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Design of an intelligent SMS based remote metering system

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ABSTRACT
Automatic Meter Reading (AMR) is a state-of-the-art technology for reading electric, gas or water meter readings automatically from a remote place without any human intervention. Remote metering promises fast and accurate billing system. In this paper, a technique for remotely reading electricity meter readings using Short Message Service (SMS) has been illustrated. Existing Global System for Mobile communications (GSM) networks have been used for sending and receiving SMS. A prototype of the system has been designed and developed for system exploration and experiment.

Introduction

The conventional billing system for electricity, gas, or water is that an assigned person visits each house and read the meter readings manually. Then the collected meter readings are used for bill calculation. This manual process can become very time consuming and tiresome. It can cause human error and can open an opportunity for corruption done by the human meter reader. Thus the billing system can become inaccurate and inefficient.

The recent advances in the field of information technology have made the exchange of information fast, secured and accurate. The digital revolution caused the rapid drop of digital devices such as computers and telecommunication devices. Communication networks like the internet, GSM networks, etc. are available almost all the countries of the world. In the work presented here, a technique has been developed to read electricity meter readings from a remote server automatically using the existing GSM networks for cellular phones. This technique can be applied for gas or water meters as well. The meters send the meter readings like kilo-watt-hour (kWh), voltage, current, bill, etc. by SMS to a central server. The central server then stores the information in database for analysis and sends the bill to the customer by e-mail. Prepaid scratch-card based billing scheme can also be implemented.

The SMS based data collection can be done very quickly and efficiently. Data can be collected after any desired time interval such as hourly, daily, weekly, or monthly basis. As there is no human intervention in the entire process, there is no chance of human error and corruption. Also, unwanted weather conditions like heavy snow, rain, storm, etc. will not hamper

on collecting data as long as the GSM networks are stable. By applying complex encryption algorithms on the data SMS, data security can be ensured. Though, the development cost of the SMS based remote meter will be higher than conventional meter, the electric supplier will revenue more in the successive months because it will eliminate the possibility of corruption done by the customer. Remote meter can be used in residential apartments and especially in industrial consumers where bulk energy is consumed [7].

The rest of the paper is organized as follows. In Section 2, some related works are discussed. In Section 3, the system architecture of the remote metering system and its different components are described. In Section 4, experimental results are discussed. Finally, Section 5 concludes the paper.

Related Work

One approach of AMR is that the meter reader walks by or drives by the meter and using a handheld device, reads monthly energy consumption. This approach requires human involvement and it is tiresome and time consuming. In [9], getting meter readings using PSTN networks have been introduced. In [2][8][12], automatic meter reading using wireless networks have been proposed. Some commercial AMR products use the internet for data transmission. The MainsTalk [4] and Archnet [1] use Power Line Carrier (PLC) technology to remove extra wiring for internet connection with the meter. In [13], Bluetooth technology has been proposed for remote metering. In our work, we have used a GSM modem which is connected with the meter using serial port. The information in the meter is sent to a central server by SMS. Our approach does not need external wiring and data can be transmitted to any place at any time where the GSM network is available.

System Architecture

The proposed remote metering system composed of several remote meters and a central server as shown in Figure 1. The remote meters which are placed in apartments or in industries exchange information with the central server by SMS using GSM networks for cellular phones. Both postpaid and prepaid billing scheme are feasible to implement using this architecture.

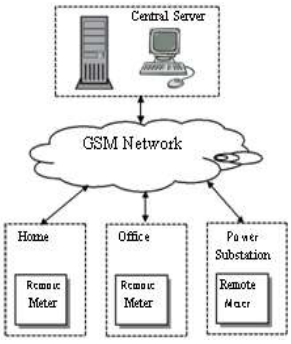

Figure 1. The Remote Metering System

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Remote Meter

The remote meter mainly consists of a micro-controller unit, a Liquid Crystal Display (LCD), an Electrically Erasable Programmable Read Only Memory (EEPROM), Real Time Clock (RTC), an Energy Measuring Module (EMM), Temper detection unit, Latching Relay (LR) and a GSM modem as shown in Figure 2.

Microcontroller Unit

An 8051 architecture micro-controller (AT89C55WD) is used as the microcontroller unit. The 8051 is an 8 bit Reduced Instruction Set Computer (RISC) microcontroller. It is one of the most popular microcontrollers in the world for its high performance, rich instruction set (MCS-51®), and low cost. It has four 8 bit ports, total 32 I/O lines. Different peripherals of the meter are connected with its ports as shown in Figure 2. It has 64KB of program memory and 256 byte of RAM. The firmware inside the microcontroller's program memory is built using two layers – the *Driver Layer* and the *Application Layer*. The *Driver Layer* contains protocols for accessing different hardware peripherals such as LCD, EEPROM, EMM, RTC, LR, GSM modem, etc. On the top of the *Driver Layer*, the *Application Layer* contains routines for load calculation, bill calculation, data SMS frame creation, etc. *Application Layer* calls different routines of the *Driver Layer* to access hardware peripherals.

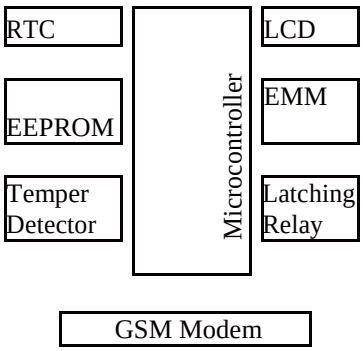

Figure 2. Block Diagram of the Remote Meter

Display Unit

A 16 x 2 character LCD (HD44780) is interfaced with the micro-controller port using 4 data wire mode. Different meter readings like current month kWh, total kWh, voltage, current, date, time, etc. are sequentially displayed here.

Permanent Data Storage Unit

If power fail occurs, the content of the RAM must be stored in EEPROM so that when power is back, the meter can start from its last state. An I2C EEPROM (AT24C64) of 8KB size is used for this purpose. Also, different billing slabs containing rates for peak and off peak hour, meter ID etc. are stored here.

Real Time Clock

An RTC (DS12C887) is used to get the current date and time information. The RTC has a lithium battery inside it which is used to run the clock even if the power is off.

Energy Measuring Module

The energy measuring module (ADE7753) is used to get the voltage, current, power factor, kWh, etc. information of the connected single phase load. A Current Transformer (CT) and a Potential Transformer (PT) are connected with the EMM to sense the current and voltage respectively. The microcontroller gets different information by reading different resister values of the EMM.

Relay Unit

A Latching Relay (LR) is used for connecting and disconnecting power supply to the customer's load. The microcontroller sends signals to the LR input signal pins to control the relay contacts.

GSM Modem

A GSM modem is interfaced with the micro-controller's serial (RS232) port for sending and receiving SMS. Using the FBUS protocol [3][5][10], the microcontroller sends different commands to the modem and receives data SMS frames from the GSM modem. The serial communication with the modem is full duplex 8 bits, no parity, 1 stop bit and at 115200 bauds. We have used *Idea* [6] Subscriber Identification Module (SIM) in the modem.

Temper Detection Unit

If any unauthorized person tries to open the meter box even if the meter has no power, the temper detection unit will activate using a 4.5 volt battery and the meter will not let any power to flow to the customer. An SMS is automatically sent to the central server reporting the temper.

Central Server

The central server mainly consists of a GSM Hardware unit and several Server Software modules as shown in Figure3.

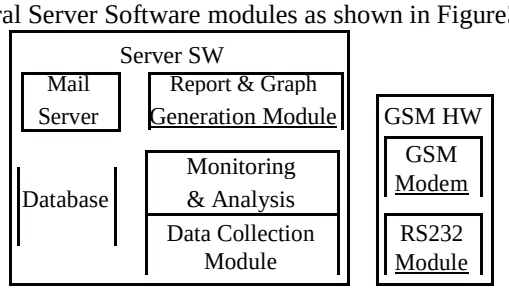

Figure 3. Block Diagram of the Central Server

GSM Hardware Unit

It mainly consists of a *GSM Modem* which is used to send and receive SMS. To interface the modem with the server's serial (RS232) port, an *RS232 Module* is used in between them. This module converts the TTL logic levels compatible with the server's COM port.

Server Software

There are several techniques of building the central server [11]. Our proposed central server is built on Linux operating system with Java as the programming language. For database, ORACLE 10g is used. The software is composed of several modules as shown in Figure 3. The *Data Collection Module* communicates with the GSM modem using FBUS protocol. When the server wants to collect information from a particular remote meter, it sends a *Request* SMS massage to the target meter and then waits for data from the GSM modem. After the remote meter receives the *Request* SMS massage, it makes a data frame consisting of the meter's information and sends it to the server by SMS. The server then gets the SMS data from the GSM modem and stores the information in the *Database.* Sometimes SMS massages are not delivered by the GSM network. We have developed the protocol such that if data SMS is not received after one minute, the server sends another request massage to the meter and waits for the data. In this way, the server makes total three attempts. If data SMS is not received in three attempts, the server shows network error massages. The overall communication flow chart of the *Data Collection Module* of the central server and the remote meter is shown in Figure 4. The data collection can be done at any time or periodically such as hourly, daily, weekly or monthly basis. The *Monitoring & Analysis Module* gets data from the*Database* and calculates the overall energy consumption patterns of the meter.

If any unexpected energy consumption pattern occurs, warning massages are generated and the server operator can send *Disconnection* SMS massage to the remote meter to disconnect the meter's relay contacts and thus stop the customer to consume further energy. The *Report & Graph Generation Module* generates detailed report consisting of the current month bill, average voltage and current, peak kW, unexpected behavior descriptions, energy consumption curve etc. For postpaid billing scheme, the bill and report are passed to the *Mail Server* and it sends them to the customer by e-mail.

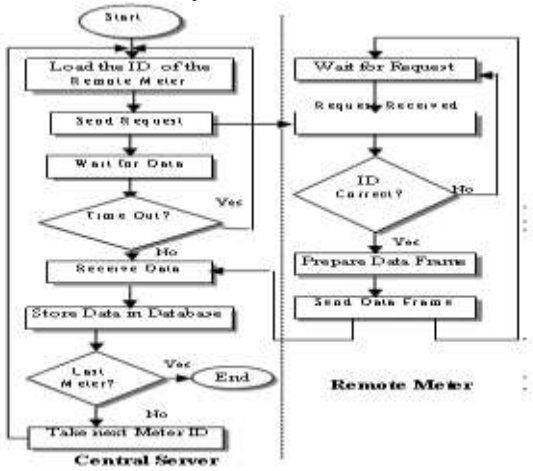

Figure 4. Communication between the Central Server and the Remote Meter

Pre-paid scratch-card based billing scheme can also be implemented using the SMS based technique. The electric supplier will produce scratch-cards and distribute them to local shops. Customers will buy scratch-cards from their nearby shop and then send a special SMS using their personal cellular phone to the central server consisting of the customer's meter ID and the scratch-card's secret pin number. When the central server receives the SMS, it checks the validity of the meter ID and the pin number from the database. If the meter ID is valid and the pin number is also valid and still unused, then the server gets the customer meter's GSM modem call number from the database and sends an encrypted SMS to the customer's meter which contains the information of how much balance will be recharged in the meter. The meter receives the SMS, decode it and recharge the balance. Then it sends an acknowledgement SMS to the server indicating whether the balance is successfully recharged or not. After receiving the acknowledgement from the meter, the server then sends a report SMS to the customer's personal cellular phone mentioning the meter's current balance.

Experiments

An SMS based remote metering system prototype is developed and several experiments have been conducted. We developed two remote meters and one central server. The total time taken to get a data SMS from the remote meter to the central server is approximately 30 seconds. This time may vary a little bit depending upon the GSM network condition. In our experiment, for 95% cases, data SMS was received successfully by one attempt. For the remaining 5% cases, data SMS was received after second or third attempt. Figure 5 shows a graph plot of consumed power of an industrial consumer. The graph is generated by the central server based on the remotely received data.

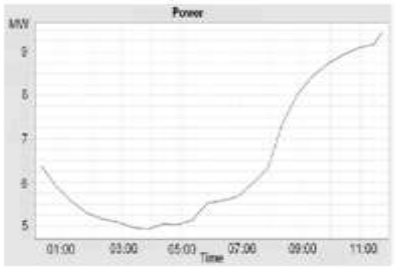

Figure 5. A Graph Plot Generated by the Central Server

Conclusion

In this paper, an SMS based remote metering system has been proposed. Different hardware and firmware unit of the remote meter is described. The central server's different modules and the communication protocol with the remote meters is also shown. We have illustrated both postpaid and prepaid billing scheme. Several experiments with two remote meters and one central server have been conducted. Our future work includes interfacing a General Packet Radio Service (GPRS) modem with the remote meter so that faster and continuous data can be received in the central server.

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