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Design of an On-Demand Electric Power Load Management Service for Smart Meters Using GSM

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Abstract: Energy is one of the most fundamental components of daily life and plays a vital role in the growth of a country's economy. Due to recent severe energy crises in Pakistan, the government is focusing on establishment of new power generation plants to overcome electrical power shortage. In addition, the load management and prevention of electricity theft are challenging tasks for the government. Many steps to control electricity usage have been taken and smart meters were introduced in major cities as a pilot project. However, still existing system has various problems, such as, ignorance of extra power load request by the consumer, poor management and consumer feedback handling. These are also few of the main causes of electricity theft in Pakistan, because consumer's need of extra power load has not been processed on time. Furthermore, no automatic service exists with implemented smart meters, which can make a direct interaction between a smart meter power company and the consumer. In this paper, On Demand Electrical Power Load Management Service (EPMLS) architecture for smart meters, using GSM (Global System for Mobile), has been proposed and discussed. The proposed architecture introduces an additional power load management service module in existing smart meters. The implementation of this service module in existing smart meters develop a real time interaction between smart meter, consumer and power companies and also help to manage load automatically.

Key words: Smart metering systems, Challenges, EPMLS architecture, Arduino microcontroller, GSM module.

INTRODUCTION

Electricity is the backbone of the socio-economic development of the nations and it depends on the production and proper utilization of electric power. Therefore, the management and control of electricity networks has top priority in government policies globally. Recent crises of the shortage of electrical power and increase in the cost of electricity in Pakistan led to various challenges for the government, such as, un-scheduled power breakdowns, inefficient load management and electricity theft. The government acquired some traditional measurements to overcome the issue of power breakdown. It included banned neon lights, neon sign boards and the extension of weekend holidays from one to two days, closing public and private market places at 9 pm, instead of the development of new power generation projects or to manage the available load. Therefore, daily life routines, economy and industrial production have been seriously affected by these unscheduled and unbearable power breakdowns throughout the country.

To control and manage the worst situation of power breakdown, the government authorities constituted high-level committees to propose the possible solution to overcome the gap between demand and supply. The proposed solutions from the committees were:

- Technological upgrading of the grid station infrastructure
- Deduction of electricity charges
- Encouraging the usage of CFL (Compact Fluorescent Lamps)
- Media campaigns against power theft across the country

According to National Energy Policy 2013-18 (GoP, 2013), the government has taken some actions to manage the power load, such as, privatizing government-owned power plants and the power distributing companies, repairing and maintenance of poor infrastructure, redesigning and strengthening the national grid transmission network and power trading system. Moreover, this policy suggests on investment in the alternate energy and less expensive power generation solutions. The policy makers have focused more on the design strategies, which only increase the generation of electrical power to complete the need of electricity and overcome power failures. However,

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there is an essential need of research in the long term planning, load management procedures and control the causes of electricity theft. This paper describes an introduction, available services and challenges in smart metering systems. It further discusses new proposed services, architecture and operational mechanism of a demand EPLMS.

Smart metering systems:

Traditional meters are based on electromechanical mechanisms, which cannot provide automatic transmission of meter reading and conventional electricity billing system needs a greater human resource. With the traditional approach, electric power companies need meter readers to visit the consumer houses personally and read the meter reading manually and then collect meter readings for bill calculation.

This manual process is very time consuming and tiresome that causes human errors and opens an opportunity for corruption. Thus, the billing system can become inaccurate and inefficient. To avoid the false and inaccurate billing and theft identification, the automatic metering system (Smart Meters) has been installed, which performed the electricity saving, power transmission control and energy monitoring remotely. Furthermore, smart meter technology has many features for consumers as well as electric power companies. In addition, these smart meters were introduced in various countries, such as, UK, Spain India, Bangladesh, Ghana, China and USA. These smart meters support different wireless communication technologies, such as, GSM, GPRS, Bluetooth, Wireless ad-hoc, Intelligent SMS based and ZigBee to communicate between consumer and power companies, without involvement of any meter reader (Gupta and Shukla, 2016; Yeolekar and Kulkarni, 2015).

Available services on smart systems:

The available smart metering systems in literature were used for multipurpose, such as, those developed for automatic energy monitoring through wireless and ad-hoc network technology. In addition, these metering systems had the ability of real time data transmission through its GPRS technology. Another system was developed for theft prevention, which is based on the current transformer to measure the total power consumption of individual houses and industries. It recorded the meter reading and transmitted to the electricity board after 60 days at once (Jalilian *et al.*, 2016). To avoid the theft, infrared sensors were placed in the screw portion of energy meter seal. Whenever, anyone attempted to remove the screw, the meter sent an alarming message to electricity board. Table 1 shows a comparison summary of technical features of smart meters proposed in the literature.

Table 1: Comparison of technological features of smart meters.

Smart meter	Communication method	Features
CENTRON 4G LTE SM (Itron, 2014)	4G LTE , IP,ZigBee	• High-speed • Wide coverage • Support smart gird • Low latency
SGM1100, SGM1000, SM Series (www.aclara.com n.d.)	ZigBee, PLC modem	• Different-measurements • Water, gas, electricity • Good security system • Scalability • Remote configuration
WS310-GPRS Smart energy meter (paxhz.com n.d.)	DTSD5 GPRS	• Remote reading and configuration • High power • Advanced automatic meter reading (AMR) applications • Cost-effective solution
E450- Advanced residential meter (http://www.landisgyr.eu/ n.d.)	PLC Communication, VPN	• Accurate monthly and quarterly billing system monitoring • Consumption by online portal • Remotely configure the meter

Another development in the smart meter was an automatic energy meter reading system with instant billing (Ashna and George, 2013; Malhotra and Seethalakshmi, 2013), based on GSM technology. It sends meter reading through SMS to electric power company. This system provides a better solution as compared to the traditional metering systems and it frequently transfers power consumption data from the remote station to the suppliers. It is also capable to generate electricity bills timely, a better understanding of energy demand patterns, manages meter failures and controls frauds more efficiently. Another idea of smart meter is prepaid energy meter based on GSM technology (Anon, 2013). It provides facility to electricity consumers to pay their electricity bills in advance. Once the prepaid balance is exhausted, the consumer power load will be disconnected automatically. In order to reestablish electricity connection, power utility company provides a prepaid balance card for recharging the prepaid smart meter.

Furthermore, this system also has theft detection techniques and real time data transmission from the remote places. Different types of the smart meters based on different transmission technologies, such as, postpaid GSM based energy meter, reconfigurable prepaid energy meter and GPS based meter reading systems have been proposed by researchers. The features included are, theft detection, warning alters, auto disconnection of electricity power and auto identification of smart meter location (Hussain *et al*., 2016; Yao *et al*., 2014).

A new approach was introduced by the experts' group of Bangladesh (Fadlullah *et al*., 2011), who incorporated different technologies to achieve, the real time data transmission, wide area network coverage, robust data transmission, lowering power consumption, cost-effective and reliable network to electricity suppliers (Ellenki *et al.*, 2014; Ashna and George, 2013; Shah, 2013). Furthermore, the proposed system used USB (Universal Serial Bus) and GPRS technology to establish the connection, higher data transmission and more security between smart meters and electricity suppliers (Malhotra and Seethalakshmi, 2013; Bashar *et al.*, 2013; Rashdi *et al.*, 2013). In this system, the USB has its own universality and durability, it uses TCP/IP and PPP protocol for communication and GPRS is an extension of GSM network (Rupok *et al.*, 2011).

Challenges in smart metering systems:

Smart metering technology is designed with two options, i.e., post-payment and pre-payment. They establish unidirectional and bidirectional communication channel from power companies to consumers. Moreover, some smart meters cut-off electricity if any malpractice occurs. However, no three mode communication method has been proposed yet. A summary of possible challenges in smart meters is listed in Table 2.

Table 2: Challenges in smart metering system.

Advanced Smart Metering Infrastructure for Future Smart Homes (Rodriguez-Diaz and Palacios-García, 2015).	• Proposed more smart devices • ZigBee or Bluetooth that allow the interconnection of the different home appliances • More amount of wireless signals in home • More smart meters are used to obtain the pattern of electricity consumption • Prepaid system
A Shipshape Prepaid Energy Metering Organism (Deepakumar and Latha, 2014).	• Bidirectional communication b/w two ends • Advance payments • Cannot be reconfigured remotely
Power Distribution Scheme Using Smart Meter, Perspective (Hossain *et al.*, 2015).	• Divide fixed unit per day • Cannot adjust the changed tariff • Cannot be statistically reconfigurable
Microcontroller and GSM Based Digital Prepaid Energy Meter (Sarwar, 2016)	• When balance is exhausted the power is cut-off automatically without any warning or alters

RESULTS AND DISCUSSION

On-demand electrical power load management (EPLM) service:

On Demand EPLM Service is designed for smart meters with GSM technology. The architecture of EPLM service is illustrated in Fig. 1. The architecture has four main components:

a) Arduino Mega 2560 based control unit
b) Smart Meter
c) GSM communication Modules
d) Central Database

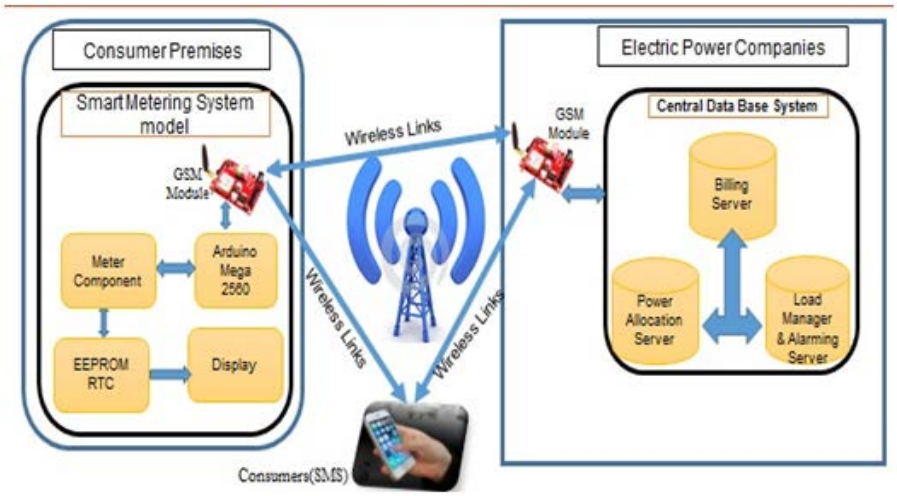

Fig. 1: EPLMS Architecture and its components.

a) Arduino Mega 2560 based controller unit

Figure 2 shows an Arduino board, used as the main controller of the architecture in the design of EPLM and placed as in a smart meter. This board is based on AT Mega 2560 microcontroller and has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB

connection, a power jack, an ICSP header, and a reset button. It comprises all the devices needed to support microcontroller. This board is connected with a PC using USB port and powered by using AC-to-DC adapter or a battery.

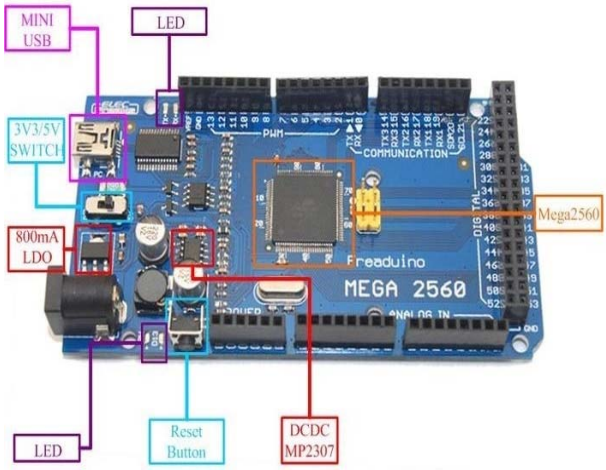

Fig. 2: Arduino module based on Mega 2560.

It is also used to measure the time and dates even when the main component is switched off. EEPROM (Electrical erasable programmable read only memory) is being used by the programmer to read and write the programs. It is also used for storage of the energy consumption units. ICs ADE 7757: It is low cost, single chip solution for energy measurement. It is highly integrated chip consisting of two ADCs, a reference circuit and fixed DSP for the calculation of real power.

b) GSM communication module

GSM communication module of EPLMS is responsible for every type of communication between power companies, meter system and consumers. GSM module will be installed at both sides for wireless data transmission. A RTC (Real Time Clocking) integrated circuit is being used to keep a track record of real time transmission.

c) Central database

In EPLMS architecture, the power companies need a central database with the following three servers for different functions:

1. **Instance billing server:** It is responsible for bill calculation, billing status, billing stages and extra units bills.
2. **Power allocation server:** For allocation or reallocation of extra electricity subject to the availability and unavailability of electrical power.
3. **Load manager/alarming server:** Used for sending alerts when any malpractice incident is identified.

Operational mechanism of on-demand EPLMS:

The state of electricity transmission from the grid station to smart energy meter inside any home is described in Figs. 3, 4 and 5. According to the data flow algorithm, a smart meter will receive and send various alerts to end consumers and electric power companies besides the state of electricity transmission will be changed according to the demand of the end consumers. EPLMS architecture contains three types for electricity consumption states:

1) Standard electrical power transmission,
2) Electrical power over usage situation,
3) Additional power request based demand.

1) EPLMS standard electrical power transmission:

In standard energy consumption, a smart meter will receive normal 220V from grid station. Five-kilowatt electricity will be allocated frequently to every individual home by the power companies. The standard system flow of electrical power is depicted in Fig. 3, where consumers will have consumed their electricity within allocation limit.

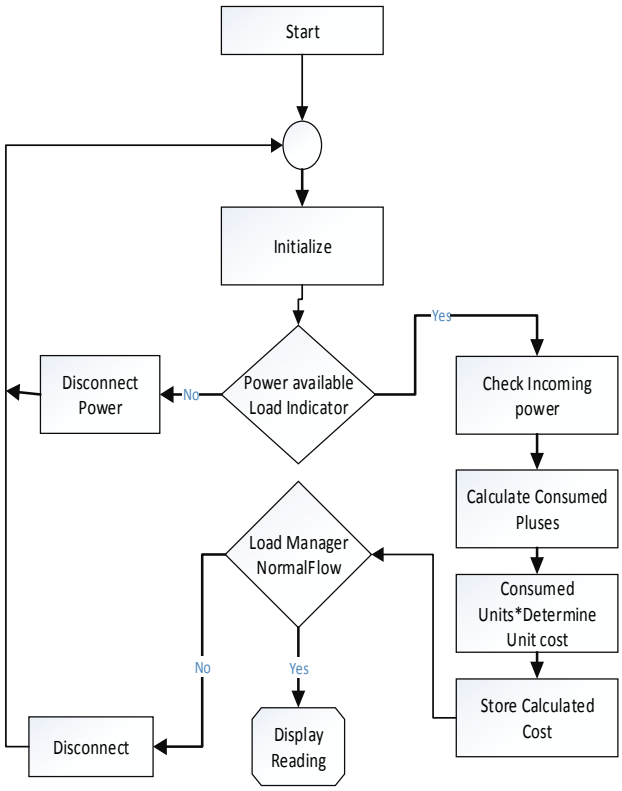

Fig. 3: Standard system flows with allocated power by the company to a consumer

2) EPLMS response on power overconsumption:

When a consumer will over consume the allocated electrical power limit, the smart meter will send initial SMS alert to consumer and power companies to inform about the over consumption state. Then the system will send continuous SMS alters to the consumer to reduce the electricity consumption within specified time of interval (Fig. 4). When a consumer reduces his consumption in the response to SMS alerts, the electricity will continue its normal flow. In case, a consumer fails to the response of electricity over consumption alerts, the electricity will be switched off automatically.

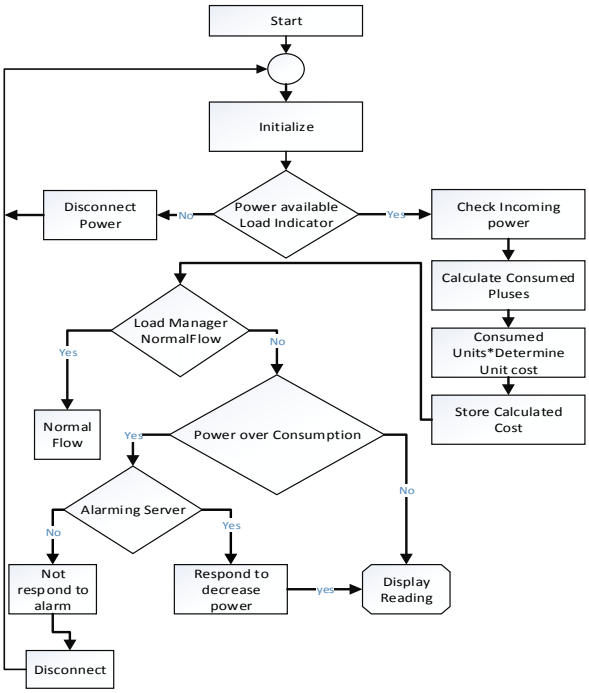

Fig. 4: Electrical power over consumption.

3) Request for allocation of Additional power through EPLMS:

Whenever, a consumer needs extra electrical power, he/she will send a request SMS to the power company for additional load allocation (Fig. 5); if extra electrical power is available within the system, the power company will reconfigure smart meter from its previous state and additional power will be allocated to the consumer. After the reconfiguration process, the consumer will receive confirmation SMS about the extra load allocation. In other cases, the alert SMS may inform a consumer about de-allocation, overconsumption, automatic switched off and other alerts.

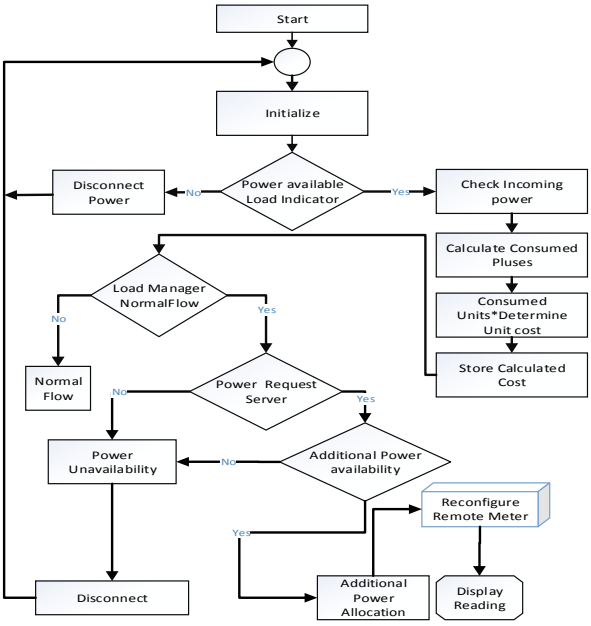

Fig. 5: Request based electricity demand.

CONCLUSION

The concept of EPLMS was originated after carefully investigating the reasons for severe power breakdown in Pakistan. These frequent breakdowns are causes of inefficient electrical power load management and electrical power theft. The smart meters proposed previously in the literature do not have service/architecture, which provides an interactive communication mechanism between power companies, consumers and smart meters for the automatic electrical power load management. Development and implementation of EPLMS will offer a significant feature to automatic load management for the existing metering system in Pakistan. It will help power companies to collect data about supply demand, prevention of electricity theft, automatic power load management and false billing. In addition, with the help of GSM service, it will develop an interactive communication via SMS alerts, such as, billing, tripping, on demand status, power breakdown schedule, theft circumstances and inquiries between consumer and power supply company. The concept of EPLMS architecture discussed in this paper is being further investigated.

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