireless networks are used, sensors can be even more flexibly placed throughout the shop floor.

Eventually, data are fed into EEM software for analysis, into other enterprise systems such as Building Management Systems (BMS), Advanced Production and Scheduling systems (APS), Manufacturing Execution Systems (MES), Manufacturing Resource Planning (MRPII), or simply into the Enterprise Resource Planning (ERP). The data from smart metering systems can also be integrated with a supervisory control and data acquisition system (SCADA).

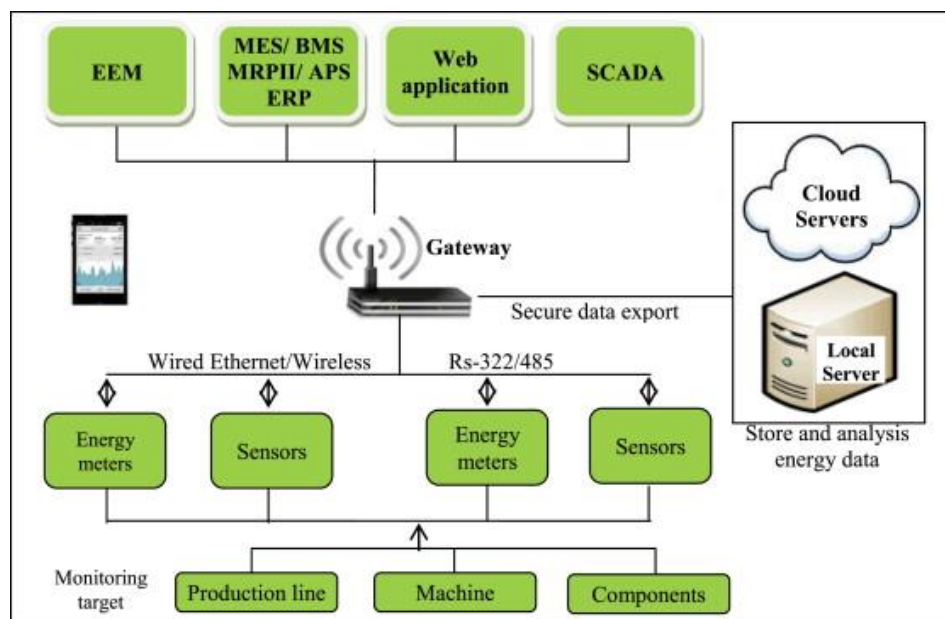


Figure 1. General System Architecture for Energy Monitoring Using IoT

4.2 Design of Method

The concept of Internet of Things (IoT) plays an important role in changing the current Internet into well featured internet (Muhammed & Hanees, 2018). The proposed IoT based smart energy meter contains mainly five modules.

1. Microcontroller module
2. Theft detection module
3. Energy Meter module
4. Automated Meter Reading (AMR) module
5. Wi-Fi module

In the design of smart energy meter, the microcontroller is interfaced with AMR module, Theft detection module and Wi-Fi module. The microcontroller is a core component of the smart energy meter system which is placed at the consumer end for the purpose of measuring the meter reading, theft detection and storing the data. This data is transferred between consumer end and energy supplier end using IoT ESP3866 Wi-Fi. The AMR module continuously monitors the meter and collects the reading and sends to the microcontroller. In the current scenario, there is a need to uniquely identify the smart meter device remotely in a reliable manner. To achieve the characteristic of device remotely we have provided IP address for each connection. In this paper we have concentrated on the theft detection, optimum utilization of power and convey the energy consumption information to the user end. The block diagram given in Figure 2 illustrates the proposed system.

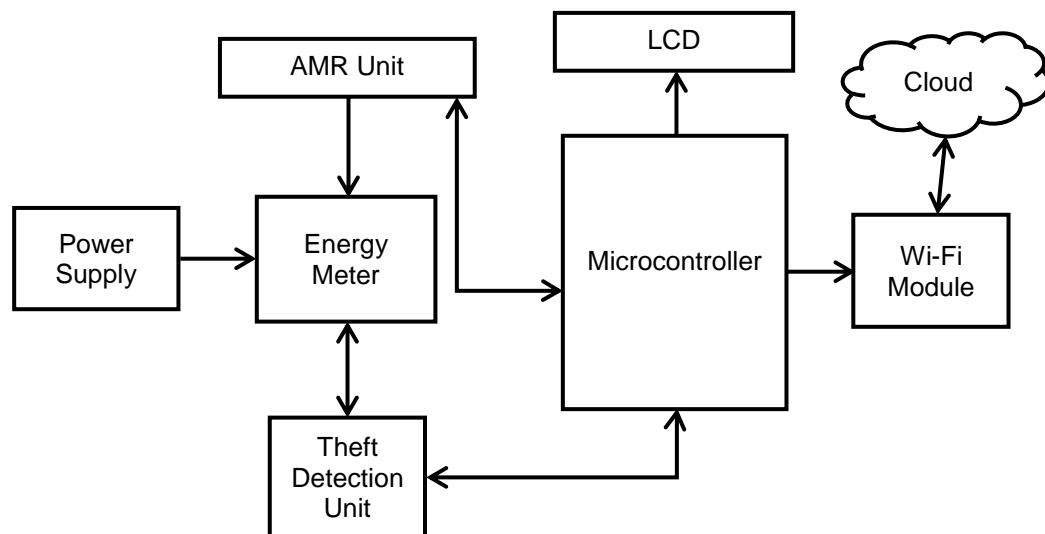


Figure 2. Block Diagram of IoT Based Smart Energy Meter Reading and Monitoring System

A. Process at Consumer End

At the consumer end, the power supply module provides the entire power needed by the system to function. Also this power supply charges the DC Backup so that when there is no power from the utility company, the DC Backup can energize the system. Microcontroller is used to collect and store the meter reading information from the electricity meter and also performs the control process and sends the

required information to energy provider such as number of units consumed using Wi-Fi module. The purpose of LCD module is to get visual information about the number of units consumed, alert messages and connection status. This is a backup power supply unit (DC backup) for the system. The purpose of the DC backup is to makes the system active even there is no energy supply from the utility company. A small 8.4V, 5600mAh rechargeable battery is used here.

B. Process at Supplier End

At the energy provider end, there is a server computer to receive the meter reading and generate the bill. If any theft is detected the system sends an alert message and disconnect the energy supply. If consumer fails to pay the electricity bill amount within the due time by the supplier, the system can disconnect and reconnect the by sending the appropriate command to the controller.

4.3 IoT Analytics and Results

Data analytics is the process of inspecting big datasets to draw inference about the content of the data. In this research, a data analytic platform was used to monitor the data sent by the energy meter so as to calculate the bill and detect the electricity theft. The Thingspeak.com IoT Data Analytic was used to visualize the status of the meter on the Internet. The infrared sensor senses when the meter has been tampered with, sends signal to the controller and network interface units. The network module connects the meter to the Internet by first connecting to an Internet-ready WiFi network and subsequently uploads the status of the meter to the Internet. An energy providing company may have several energy meters to be watched and may not be able to effectively monitor the meters at the same time but with the use of a data analytic several meters can be monitored at the same time effectively. Figure 3 shows a sample interfaces that display the unit consumed and respective bill for it in the server.

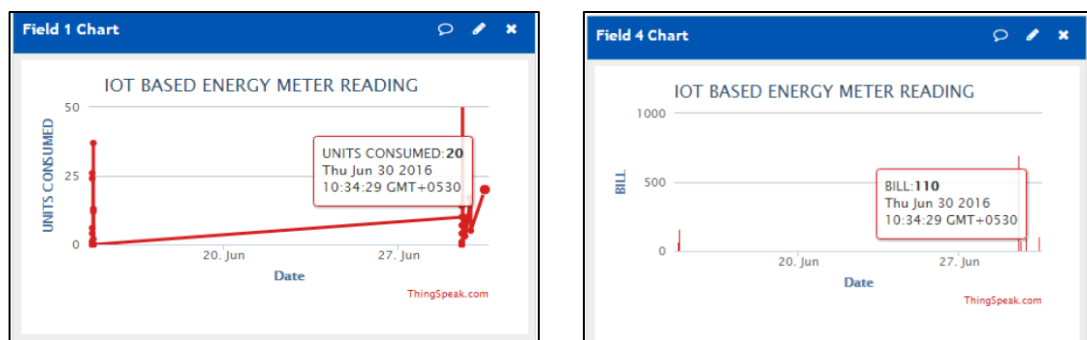


Figure 3. Sample Interface of the Consumed Unit of Energy and Bill in the Server

5. CONCLUSION

IoT based smart energy meter reading and monitoring system was proposed in this paper. The system provides many significant advantages, such as wireless data transmission, low-workload, remote monitoring and controlling, anti-theft mechanism and less-expenses. The system would provide a simple way to collect the meter reading and detect an electrical power theft without any human involvement. The use of embedded microcontroller and Wi-Fi module increases the stability of wireless data transmission. By using this system the customer can anytime check their consumed unit and bill in the Internet in which paper is not required for billing which saves paper and printing cost. The bill can be paid using online customer support system. In future, the project can be integrated to form smart cities using Internet of Things based sensors as done globally. When compare with the existing GSM based and other traditional energy metering and monitoring system, the propose system is more efficient and cost effective. It allows the consumer to check the energy consumption and bill any time they login to the system whereas other existing system send the bill monthly or on request to the customer.

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