A Multi-Interface Meter Concentration Unit to Improve Residential Energy Efficiency Awareness

BAYCAN VURAL, ESER TAKMAZ
R&D Center
Panasonic Eco Solutions Turkey
Abdurrahmangazi Mah. Ebubekir Cd. No:44 34887 Sancaktepe - İstanbul
TURKEY
bvural@viko.com.tr http://estr.panasonic.com/tr

OĞUZHAN URHAN
Electronics & Telecom. Eng. Dept.
University of Kocaeli
Umuttepe Campus, 41380 İzmit-Kocaeli
TURKEY
urhano@kocaeli.edu.tr http://www.kocaeli.edu.tr

Abstract: - This paper presents a multi-interface meter concentration unit that can read meters in homes by making use of commonly utilized wired and wireless interfaces. The system developed utilizes Wireless Meter Bus (WM-BUS) and RS-485 interfaces to read different meters such as electricity, gas, water. The measured consumption amounts can be provided to household via Bluetooth interface. A mobile device application is developed for this purpose to show past and current consumption values. By this way, it is aimed to raise awareness of energy consumption in residential usage. Additionally, measured consumption data by the device can be accessed by utility companies via internal GPRS interface to enable efficient smart grid applications.

Key-Words: - Energy Efficiency, Automatic Meter Reading (AMR), Home Concentration Unit (HCU), Smart Home.

1 Introduction

One of the main target of the smart grid concept is provide a communication infrastructure similar to the Internet for energy business. Within this scope, there are bidirectional power and data transfer opportunities which could improve existing services in many ways. A general overview about smart homes and smart grids is presented in [1] where it is concluded that smart meters are main actors for the integration of these concepts. Additionally, as described in [2-7], it could be possible to reduce energy consumption of the household using the infrastructure provided by smart meters. For example, in [5], it is shown that it might be possible to achieve by about 10% reduction in gas consumption by making use of an additional display separate from the meter. In [6], it is shown that it is possible to achieve by up to 18% consumption reduction in electricity when a TV or PC is utilized as the display. It is concluded in [7] that, user friendly displays showing instantaneous usage and providing feedbacks can be useful for this purpose.

Day by day old fashioned electromechanical meters are replaced by new generation smart meters which provide higher accuracy, advanced thief prevention and some additional functionalities. These smart meters generally include a microcontroller to compute the consumption and also enable meter read through a wired (e.g. RS232, RS485) or wireless (e.g. IR, RF) interfaces. In recent years, automatic meter reading (AMR) attract plenty of attention because it may present many benefits such as automated billing, real-time pricing, outage notification, etc. [8].

There are several different ways to reading consumption from the meters in smart grid concept such as power line communication (PLC), short range and long-range wireless communication. In the case of power line communication, existing power lines are also used for data transmission. However, because of the distribution transformers and underlying structure (e.g. noise and attenuation) of power lines, it is not possible to have a single PLC network to cover a large area. Thus, data coming from PLC modules which are installed in homes need to be combined and transferred to a reliable data network by a concentration unit. In [9], meters are read through RF and meter data is transfer to a data concentration unit via PLC. Finally, the collected data are transmitted to a control center using fiber infrastructure. A noise reduction technique is presented in [10] to improve meter reading performance over the PLC networks.

In the case of short range wireless communication, mostly used options are Bluetooth and ZigBee (or similar wireless sensor network - WSN- protocols). In [11], meters are read through Bluetooth interface and transfer of these data via fixed-line or wireless telephone networks is discussed. WSN concept can also be utilized in meter reading [12]. For example, in [13], a meter reading system based on IEEE 802.15.4 protocol is presented with a pilot application. The collected meter data in wireless network is then transferred to IP network using a WSN-IP network gateway.

Another approach to read meter data is to utilize a long-range communication approach such as GSM, GPRS, 3G, WiMAX (Worldwide Interoperability for Microwave Access) or 4G LTE (Long Term Evolution). In [14], a GSM interface module is integrated to electricity meter and consumption is read by making use of SMS (Short Message Service). Meter data is read over a serial interface in [15] and several meter reading are combined in a unit so-called as "Collector". Next, these data are transferred to a management center by making use of GPRS/3G interface. Possible use of WiMAX in smart grid applications is discussed in [16] where a comparison between broadband over power lines (BPL) versus WiMAX reveal that the WiMAX has plenty of advantages over BPL such as network infrastructure and cost. Thus, it may be probable to have this kind of broadband services for meter reading applications in future. In [17], a detailed coverage and capacity analysis of 4G LTE for smart metering applications are given. It is concluded that this kind of metering application may suffer from coverage rather than capacity. Thus, when the amount of data to be transferred is considered, the coverage problem should be focused.

In this paper, we present a Multi-Interface Meter Data Concentration Unit (MI-MDCU). The proposed MI-MDCU has RS-485 and WM-BUS interfaces for meter reading whereas it is equipped with Bluetooth and GPRS interfaces for data transmission to household, other MI MDCUs and utility companies. One of the main target of the MI MDCU is to raise energy efficiency awareness by providing instant and past consumption for household. A mobile device interface based on Android operating system is developed for this purpose. This application is able to provide push notifications and detailed analysis of current and historic consumptions. The MI MDCUs can transfer meter consumption data to another available MI MDCUs over Bluetooth and thus it is not necessary to have a GPRS interface for each MI-MDCU. An MI-MDCU can be configured to gather consumption information from other the MI MDCUs and provide these information to a data-center.

The paper is organized as follow. A general overview of the proposed system is described in Section II whereas system implementation is explained in the subsequent section. Finally, Section IV concludes the presented system.

2 System Overview

The MI MDCU presented in paper allows two different interfaces for meter reading and two wireless interfaces for meter data transmission as shown in Figure 1. In our specific implementation, water and gas meters are read through the WM-BUS which is a commonly utilized protocol for wireless meter reading in short distances (by up to several hundred meters in practice). The consumption of the electricity meter is read over the cabled RS485 interface. It is of course possible to read different meters supporting WM-BUS and RS485 interfaces.
The consumption data read from these meters can be transmitted to household user or another MI MDCU through Bluetooth interface. We developed a mobile device application for this purpose. This application allows users to observe instant and past consumptions.

It is possible to connect a GPRS modem to developed MI MDCU via serial RS 232 interface. By this way, consumption values can be read by service providers (i.e. utility companies) remotely and automatically. Note that, it is possible to gather consumption of the various MI¬ MDCU to a single

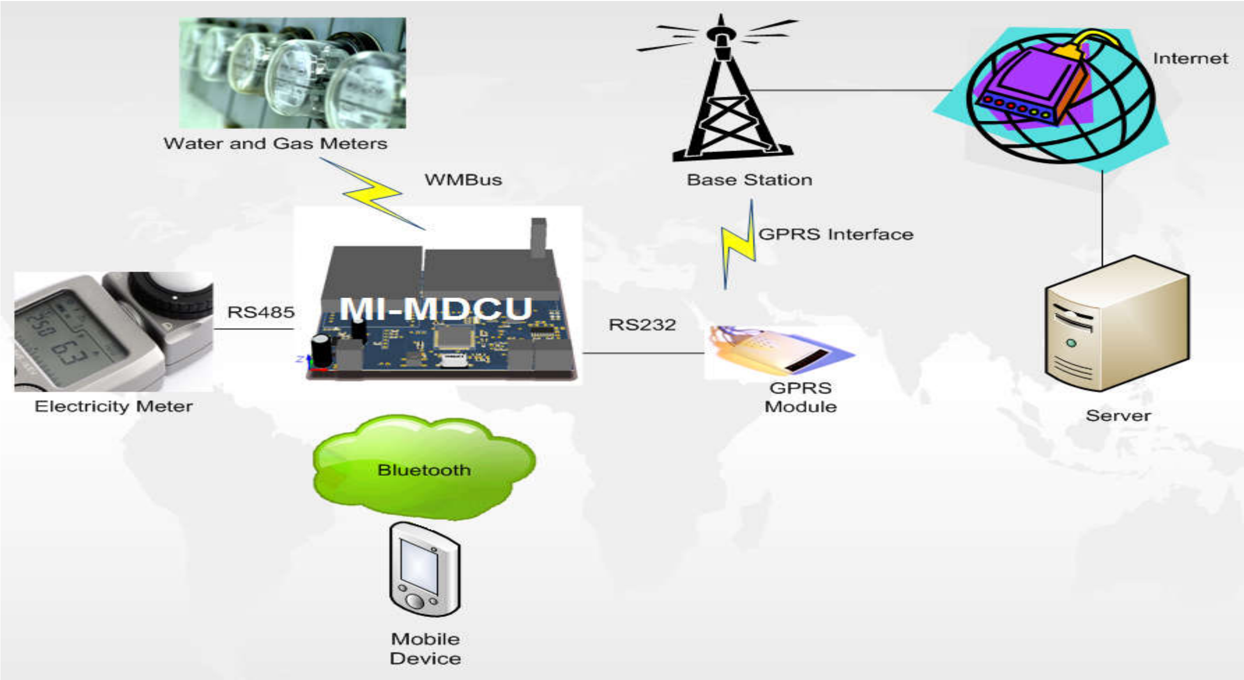

Fig. 1. Overview of the proposed system.

MI MDCU via Bluetooth interface and transmit these data to a control center via GPRS interface.

3-dimensional model of the MI MDCU is shown in Fig. 2. As shown in this figure, the device requires external 5V supply voltage. It contains a power supply part to provide required supply voltage all the components on it. The system is controlled by a 32-bit MCU (microcontroller unit) which has various peripheral interfaces such as USART, I2C, SPI, CAN (Controller Area Network), IrDA, 10/100 Ethernet and USB. Thus, the developed platform can be easily integrated to other commonly available communication interfaces.

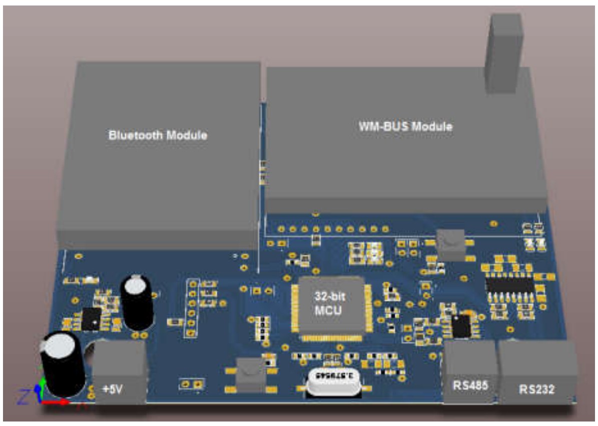

Fig. 2. 3-D representation of MI-MDCU.

3 System Implementation

As briefly described in previous section the MI-MDCU has plenty of available interfaces for meter reading. In our implementation, we prefer to employ TIA/EIA 485 A (i.e. RS-485) and WM-BUS (EN 13757-4) interfaces for meter data reading since these protocols are widely used in many meters. For the transmission of collected data to users, other MI MDCUs or utility companies Bluetooth and GPRS interfaces are utilized. A picture of developed MI-MDCU is shown in Fig. 3.

The RS485 enables a multi-drop communication interface using differential signaling for noise immunity over twisted pair lines. This

Fig. 3. A Picture of MI-MDCU.

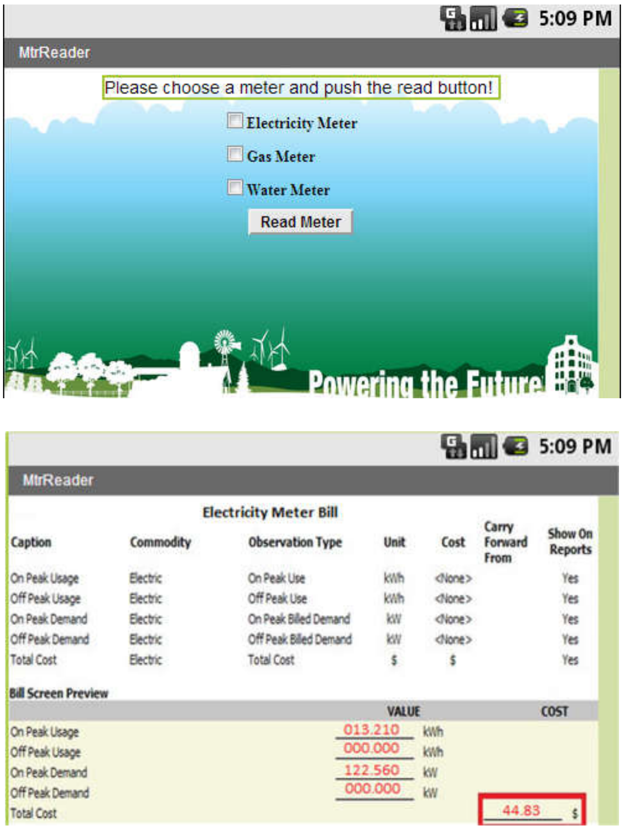

Fig. 4. Screenshots from the mobile device application.

serial interface may provide a communication environment by up to 1200 meters cable length. The data transfer rate can go by up to 20Mbps in practice when shorter cables are used. We utilized a RS 485 bus transceiver to enable communication between outside RS 485 bus and UART (Universal Asynchronous Receiver/Transmitter) module of the 32-bit MCU controlling the MI-MDCU.

The WM-BUS standard determines the rule of communication between a meter and other devices such as meter-read devices or data collectors. It has several communication modes such as S1, S1-m, S2, T1, T2 and R2 where some of them allows only unidirectional mode in which case the meter transmits its data several times in a day periodically. In the case of bidirectional communication mode (S2, T2 and R2), a handshake is performed prior to communication. For example, in T2 mode, the meter transmits "Access Demand Request" (AD Req) periodically. When an AD Req is received by a reading device, acknowledge (ACK) data is sent to the meter. After the ACK signal, the data read requests coming from a reading device or data collector is responded. We utilized T2 communication mode in our implementation using a WM BUS module operating at 868MHz. The communication between WM-BUS module and the MCU is carried out via UART by making use of command list provided by the module manufacturer. The communication between the MCU and Bluetooth module is carried out in a serial way (via UART) by making use of instruction set provided by the Bluetooth module vendor.

This interface enables data transmission to mobile devices by making use of the application developed for this purpose. A couple of screenshots from this application is given in Fig. 4.

The MCU is connected to the external GPRS module via RS232 interface where a single-ended point to point communication is possible. The data communication is executed by the MCU making use of AT command list supported by the module.

The connection of MI-MDCU and GPRS module is shown in Fig. 5. It should be noted that the GPRS module is not a mandatory part of MI-MDCU. It is possible to utilize Bluetooth interface to transfer collected meter data to other MI-MDCUs. Thus, in this scenario one of the MI-MDCUs acts as a gateway between MI-MDCUs and TCP/IP Network. Additional identification information about MI-MDCUs and connected meters are also transmitted via this interface.

Fig. 5. The connection between MI-MDCU and GPRS modules.

Fig. 6. A picture from the test-bed.

A picture of test-bed employed is given in Figure 6 where several meters are connected to the MI-MDCU over RS-485 and WM BUS interfaces. Experiments performed on this test bed show that the MI-MDCU is able to read different meters coming from different vendors successfully using supported interfaces. The data read via Bluetooth interface is confirmed by simply comparing meter monitors and application output screens. Additionally, an application program running at the server side is also developed to control transmission of collected meter data via GPRS. This server application utilizes TCP/IP sockets to read data from GPRS enabled MI-MDCUs. In our implementation GPRS enabled MI-MDCUs are always powered and configured as a server in socket communication whereas server computer in the utility company behaves like a client to connects and read data from MI-MDCUs. This approach basically allows utility company to read data from MI-MDCUs on-demand when it is required. Our experiments show that it is possible to connect and read data from multiple MI-MDCUs sequentially.

It is important to note that data collection from various MI-MDCUs need to be secured against attacks. There are various recent works on this issue as in [18-21] to solve possible security problems. For example, in [18] it is proposed to employ hash-based message authentication code to handle security issues in a computationally lightweight manner. In [19], an Elliptic Curve Cryptography (ECC) based authentication and key management system is presented. A certificate-less public key cryptography approach is presented in [20] to eliminate the burden of meter certificates. In general, it seems that a public key infrastructure (PKI) is inevitable for automatic meter reading as explained in [21]. We have not employed a cryptographic method in MI-MDCU right now. But, we are planning to use it in near future. The ARM Cortex M4 based CPU handling the whole system contains a true number generator and crypto/hash processor as well. Thus, it will not be an important issue for the implementation.

4 Conclusion

In this paper, a multi-interface data concentration unit for home use is presented. The proposed device is able to provide consumption values to household or another MI MDCUs via Bluetooth interface. By this way, energy efficiency awareness can be increased. Additionally, it is possible to combine meter data coming from different MI MDCUs in a single MI-MDCU. By making using of GPRS enabled MI-MDCUs, it is possible to transfer collected consumption data to utility companies. The experimental results show that it might be feasible to employ such a system for smart metering applications.

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