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Energy Meter Data Acquisition System with Wireless Communication for Smart Metering Application

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***Abstract*—The Energy meter data acquisition system with wireless communication is presented in this paper. The proposed method is based on wireless communication with use of a RF Transceiver and GSM module. The power consumption is measured with digital energy meter in terms of units and then the power measurement readings are transmitted with use of RF transmitter from energy meter to the center node which contains a RF receiver and GSM module as Data Forwarder. The GSM module will forward the data to the end utility office. So the whole proposed method will work in two type of communications. First short distance wireless communication with use of RF Transceiver from energy meter to the center node. Second will be for long distance wireless communication from center node to the end utility office with use of GSM module. All the hardware and software based details are described in the paper. The system has many significant advantages such as, wireless communication, low power consumption devices, Accuracy, Large coverage area.The power consumption data are received at the end where they are stored and used for future references and customer billing system.**

Keywords. *Smart Grid, Smart Metering, Wireless Energy Meter, Power*

I. INTRODUCTION

Developing countries are facing acute problem of power theft and unorganized power management due to lack of sufficient and efficient past energy consumption data. This has led to huge losses to power companies or unbearable high electricity costs for customers. Smart Grid and its part, smart meter is a pragmatic and efficient solution for this. The main parameter for smart metering is no need of human efforts and physical challenges. The technology should also be financially supportive. The wireless data transmission is very essential in the system. With the data collected automatically without human errors will be accurate compared to manual meter reading. So the power generation estimation for future at power plants will be easy and precise. With the precise statistical data pricing scheme for different time and tariff schemes can be applied. This will avoid the situations like blackout and shortage of power. Here, our main goal is to study and analyse Smart Metering. Smart metering is analysed based on how it can be established, how it works, which technologies are being used for communication and performance. Many rural areas in different parts of country are affected by the electricity outage problem due to the peak load time or suffers blackout when no sufficient power is available.

The end node in this proposed system design is a domestic house, from where the power consumption data are collected, hence providing high resolution data in consumption pattern. Till now the data collected are not of such high precision and hence irregularities while reporting to higher authorities, creating cumulative errors in the overly decision making for National Power Strategies. Such thing can be reduced with better data collection which is fulfilled by this proposed system. As per this project, the data are collected on hourly basis in UNITS (1 unit = 1 KWHr) by AD7751 Single phase AC Power Measurement IC commercially used in presently available digital meters on houses. Data can be collected from 4 to 5 houses which is transferred to a center node wirelessly. The center node in turn sends this data to server through message service of a normal GSM network. Use of GSM adds extra flexibility in the design. House to center node to Database both connections being wireless, there is no need for any Physical wired connection, hence it can be implemented in rural areas as well where monitoring consumption is very tough. GSM coverage is robust in Indian rural area; so on field implementation can be very fast. As the data are available online, users as well as Power company offices can check the consumption in real-time, this brings transparency in operations of company.

II. SMART METERING REVIEW

The ARM based system was proposed[3] which uses Blue-tooth device for wireless data transmission for meter readings. Different Energy meters at different houses are connected with nRf903 bluetooth devices and Hyundai's HY57V641620 SDRAM to run the operating system. Those devices forward the data to a center hub, where all data are collected. As the Proposed system works well but the coverage range of nRf903, its power consumption are still issues which can be changed with other appropriate solutions. Another system for wireless data transmission proposed by A. Tan [5] "eBilling" uses GAPMR (GSM Automatic Power Meter Reading System), which contains GSM module for transmitting the meter reading data through SMS in form of message. At the end side another

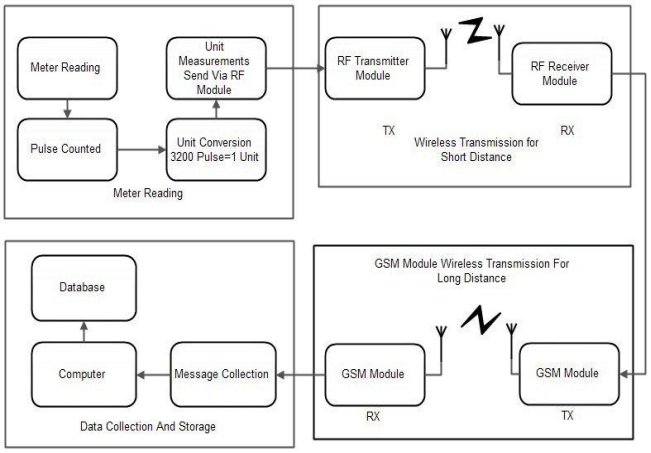

Fig. 1. Block Diagram of Proposed System

GSM module receives all the messages according to the meter address and stores the data. Here again the issue of cost come across for implementation. A GSM module has to be connected with each Energy meter which will increase the overall cost of the system. Now if the power consumption data are fetched to the utility companies and electric board offices they can see the energy consumption by the consumers in real time. so they can predict the over all power usage by the day. This will as a result give a good estimation of future power usage and can help to implement different tariffs schemes for residential and industrial usage. Different tariff schemes for energy meter and power consumption[2] was proposed. According to that any method or technology can be used for power measurement and for communication between energy meter and utility offices. Here now the main issues related to the different methods are communication channel, its feasibility, power measurement system and it's accuracy, wireless communication device with good coverage area, appropriate data rate. So for solution of this purpose the meter reading system should be automatic so that on particular time set the meter readings are taken. But only meter reading will not be enough otherwise the person will have to go again every house for taking those readings. So there should also be a system for these meter reading data transmission from energy meter to the electricity office or direct to the utility companies. The AD7751[25] Power measurement IC gives accurate and fast output in terms of pulses, which are measurable in Units (3200 pulse= 1Unit). CC2500 RF Transceiver with coverage area of 60-80 meter fulfills the criteria for short distant wireless transmission and ultra low power consumption device[25]. With the SIM300 based GSM module the long distance data transmission is possible in the center node of proposed method. So, in Proposed Method The system covers all the aspects of advantages in terms of power saving, good coverage area and accuracy.

III. Proposed System

The proposed System can be divided into main four sections. Fig. 1

- Meter Reading System
- Wireless Communication for Short Range

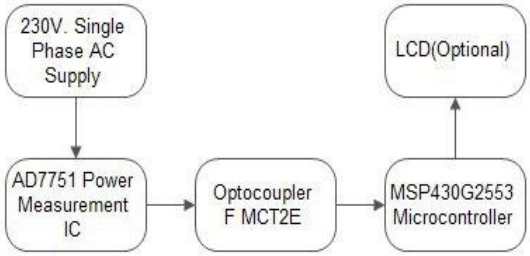

Fig. 2. Block Diagram of Meter Reading System

- Wireless Communication for Long Range
- Data Collection and Storage

These four sections combined can give a better solution for smart metering application. The main idea behind keeping the center node is to minimize the hardware used for the installation on every meter. The RF transceiver used is CC2500 of very low cost and reliable for short range communication. CC2500 is installed on every energy meters and those end nodes will be sending data statistics to a center kept another CC2500 receiver which is called center node. Now from the center node a GSM module is connected to the CC2500 RF Transceiver. This will forward the meter reading data to the other end with long distance.

Thus only RF transceivers are installed on every energy meters instead of GSM modules as described in the proposed system. This will lower the cost of overall system. The microcontroller used in the proposed system is of ultra low power consumption[25]. The center node between the different end nodes will be working on battery supply in most of the cases so that is most important that the center node requires minimum amount of power. This will increase the lifetime of the node.

A. Power Measurement

The power measurement of the energy meter is done with the 5V operated AD7751 Energy meter IC and 3.6V operated MSP430G2553[25] microcontroller in terms of pulse counting as shown in the block diagram of Fig. 2. The whole setup was tested with 100W bulb and the results are also shown in the later sections.

The Fig. 3 shows the prototype of the proposed system for meter reading system.

As shown in the Fig. 4, according to the working algorithm the pulse counting will be done by the MSP430G microcontroller and the unit conversion is also done by same. As the time increases and units are counted the loop will return to the same situation for start of the unit count.

B. Data Transmission for Short distance with CC2500 RF Transceiver

The 3.6V power operated RF Transceiver CC2500 used is of very low cost and with good accuracy and enough coverage area for the data transmission between the energy meters to the center node connected with ultra-low power operated MSP430G2553 microcontroller. The Fig. 5 shows the block

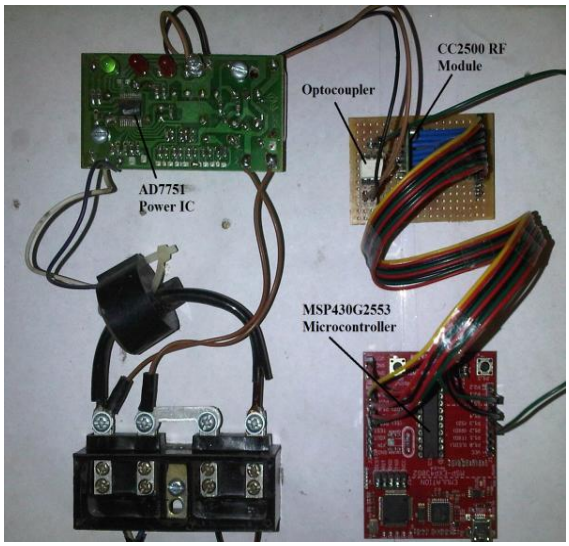

Fig. 3. Block Diagram of Meter Reading System

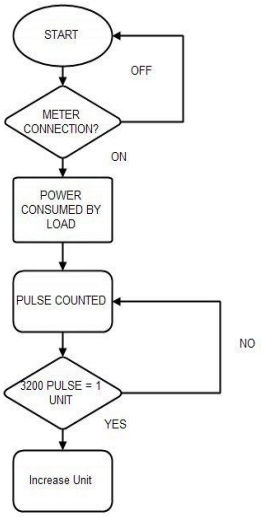

Fig. 4. Flow Diagram of Meter Reading System

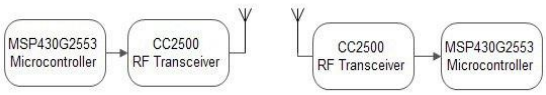

Fig. 5. Block Diagram for the Wireless Communication with CC2500 and MSP430G

diagram of the center node in which data communication is done with CC2500 having maximum capability of 30 nodes within a network.

The CC2500 RF based Transceiver works on 2.4 GHz frequency with 1.2 to 500 Kbps data transmission rate, which is enough to transmit the meter reading packets within 60 meters practically measured. This fulfills required criteria of Smart meters. The meter reading data transmission part is completed here from energy meter to the center node. The prototype is working well and gives nearly accurate output for transmission as shown in the Fig. 12 and Fig. 13.

The algorithm also works for the CC2500 RF Transceiver

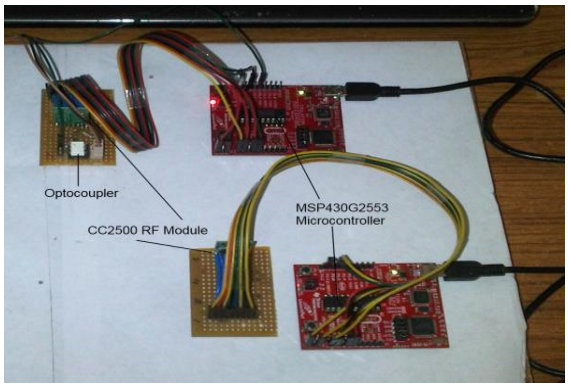

Fig. 6. Prototype setup Data Transmission between CC2500 and MSP430G

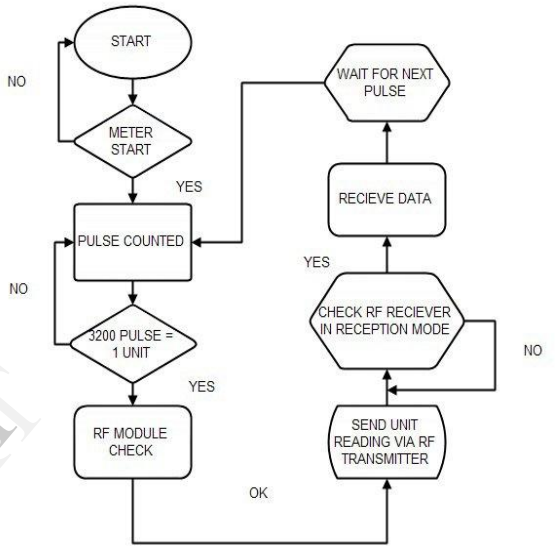

Fig. 7. Prototype setup Data Transmission between CC2500 and MSP430G

for transmitting the meter readings. Every time the meter reading is sent in terms of KWHr from the CC2500 transmitter and then transmitter will go in sleep state. The transmitter will stay in sleep state until the next event occurs.

The CC2500 operates at 400nA current consumption in sleep mode with use of FSK modulation technique. 240μ second wakeup and sleep time gives fast access to the operation of the transceivers. No external filters or switch are needed for the CC2500 operations.[28]

The same procedure occurs for the receiver in the center node. Until the next meter reading is sent from the transmitter the receiver will stay in stand by mode. On reception of the packet the receiver will awake and receive the Data Packet and will again go in sleep state[27].

This most effective technology of MSP430G microcontroller and CC2500 RF transceiver save the power very much. There are mainly five power saving modes with different conditions which helps very much in programming for different power states and versatile power saving modes. This will help the center node to stay alive for a long time with battery power operation.

The meter readings are sent to the center node in packet form in which the packet contains different information of

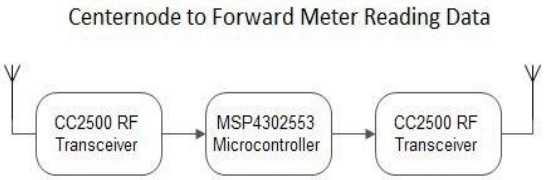

Fig. 8. Prototype setup Data Transmission between CC2500 and MSP430G

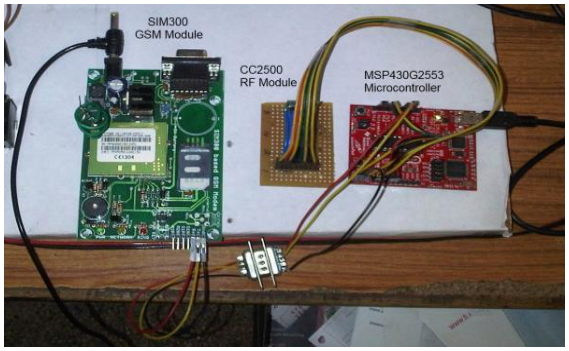

Fig. 9. Prototype setup of center Node

meter readings, the different bits of packet contains meter number, pulse readings, unit readings, time, etc. according to the meter address information in the packet the readings are forwarded from the center node to the utility office via SIM300 based GSM module.

The Programming and debugging platform used IAR Embedded workbench is a very powerful tool for programming and testing of the MSP series microcontroller, its applications and also CCXXXX series wireless communication devices in C language with built in availability of libraries and output checking tools in real time.

C. Center node (CC2500 with SIM300 based GSM module

On reception of the meter reading packet at the center node the 20 pin out of 8 pins connected to microcontroller CC2500 will receive in reception mode and extract the meter address and reading data from the packet. According to the meter address the reading will be forwarded through the SMS with the use of GSM module. With the use of UART of MSP430G2553 the GSM module is given AT command for sending the message which contains the meter reading. With easy use and wide spread network of GSM network, it gives very good result for long range communication[5].

The center node works as data forwarder in the middle of the whole system. The center node works to combine two different components working on different protocols. CC2500 RF transceiver uses SimpliciTI protocol for wireless communication. While the SIM300 based GSM module works with AT commands by UART with MSP430 microcontroller as shown in the Fig. 8, block diagram of center node.

The 12V, 1A power operated SIM300 based GSM module works with AT commands. Different AT commands are used to perform different actions. The AT commands for sending the SMS will be used by MSP430G2553 microcontroller with UART. Any of the available carriers can be used with SIM (Subscribers Identity Module) which supports sending text messages. The prototype was tested and programmed for sending the text messages.

The main three lines Tx, Rx in both GSM module and UART of microcontroller are connected inversely to each other and GND is connected to GND for the UART communication.

The algorithm for the SMS sending works nearly same as the data transmission algorithm in CC2500, which is shown in the flowchart Fig. 10

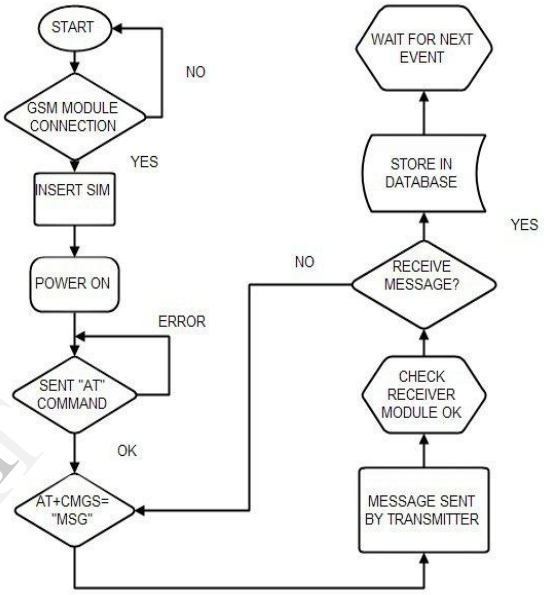

Fig. 10. Flow Diagram for working of Center Node

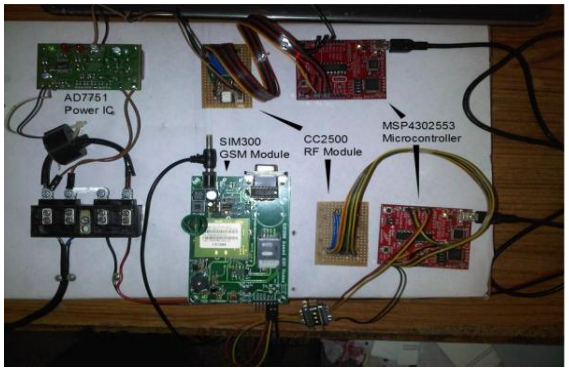

Fig. 11. Prototype Implementation of Overall System

IV. TEST AND RESULTS

Finally the overall system prototype is implemented and tested for the results. The results of the performance of the prototype are taken for different conditions based on the distance between the energy meter and the center node.

In the test series first the meter readings for the power consumptions are taken for 100Watt bulb for 20 meter, 40 meter and 60 meter respectively. In the second series of tests the meter readings of power consumptions were taken for

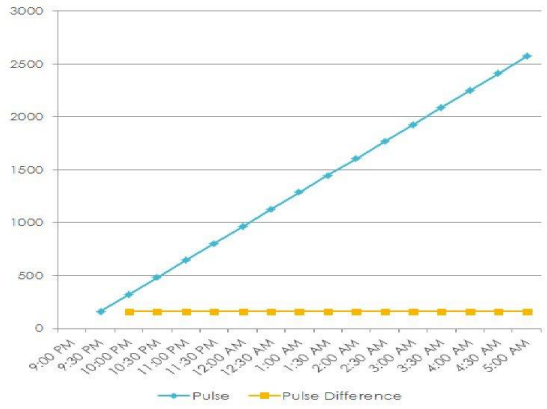

Fig. 12. Meter Reading observation Chart for One 100W bulb fro 20 meter Distance

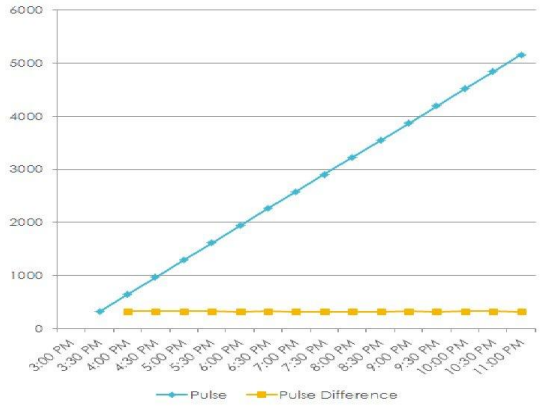

Fig. 13. Meter Reading observation Chart for Two 100W bulb fro 20 meter Distance

the two 100Watt bulbs for 20 meter, 40 meter and 60 meter respectively. The Fig. 11 shows overall system implementation prototype.

The results taken by the systems were nearly accurate with some minor errors. As shown in the Fig. 12 and Fig. 13 the graph shows linear increase in the pulse counting for one 100Watt bulb and two 100Watt bulbs respectively for 20 meters distance.

With the low cost of design, less complexity and simple implementation the proposed system and its prototype implementation satisfies generally all the criteria required in the smart metering application.

The message collection of the meter readings at the utility office is done with the use of one SIM300 based GSM module same used in the center node and data collector software Ozeking.

The software gives output of the power consumption meter readings in form of excel sheets, which are very convenient to modify and use those data in that form. These files can be directly uploaded to the internet web so that the consumers can also view those power usage data made by them.

The web page with user friendly design is also implemented with XAMPP database, Apache and MySQL, where a consumer can log-in with the account details and accesses the past power usage data. Thus the consumer will be aware

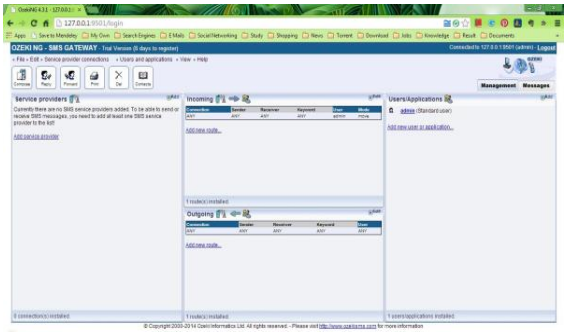

Fig. 14. Snapshot for the Home-screen of Ozeking SMS Manager

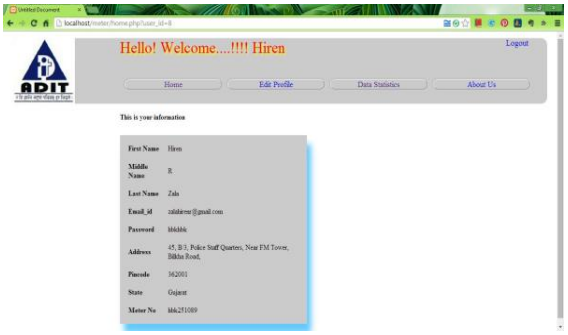

Fig. 15. Snapshot for the Home-screen of Web Page of Online Meter Reading

of the current usage and for the planning of future usage and management.

This access will also be available to the utility company also so the future power generation can be predicted with the current power consumption with use of future forecasting system.

V. Conclusion

The one sided wireless communication from energy meter to the end node is completed in the proposed method successfully. Using CC2500 transceiver we cant extend node more than 30. Using SimpliciTI protocol we can create star and tree topology.

In advancement the wireless modules used can be replaced with the other technologies and result can be further improved. On the other hand the second side of Smart Grid Demand Response can be added to the method where the feedback response from the utility office can be applied. More security, robustness and tampering solution issues can be added to the system.

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