WIRELESS TELEMETRY SYSTEM FOR 3-PHASE ENERGY METER USING ZIGBEE AND GSM

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ABSTRACT--- *The paper discusses the design and implementation of a wireless telemetry system (Automatic Meter Reading System) for 3-Phase Digital Energy meters using ZigBee and GSM module. The model is fully automated and will replace the conventional meter reading system which is prone to errors due to dependency on the meter readers and will allow remote access of the meter data by the billing server as well as the consumer. An interactive, user friendly graphical user interface and database is developed using Microsoft visual studio and MySQL at the billing end. The hardware, working principle and software tools will be discussed in greater detail in the paper.*

Keywords—Automatic Meter Reading System (AMRS); Wireless Telemetry; GSM; ZigBee; Short Messaging System (SMS); Visual Studio; MySQL; 3-phase Energy Meter.

1 INTRODUCTION

In the recent years there has been a marked shift towards unconventional meter reading techniques. With the development in the fields of automation and telemetry, many different models have been proposed and developed to provide cost effective and reliable Automatic Meter Reading (AMR) solutions. AMR focuses on the wireless acquisition and transmission of real time consumption, diagnostic and status data from the metering device to one central server for billing and analysis [1].

The most common method of meter reading known today can be divided into three main categories: conventional manual meter reading, wired and wireless meter reading [2, 3, 4, 5, 6]. Manual meter reading has been prevalent for a considerable length of time, but drawbacks of this method of reading are manifold due to the dependency of the reading on the meter reader [7]. Hence it is prone to human error as well as premeditated malign intentions, most common in our set up, a phenomenon known as 'Meter Fixing'. Other shortcomings of this method include inaccuracy, no definite reliability because the reading can be affected by external conditions in which the reading was taken [3], delayed work and over billing or under billing and last but not the least the need of a large manpower [3]. Wired AMR systems like Power Line Carrier (PLC) and Telephone Line Network make use of already existing telephone and electric power line networks for transmission of meter data to the utility company [5]. This method of reading experiences many drawbacks like low stability and reliability due the susceptibility of carrier wave to noise interferences [6]. Other concerns include the high costs of transmission, installation and maintenance of the system and security of the data being transmitted [5].

For wireless approach there are many methods in use today including the use of GSM/GPRS, Bluetooth, WiFi based local area networks and ZigBee technology [9,8]. However, as the utility companies strive to achieve standardization in automation in meter reading and billing, there is need of low cost technology with an easy to implement infrastructure such that there exists interoperability between equipments from various vendors. This has led to the popularity of ZigBee technology defined in IEEE standard 802.15.4. It is a low power consumption, small-medium range, low-complexity, economical and low data rate protocol which allows bidirectional wireless communication. [10][2] Networks built with ZigBee technology have unique features such as high network capacity, short time delay, data transmission security and interoperability between devices from different vendors [2]. The foundation of this technology has been established by IEEE 802.15.4 which specifies standards for Media Access Control (MAC) layer and Physical (PHY) Layer of the device [11]. Standards for high level layers e.g. application layer, MAC sub-layer and network security layer have been defined by ZigBee alliance –founded in 2002 [12 5].

This paper discusses the development of a wireless automatic meter reading system, which is implemented using GSM and ZigBee technology. ZigBee & GSM based wireless meter reading alludes to the utilization of short-range wireless communication technology in conjunction to high range, large area coverage technology like GSM to read and process metering data automatically, making efficient use of GSM spectrum. This use of GSM allows the consumer to request the consumption data from the meter at any time via a Short Message Service (SMS) – a popular feature of GSM networks. ZigBee & GSM based wireless meter reading refers to the use of short-range wireless communication technology in conjunction to high range, large area coverage technology like GSM to read and process metering data automatically, making efficient use of GSM spectrum. This use of GSM allows the consumer to request the consumption data from the meter at any time via a Short Message Service (SMS) – a popular feature of GSM networks.

2. AN OVERVIEW OF GSM & ZIGBEE TECHNOLOGIES

2.1 ZigBee Technology

ZigBee is a network protocol based on certain standards sustained by the ZigBee Alliance that is based on IEEE 802.15.4 network specification.[13] ZigBee Alliance is a group of establishments that are responsible for maintaining and publishing different standards of ZigBee. It is preferred for scenarios where fast information procurement is not required – similar to the case discussed in this paper. Low data rates, low power consumption, secure networking, and low economics are the distinguishing features of ZigBee

technology. [14]

The PHY layer and MAC layer of ZigBee protocol stack are defined by IEEE 802.15.4. The two types of devices present in IEEE 802.15.4 protocol are FFD (Full Function Device) and RFD (Reduced Function Devices). A FFD is responsible for performing all the functions defined by the IEEE protocol. A RFD can have limited attributes i.e. low processing power and low memory space as well. A FFD can have any role in the network. It can be ZigBee coordinator or a ZigBee router.

ZigBee coordinator forms the network by assigning a unique PAN identifier to itself and assigns a unique 16 bit or 64 bit address to the end devices and routers as shown in figure 1. End devices have no role in routing. The length of address depends on the address length chosen by the networking layer of ZigBee [14]. Each device in the network is given a unique network address through the networking layer. The combination of 16 bit address and PAN identifier can be used to communicate between independent networks.

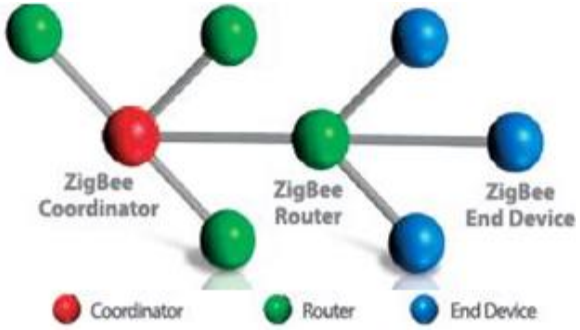

Figure 1: ZigBee Devices [15]

Figure 2 shows the top most layer of the ZigBee protocol as the application (APL) layer which controls all the layers below it [14]. The customization of the device for a number of applications is done by the manufacturers by defining the ZigBee application objects. The two products with similar profile of applications will be able to communicate with each other.

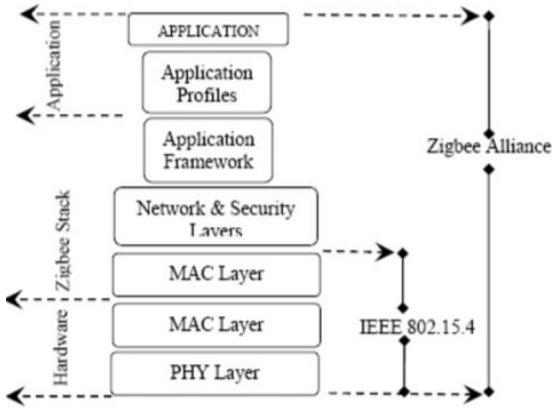

Figure 2: ZigBee Protocol Stack [5]

The type of ZigBee network will be decided by the NWK layer of the ZigBee protocol. The network can be star or peer-to-peer network as shown in figure 3. If there are no restrictions on the ZigBee network it will be mesh network [14]. If the restrictions are imposed on the network, the network will be ZigBee tree network. ZigBee coordinator will form the root of the tree and routers will be the branches of the tree and end devices will form the leaves of the tree [2].

Security is provided by the security layer of ZigBee protocol stack. The data Message Integrity code (MIC) will be used for data authentication. Confidentiality problem will be solved by encrypting the messages. Encryption key will be used for this purpose. Addition of encryption key modifies the message due to the addition of a security key (string of bits). The message will be recovered by the intended recipient only [16].

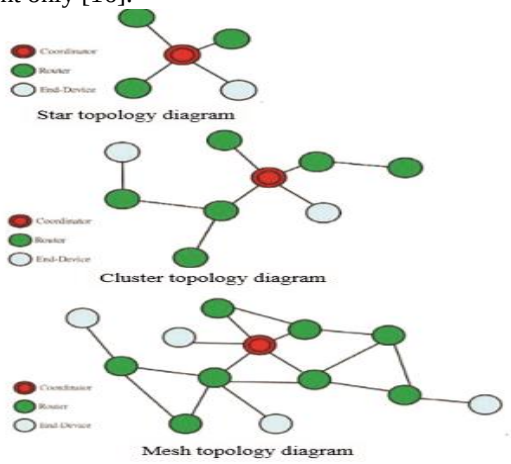

Figure 3: ZigBee Network Topology [2]

ZigBee bands of operation are 868 MHz, 915 MHz and 2.4 GHz. 2.4 GHz band is used globally for communication between ZigBee devices. IEEE 802.15.4 defines three types of modulations: offset quadrature phase shift keying (O-QPSK), binary phase shift keying (BPSK) and amplitude shift keying (ASK) [16]. The digital data remains in phase of the signal in BPSK and O-QPSK. Whereas, in ASK, the digital data remains there in the amplitude of signal.

2.2 GSM Technology

Since ZigBee is short range technology, there was a need to employ a wireless technology with effective and efficient methods of transmitting and receiving meter data over great distances and a means to connect to billing server at the utility company's end. For this purpose, GSM (Global System for Mobile communication) technology is chosen. GSM has several advantages over other wireless approaches like WiFi and Bluetooth [4]. Table 1 compares the existing wireless technologies.

GSM provides the largest and widest area coverage and has an infrastructure that's already well established in most countries of the world [3], and according to an estimate it covers more than 80% of the world's population [17]. Therefore, it's the most suited wireless technology for AMR. Other features of GSM that make it desirable are the security in data transmission, its high uptime and large transaction volume [18].

Most commonly GSM service is provided in 900 MHz & 1800 MHz bands [20]. The local authorities determine the exact frequency used for implementing a GSM network [5]. Since the GSM network capacity is not unlimited and the

increase in capacity comes with added cost, the frequency band should be used efficiently and with proper planning of the expected traffic from users in a particular area. The division of frequencies have effect on data rates and other parameters as well. Table 2 explores effect of frequency upon data rate, channels and modulation techniques.

TABLE 1: COMPARISON OF EXISTING WIRELESS TECHNOLOGIES [19]

Market Name Standard	ZigBee 802.15.4	GSM/GPRS CDMA/1xRTT	Wi-Fi 802.11 b	Bluetooth 802.15.1
Application Focus	Monitoring & control	Wide Area Voice & Data	Web, E-mail & Video	Cable Replacement
System Resources	4kb -- 32 kb	16 MB+	1MB+	250kB+
Battery Life(Days)	100 – 1000+	1 – 7+	5-- 5	1--7
Network Size	Unlimited	1	32	7
Bandwidth (kbps)	20 --250	62 –128+	11,000+	720
Transmission Range (Meters)	1 – 100+	1000+	1 – 100+	1 – 10+
Success Metrics	Reliability, Power, Cost	Reach , Quality	Speed, Flexibility	Cost, Convenience

The ZigBee devices however operate in the ISM band which is free and has no major capacity constraints [2]. Hence, in the proposed model, instead of connecting every Energy Meter with its own individual GSM modem, one ZigBee End Node Device (END) is connected with each meter which communicates with GSM to push its data to the consumer and to the billing server as shown in figure 4.

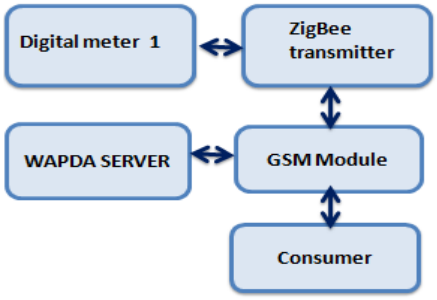

Figure 4: One Node Block Diagram

Since this AMR is a sample model created on a limited budget, it utilizes only one ZigBee device which acts as both the END-while communicating with the energy meter, and at the same time as the coordinator –while communicating with the GSM modem. In the commercial implementation, as being proposed at the end of this paper, there will be one END attached to each energy meter and only one coordinator ZigBee with the GSM modem. All ZigBee ENDs will be connected to the coordinator node. Whole data will be transmitted to the principal computer using GSM from that node. From this we can see that most of the inter-device communication is in free ISM band and the limited resource i.e. GSM band is used to transmit the data from all the meters at once using the same GSM channel.

3. DETAILED DESIGN OF THE SYSTEM

The ZigBee module used in the project is cc2530 USART 0 and USART 1 are its interfaces for serial communications, used independently in either asynchronous UART (Universal Asynchronous Receiver Transmitter) mode or synchronous SPI (Serial Peripheral Interface) mode. The flow diagram of cc2530 programming can be seen in figure 5. The two USART (Universal Synchronous Asynchronous Receiver Transmitter) interfaces have identical functions and separate I/O pins have been assigned to them. We have used UART mode for both these interfaces. Asynchronous communication makes use of a start bit and stop bits which tells the receiver about the start of the byte and end of the code word [21]. Each USART has interrupt flags associated with it which set on the completion of data received and on the beginning of data offloading from the data buffers in transmit operation. The operation of UART is controlled by the USART control, status registers (UxCSR), and the UART control registers (UxUCR), where x can be 0 or 1. The UART mode is selected when UxCSR.MODE is set to 1. UxCSR is used to select the SPI or UART mode. UxUCR is used to select the 8 or 9 bit data transfer and it contains the start and stop bits. The baud rate is set by the writing the UxBAUD for the mantissa and the four least significant bits of UxGCR for the exponent in the following formula.

Frequency	868/915 (MHz)		2450 (MHz)
Band (MHz)	868 – 868.6	902 – 928	2400 – 2483.5
Data Rates	20 kbps	40 kbps	250 kbps
Channels	1 Channel (Channel 0)	10 Channels (Channels 1-10)	16 Channels (Channels 11 – 26)
Modulation	BPSK	BPSK	O-QPSK
Applicability	Europe	USA	World

Table 2: Frequencies, Data Rates, Channels and Modulation [5]

$$\text{Baud Rate} = \frac{(256 + \text{BAUD\_M}) \times 2^{\text{BAUD\_E}}}{2^{28}} \times f$$

Where 'f' is the clock frequency of the crystal.

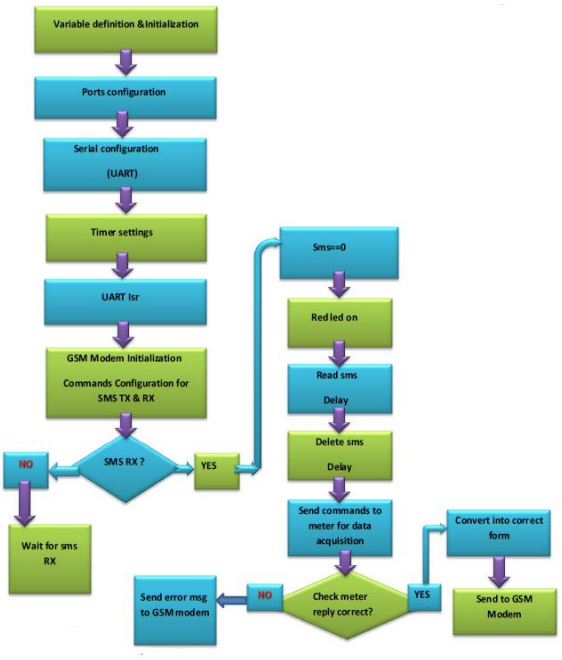

Figure 5: Flow diagram of cc2530 programming

The variables corresponding to various bits are defined and ports are configured for use as either input or output. UART mode is selected for serial communication between the meter and ZigBee and between the GSM and meter. Hardware flow control is disabled so only two bits will be used for communication. Timers are set in order to give the delay between instructions. 32 kHz clock frequency is selected by setting the CLKCONCMD register. Receivers are enabled by calling the function UART Isr. At commands are sent to the GSM modem in order to make it attentive and setting the SMS mode of the modem [22]. As the GSM module receives the message, it sends signals to the ZigBee module to read the data from the meter. ZigBee will send the data to the GSM module. GSM will send the message containing the consumption of energy to the user end.

3.1 Working Mechanism

There are three main boards in the circuitry:

- GSM Board.
- Supply converter board
- ZigBee

GSM module used here is operated at 3.8V. Therefore, a supply converter board is used to convert 12V from the battery into 3.8V. Infra-Red communications are used to collect data from the 3-phase energy meter via IR transceiver. This IR transceiver is in IR serial cable with opto-coupler at one end that is interfaced with the IR communication port present on the meter. IR transceiver should be aligned with IR comm. port to have proper communication with the meter to ensure proper data transfer between the meter and the transceiver.

An empty message is sent to the GSM modem which is an indication to start the communication. GSM modem transfers this message to ZigBee MCU that acts as a command for it to collect the data from the meter. At the pin 7 of port 0 of 25 ZigBee, a red LED is connected which on receiving the empty message starts blinking. Subsequently cc2530 sends commands to the meter through IR serial cable to send energy consumption data. If there is proper connection of IR transceiver with meter comm.-port, ACK is sent by the meter followed by consumption data. Then this data is received by cc2530 which converts it into 8 bit non-parity data. After performing array extraction on this data, this data is transmitted to GSM module which then transmits it to the desired destination i.e. WAPDA end or the number from which the data was requested.

The data at the WAPDA end is kept in the structure query management database engine. Using visual basic graphical user interface (GUI) has been developed which displays the data record as well as consumption trends in the graphical form as shown in figure 6.

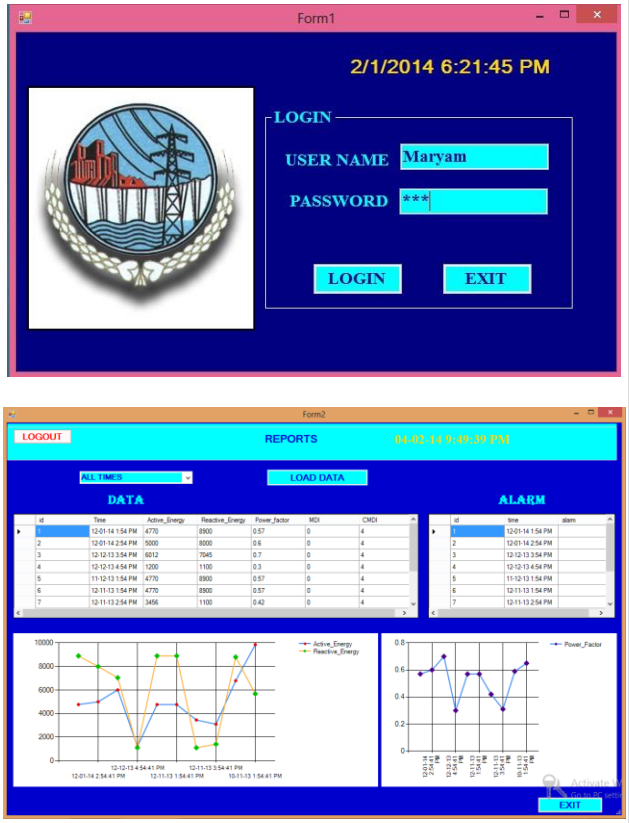

Figure 6: User interface

4. CONCLUSION:

The technology used to collect data from various metering devices is known as automatic meter reading system. It transfers this data to a central station to analyze it for the purpose of billing. This is an effective means of collecting data to allow considerable saving of time and greater accuracy of the data. Digital meters have replaced analog electro-mechanical meters with the introduction of new technologies. These meters are more suited to the implementation of the systems based on automatic meter reading.

.This paper describes the design and testing procedure of an Automatic Meter Reading system using ZigBee and GSM technology. A One-Node model of an automatic meter reading (AMR) system has been implemented and a full-fledge AMR ZigBee based network for commercial implementation is proposed. Significant features of this system include wireless connectivity, efficient spectrum usage and extremely low power consumption.

5. FUTURE WORK:

A One Node Model of an AMR system using ZigBee and GSM has been developed in this paper. In a recommended ZigBee network, each meter will be optically coupled with the ZigBee end device. All the end devices will form a network controlled by coordinator ZigBee. The range of ZigBee network can be increased by using ZigBee routers. The coordinator ZigBee connected with the GSM will send all the measurements to the WAPDA end which will upload them on an online server. The user can access the data online or request the reading by sending an SMS containing the meter identification number to the GSM modem. GSM system and ZigBee should be employed in this system as a protocol of communication. The main reason for using a ZigBee module is the requirement of being low powered and economical, instead of a system with high speed rate of data. The 2.4 GHz frequency band will be used in this system.

Optical networks and wireless sensor networks may also be employed as an extension of the concept of automatic meter reading. Bandwidth sharing and dedicated link applications can be used for the optical networks based applications. Automatic meter reading is expected to get more successful in the future because of the advancements in the technology, especially the research based on 5G networks.

REFERENCES

[1] F. Cleveland, Use of Wireless Data Communications in Power System Operations. Based on EPRI Report 1011751, March 2006

[2] Hung-Cheng CHEN, Long-Yi CHANG, "Design and Implementation of a ZigBee-Based Wireless Automatic Meter Reading System"

[3] Amruta Kotasthane & Hate S.G) "Automatic meter reading system using wireless sensor network and gsm"

[4] Na Wu*, Yinjing Guo, Yongqin Wei, Aying Wei, "Design of the Remote Wireless Meter Reading System Based on GPRS"

[5] Aryo H. Primicanta, Mohd Yunus Nayan, and Mohammad Awan, "ZigBee-GSM Based Automatic Meter Reading System",

[6] L. Cao, W. Jiang, Z. Zhang, "Networked Wireless Meter Reading System Based on ZigBee Technology", IEEE Chinese Control and Decision Conference 2008, pp. 3455-3460.

[7] A. Sai Suneel, "Telemetry system for utility metering application through GSM network", Publications of problems & application in engineering research, vol 04, special issue 01, 2013

[8] "Comparison of wireless technologies" [Online] Available: http://www.windowsfordevices.com/c/a/News/Module-adds-ZigBee-to-PC104-stacks

[9] Ashna K. and Sudhish N. George, "GSM based automatic energy meter reading system with instant billing", International Multi-Conference on Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), 2013.

[10] Kartik Rathod, Nilay Parikh, Aesha Parikh an dVrushank Shah, "Wireless Automation using ZigBee protocols" Ninth International Conference on Wireless and Optical Communications Networks (WOCN), 2012.

[11] Tanmoy Maity and Partha Sarathi Das, "Intelligent online measurement and management of energy meter data through advanced wireless network" International Conference on Devices and Communications - ICDeCom, 2011

[12] "ZigBee, a technical overview of wireless technology." [Online] Available: http://ZigBee.hasse.nl.

[13] Fred Eady, "Hands-On ZigBee, Implementing 802.15.4 with Microcontrollers", Newnes, 2010

[14] Shahin Farahani, "ZigBee Wireless Networks And Transceivers" First Edition, Elsevier Company, 2008

[15] "ZigBee Devices", [Online] Available: www.moxa.com/product/NPort_Z3150.htm

[16] Shahin Farahani, "ZigBee Wireless Networks and Transceivers" Revised Edition, Newnes, 2011

[17] "Architecture of the GSM Network Information Technology Essay", [Online]
Available:http://www.ukessays.com/essays/information-technology/architecture-of-the-gsm-network-information-technology-essay.php#ixzz2tVWD8UyL

[18] Q.S. Mahdi, I.I. Hamarash, J.A. Hassan, "Availability analysis of GSM network systems" 9th International Symposium on Antennas Propagation and EM Theory (ISAPE), 2010.

[19](Online)Available: http://www.zigbee.org/en/about/faq.asp

[20] S.Arun and Sidappa Naidu, "Hybrid Automatic Meter Reading System", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, Issue 7, 2012.

[21] "CC253x System-on-Chip Solution for 2.4-GHz IEEE 802.15.4 and ZigBee® Applications A CC2540 System-on-Chip Solution for 2.4-GHz Bluetooth® low energy Applications, User's Guide", April 2009, Revised December 2010