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IOT Based Energy Meter Billing and Monitoring System - A Case Study

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Abstract— *This article proposes and analyse a system which is used for energy meter billing and monitoring. The system is fully Internet of Things (IOT) based and highly desirable in field of energy. In this system consumer can do power management by knowing energy usage time to time. The customer needs to pay the bill on schedule, if couldn't, the electric power connectivity can be turned off autonomously from the distant host. The article explains the modelling and working of different units of the system and also discussed the basic components and their functions such that IOT and its working, microcontroller(ARM7-LPC2138) and its architecture, USB to TTL Converter and its features, GSM system, Relay and LCD display and its interfacing with microcontroller*.

Keywords— *IOT, Energy Meter Billing, ARM7-LPC2138, Relay, GSM, USB to TTL Converter*.

I. INTRODUCTION

The Existing domestic Energy meter reading systems universally exist many problems, such as difficulty in construction, too narrow bandwidth, too low rate, poor real time, not two way communication quickly etc. To solve above problems, this paper uses the wireless technology for Automatic Meter Reading system. A proposed method provides the communication between the Electricity Board section and the consumer section using Internet of things (IOT) for transmitting the customer's electricity consumption and bill information that is calculated using ARM7 microcontroller. The power fluctuations are monitored using the voltage sensor and current sensors are fed to the microcontroller which indicates it to the Electricity Board. Depending on the power generation, the house hold devices are controlled automatically. From Electricity Board section the information regarding the bill amount and payment are communicated to the consumer via Global System for Mobile communication. The power and billing information is continuously transmitted by the use of Internet of Things and monitored by the Electricity Board section. Whenever there is power theft identified can be sent from the Electricity Board section to cut the supply to the customer.

From thorough review of related work and published literature, we have observed that many researchers have done rigorous work on Power Line Communication (PLC) and IoT. It is observed from the careful study of reported work that in the real world, PLC and IoT based meter can improve the efficiency of power system and can help to analyze the unnecessary loss of power in different areas.

A. Existing method: The present system only provides feedback to the customer at the end of the month that how much power is consumed in the form of bill. The consumer has no way to track their energy usage on a more immediate basis. The consumers are growing exponentially fast and load on power providing divisions is rapidly rising. In the existing system meter tampering can be done easily and it's one of the major drawbacks for an energy crisis.

B. Proposed method: In the proposed system, consumer can do power management by knowing energy usage time to time. The Customer needs to pay the bill on schedule, if couldn't, the electric power connectivity can be turned off autonomously from the distant host.

IOT: The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data. IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. 3 "Things," in the IoT sense, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, electric clams in coastal waters, automobiles with built-in sensors, DNA analysis devices for environmental/food/pathogen monitoring or field operation devices that assist fire-fighters in search and rescue operations. These devices collect useful data with the help of various existing technologies and then autonomously flow the data between other devices.

1] WORKING: Internet of Things is not the result of a single novel technology; instead, several complementary technical developments provide capabilities that taken together help to bridge the gap between the virtual and physical world. These capabilities include:

Communication and cooperation-

- Addressability
- Identification
- Sensing
- Actuation¬
- Embedded information processing
- Localization
- User interfaces

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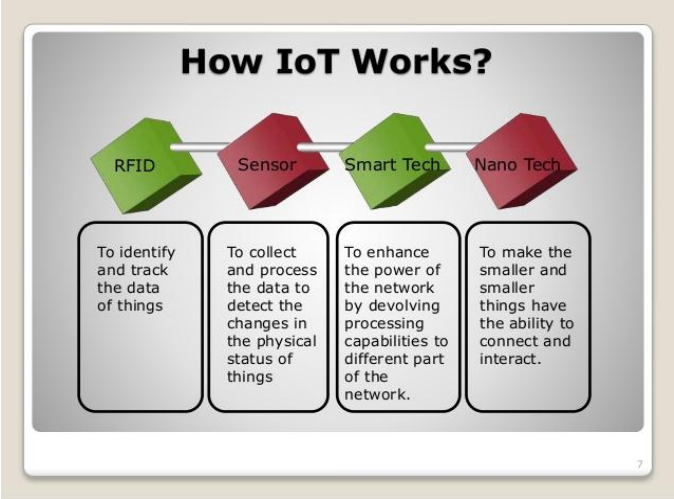

Fig. 1. IOT working.

The IOT is more than internet connected consumer gadgets. Sooner or later every IT organization will need to create a framework to support it. Energy companies already use networked sensors to measure vibrations in turbines. They feed that data through the network to computing systems that analyses it to predict when machines will need maintenance and when they will fail. Jet engine manufacturers embed sensors that measure temperature, pressure, and other conditions to improve their products. There are different types of Layers present in IOT:

Interface Layer: The first layer of IOT is interface layer. This layer provides the interaction methods between users and application. This section looks how user can easily use the system. This includes three main approaches. Firstly, we need the ability to create web-based front-ends and portals that interact with devices and with the event-processing layer. Secondly, we need the ability to create dashboards that offer views into analytics and event processing. Finally, we need to be able to interact with systems outside this network using machine-to-machine communications (APIs). The recommended approach to building the web front end is to utilize a modular front-end architecture.

Service layer: This layer is used to create and manage services to satisfy user's needs. To do so, it process data deep processing. To make more user friendly application, it provides database with different data and divides work. This is an important layer for three reasons:

1. The ability to support an HTTP server and/or an MQTT broker to talk to the devices;
2. The ability to aggregate and combine communications from different sensing devices and to route communications to a specific device (possibly via GSM/GPRS).
3. The ability to bridge and transform between different protocols that is to offer HTTP based APIs that are mediated into an MQTT message going to the device.

Networking or Communication Layer: The Networking or Communication layer supports the connectivity of the devices. There are multiple potential protocols for communication between the devices and the cloud. The most well-known three potential protocols are

- HTTP/HTTPS (and REST full approaches on those)
- MQTT
- Constrained application protocol (COAP)

Let's take a quick look at each of these protocols in turn HTTP is well known, and there are many libraries that support it. Because it is a simple Text based protocol, many small devices such as 8-bit controllers can only partially support the protocol –for example enough code to POST or GET a resource. The larger 32-bit based devices can utilize full HTTP client libraries that properly implement the whole protocol. There are several protocols optimized for IOT use. The two best known are MQTT6 and COAP7. MQTT was invented in 1999 to solve issues in embedded systems and SCADA. It has been through some iterations and the current version is undergoing standardization in the OASIS MQTT Technical Committee.

Sensing Layer: Sensors collect data from the environment or object under measurement and turn it into useful data. This layer covers everything from legacy industrial devices to robotic camera systems, water-level detectors, air quality sensors, accelerometers, and heart rate monitors. And the scope of the IOT is expanding rapidly, thanks in part to low-power wireless sensor network technologies and Power over Ethernet, which enable devices on a wired LAN to operate without the need for an A/C power source.

IOT Platforms and Security: Even with the recent attention given to security for IOT devices, it can be easy to overlook the need for end-to-end security for an IOT platform. Every part of a platform should be analyzed for security prospects. From internet connections to the applications and devices to the transmitted and stored data, there is a potential for an attack vector. Without question, the single most important non-functional requirement of an IOT platform is that it offers robust security.

II. System Model and Components Analysys

Block Diagram-

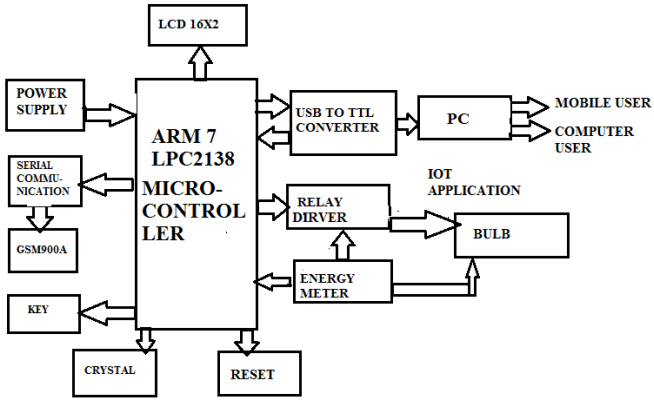

Fig. 2. Block diagram of proposed system.

In our proposed system we use Relay, GSM, display device, microcontroller LPC 2138, GSM and IOT web server. A relay is attached through on bulb any other application in the customer home any other places Microcontroller will

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count that pulses and decrement the balance count which is added by the SMS send through GSM by MSEB by paying appropriate amount, when the balance count becomes less (threshold value) it sends a message "Balance is less" to the display device, and customer can recharge their account by recharging their account for uninterrupted energy source and if customer didn't recharge their account and balance count becomes zero microcontroller will turn off the relay in the meter and energy supply will interrupted to the customer.

This system displaying the information about the energy consumed in terms of units, about the bill and if any theft occurs that will be displayed in the website. Hence every user can check the information anywhere globally. Thing speak web page is used for displaying the information of the system. The hardware components used in the proposed system is as below:-

- ARM7-LPC2138
- USB TO TTL CONVERTER
- GSM
- Relay
- LCD

1] ARM7-LPC2138: NXP LPC2138 Target Board is an evaluation and a development system for NXP ARM7TDMI-S based LPC2138 microcontroller. The ITLPC2138 package consists of a USB cable and a target board populated with NXP LPC2138 CPU, minimum peripherals, JTAG debug connector, ETM trace connector and an on-board integrated I SYSTEM debugger. The user can write and debug the application using the on-board integrated I SYSTEM debugger, which connects to the PC through the USB connection. The board requires no external power supply since it's powered from the PC USB port. An external ARM7TDMI-S debugger (including e.g. ETM support) can be used for debugging as an alternative to the on-board integrated debugger

Fig. 3. ARM7-LPC2138.

The LPC2131/32/34/36/38 microcontrollers are based on a 16/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine the microcontroller with 32 kB, 64 kB, 128 kB, 256 kB and 512 kB of embedded high-speed flash memory. A 128-bit wide memory interface and a unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty. Due to their tiny size and low power consumption, these microcontrollers are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. With a wide range of serial communications interfaces and on-chip SRAM options of 8 kB, 16 kB, and 32 kB, they are very well suited for communication gateways and protocol converters, soft modems, voice recognition and low-end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit 8-channel ADC(s), 10-bit DAC, PWM channels and 47 GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

a) ARM7-LPC2138 Features

- 32-bit RISC processor (32-bit data & address bus)
- High performance RISC
- Virtual Memory System Support
- Excellent high-level language support
- Simple but powerful
- No Separate power adapter required (USB power source)
- Two RS-232 Interfaces (For direct connection to PC's Serial port
- On Board Two Line LCD Display (2x16) (with jumper select option
- On Board 8 LED Interface to test Port pin (with jumper select option)
- On Board Pot interface to ADC
- On Board Buzzer Interface
- On Board 4x4 (16 Keys) Matrix Keyboard
- On Board I 2C EEPROM On Board External Interrupt Button
- On Board Connector for PWM Output
- PWM controlled LCD backlight
- On Board Connector for Analog Output
- On Board Speaker Output
- LF Amplifier LM 386

b) ARM7-LPC2138 Specification

- High Performance 32-bit ARM7TDMI-S™ CPU
- 512 KB Programmable Flash Memory provides minimum of 10,000 erase/write cycles and 10 years of data-retention.
- 32 KB Data Memory (SRAM)
- In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software.
- Single Flash sector or full chip erase in 400 ms and 256 bytes programming in 1 ms.
- Embedded ICE and Embedded Trace interfaces offer real-time debugging with the on-chip Real Monitor™ software and high speed tracing of instruction execution.
- Two 8-channel 10-bit A/D converters with conversion times as low as 2.44 us per channel.
- Single 10-bit D/A converter provide variable analog output.
- Two 32-bit Timers/External event counters.

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- Four Capture and four Compare channels.
- PWM unit with six output pins.
- Low power Real-time clock with independent power and dedicated 32 kHz clock input.
- Multiple serial interfaces including two UARTs, two Fast I2C (400 kbit/s), SPI™ and SSP with buffering and variable data length capabilities.
- Vectored interrupt controller with configurable priorities and vector addresses.
- Up to 47 of 5 V tolerant general purpose I/O pins.
- Up to nine edge or level sensitive external interrupt pins.
- 60 MHz maximum CPU clock available from programmable on-chip Phase-Locked Loop (PLL) with settling time of 100us.
- On-chip integrated oscillator operates with external crystal in range of 1 MHz to 30 MHz or with external oscillator from 1 MHz to 50 MHz.
- Power saving modes include Idle and Power-down.

2] USB to TTL Converter:

Fig. 4. USB to TTL converter.

This USB to serial TTL level converter cable offers a simple and easy way of connecting TTL level devices to your computer's USB port. The cable is designed around the PL2302TA chip from Prolific which is built in to the USB housing. The other end of the cable is terminated with three 0.1" pitch terminals that provides the TX, RX, VCC and GND signals. The individual terminated wires are an advantage since it easily lets you connect the cable to a variety of devices.

a) USB TO TTL Converter Features:-

- Perfect for Field Service Applications
- Small – Fits easily into any laptop bag
- USB Port Powered
- USB 2.0 (12 Mbps) Compatible
- TTL Data rates up to 460.8 Kbps
- Supports Windows 98, ME, 2000, XP, Vista, 7 (32/64 bit),
- Connect 5 & 3.3V TTL Devices to your USB Port

3] GSM

Fig. 5. GSM.

GSM/GPRS Modem-RS232 is built with Dual Band GSM/GPRS engine- SIM900A, works on frequencies 900/ 1800 MHz. The Modem is coming with RS232 interface, which allows you connect PC as well as microcontroller with RS232 Chip (MAX232). The baud rate is configurable from 9600-115200 through AT command. The GSM/GPRS Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as DATA transfer application in M2M interface. The onboard Regulated Power supply allows you to connect wide range unregulated power supply. Using this modem, you can make audio calls, SMS, Read SMS, attend the incoming calls and internet ect through simple AT command.

a) GSM Features:-

- Dual band GSM/GPRS 900/1800MHz.
- Configurable baud rate.
- SIM card holder.
- Built in network status LED.
- Inbuilt powerful TCP/IP protocols stack for internet data transfer over GPRS.

4] Relay

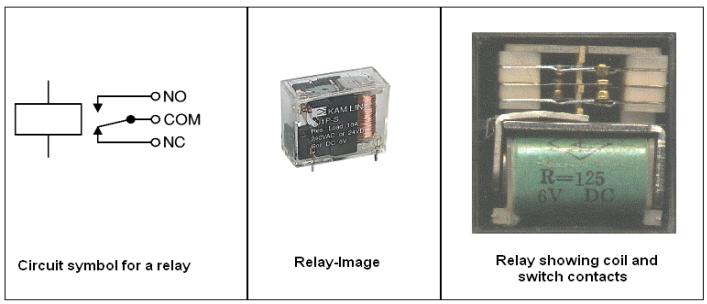

Fig. 6. Relay.

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

5] LCD Display

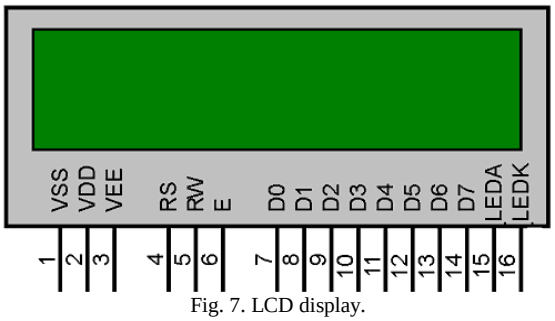

Fig. 7. LCD display.

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LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

6] Energy Meter

Electromechanical meter consists of an aluminum disc positioned between two electromagnets, one of whose coil is connected to the load and is the current coil and the coil of another electromagnet is connected to the supply voltage. The interaction of the fluxes between the two coils is responsible for providing a torque to the disc, which starts rotating, with the revolutions proportional to the load current. The counter records the number of revolutions and displays them, which indicates the energy consumed.

Fig. 8. Energy meter.

III. Software Discription

Software Required

- PCB-Dip trace
- Keil-flash magic
- Programming Language:-C-language

COMPILER: KEIL was founded in 1986 to market add-on products for the development tools provided by many of the silicon vendors. Keil implemented the first C compiler designed from the ground-up specifically for the microcontroller. The Keil Compiler generates code for any device that is compatible with the 8051, 251, C16x/ST10, or ARM microcontrollers. The Keil uVision IDE supports two distinct methods of program testing: simulation and target debugging.

Features of Dip Trace

- Printed circuit board design program
- Distributed under general public license
- Produce custom prototype quality circuit boards
- Run under Microsoft Windows NT, 2000, XP and Vista.
- Learning to use software is fast because of its standardized Windows user interface.

IV. Advantages & Applications

Advantages

- To reduce wastage of energy.
- Prevent electricity shortage during dry seasons.
- Make every customer a self-interested guardian of the power (energy) supply.
- Real time bill monitoring
- Time reduced receiving bill.

Applications

- Residential and commercial building in a public energy supply system
- MUNCIPAL CORPORATION
- PUBLIC POWER SOURCES
- MSEB
- Govt. Energy plant

V. Conclusion

Thus the article explains the basic structure and system design for IOT based energy meter billing and monitoring system emergency system. The article also explains the basic blocks and components used in this system. It's a complete case study for the proposed system design. The system is very much helpful for reduction in energy wastage and prevention in electric shortage. In this system consumer can do power management by knowing energy usage time to time. Using this system we can provide real time bill monitoring system and time reduced billing system.

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