Implementation of Last Meter Smart Grid in an Internet of Things Platform

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Abstract : The smart grid assimilates conventional grid and communication network to form an intelligent power system network with all the components interconnected with each other through internet and delivering sustainable power supply. Owing to the communication feature, smart grid infrastructure is more flexible and allows bidirectional flow of information and energy between consumers and energy utilities. Consequently, last meter smart grid has become a promising solution for all the problems of conventional power grid, increasing efficiency, effectiveness, reliability, and encountering increase in power demand. Recently, various communication network and information technologies have been recognized. This paper aims to offer a comprehensive study on Last meter smart grid architecture and function of various communication in smart grid.

***IndexTerms* - Communication, Internet of Things(IoT), Last meter, Smart grid, Wireless Sensor Network(WSN).**

I. Introduction

An electrical grid is the most compounded and one of the great achievements of the engineering stream. It generates the electrical energy, transmits over a long distance and allocates it to end users. An electrical power web comprises a large network of synchronised interconnection of generating plants, energy converting devices (transformers, inverters etc.), high voltage transmission lines, distribution lines, substations and the consumers. Generally, power plants are located far from the demand centres and are linked with the help of electric grid. Most of the power generation is done from burning coal and uranium based fuels. This generation is low in efficiency, causes pollution and also results in tremendous amount of energy wastage and hence revenue losses.[1] There are many other factors such as inefficient routing, dispensation of electricity, unreliable communication and inadequacy of mechanism to store generated electrical energy. Apart from these, exponentially increasing energy demand, aging of infrastructure and improper security are also a challenge to the power grid.

A. Smart Grid

To overcome above drawbacks, smart grid has emerged as encouraging key with the feature of communication network and information technology. A smart grid is a grid comprising wired and wireless communication infrastructure. The fundamental beneficence of smart grid is implementation of bi-directional stream of energy and communication signal. The communication network present in a smart grid accredits it to sense and inform any changes or update in the power system as well as in consumer premises. This ability is inherited from sensor network and controllers which are connected at each and every part of the power grid section. The concept of smart grid includes investigation of various drawbacks of the traditional grid and this observation provides detection of load side demands and management and to advance the conventional grid.[2,3]

The pioneer concept of smart grid started with an objective of developing demand side management, improving energy efficiency and composing self-healing against vicious, demolition and disaster.[4] More specifically, smart grid can be encapsulated as an electrical grid that uses information network, two way communication, cyber security and computational intelligence for generation, transmission, distribution and devastation to acquire safe, reliable, clean, volatile, efficient and feasible[5].

Last meter smart grid is a part of power grid which lies near the consumer premises. The main purpose to introduce last meter smart grid is to support the bidirectional transmission of power and data between consumers and energy utilities and hence converting the proposed approach from "distributor centric" to "consumer centric". It can be acknowledged as extensive perception of smart home and smart building. This system administer supervisory control and data acquisition (SCADA), advanced metering infrastructure (AMI), smart meters, fault consciousness and resilience, illegitimate illegal theft detection, load stablization as well as self-healing.[6-8] Table 1 makes a comparison between smart grid and the conventional grid.

Table 1
Differentiation between SG and Conventional Grid

	Conventional Grid	Smart Grid
Information flow	Unidirectional	Bidirectional
Power generation	Centralized	Distributed
Grid topology	Radial	Network
Sensors	Few	Lots
Testing	Manual check	Remote check
Efficiency	Low	High
Control type	Passive	Active
Environmental pollution	High	Low

A. Internet of Things

Internet of Things, termed by Kevin Ashton in 1999, can be defined as interconnection of many devices (nodes) through embedded technology to communicate with each other or to the main server.[9] The IoT has gained significant advantages over various applications by interconnecting internet to different embedded devices.
The architecture of Internet of Things is broadly divided into three main sections:- *a) Smart devices and sensors*- The main purpose of smart devices, sensors and actuator is to continuously gather the data from the surrounding and transfer it to next layer. These devices form device connectivity layer and are connected to IoT platform with the help of communication network which can be wired (CAN,PLC etc.) and wireless (ZigBee, WiFi, Bluetooth module etc.). *b) IP Gateway*- Gateway is a medium which connects the sensors and smart devices to the IoT platform and hence promotes the bidirectional traffic between users and providers. Whenever a device sends any information to the server, gateway converts its network address into an unique ID and vice versa.[10] *c) User Interfaces*- Consumers, power suppliers and application developers interact on IoT platform with the help of user interfaces which can be web based or API based . In this section, a user can approach the data uploaded on the cloud, web page or an android app by simply logging in and can use the API to obtain information.[11]

Table 2
Components of IoT

Parts of IoT Platform	Major Components
Smart devices and sensors	• Sensor and Actuator node • IP Gateway
IoT Server	• Message Dispatcher • Data management unit • Configurator unit • Secure acess manager
User Interface	• Visualization interface • Configuration interface

II. Literature Survey

A set of paper focusing on smart grid and Internet of Things have been studied to examine the existing techniques and future scope. Although the current scenario of the smart grid and communication technology has strong data base, but for the further framework, meticulous research and investigation has been done which is conferred below:-

Elisa spano et al. (2015). The author states that the classic model of power grid approaches distributor centric rather than user centric which undermines consumer existence. To overcome this, the paper presents an architecture and manifestation of the consumer authority of the last meter smart grid form on the base of Internet of Things, which has an exclusive advantage of minimising distribution of smart grid infrastructure and advance widespread acceptance of smart grid applications and smart home applications.[12]
Yasin Kabalchi et al. (2015). The paper focuses on smart metering and smart grid communication, its applications and challenges. The paper is branched into four major parts- a) smart grid and smart energy infrastructure b) smart measurement and metering c) communication technologies d) security on smart grid. The substantial situation of all four parts is outlined and future scope for each section is introduced in this paper.[13]

Ruofei Ma et el. (2012). In this paper, the key communication for smart grid has been determined and classified and its state-of-the-art analysis is reviewed. This paper offers a comprehensive study on application of wireless sensor network to the smart gird and issues on implementation of communication techniques along with interoperability, intellectual access to radio spectra, cyber security and its future trends.[14]

Xi Fang et al. (2012). In this paper, literature on enabling communication technologies to the smart grid has been surveyed. The author explores the three major system namely smart infrastructure system, smart management system and smart protection system. The smart infrastructure system consists smart energy, smart information and smart communication subsystem while smart management system covers distinct management objectives improving efficiency, reducing cost and profiling demand. The smart protection system amounts to improvement of security and privacy of the network.[2]

There are numerous surveys focusing on overview, principles, applications and challenges of IoT [15-17], security [18-19] and cloud computing [20]. The prevailing overview of smart grid concept [4], objection and standardisation [21], power demand forecasting [22] etc. are surveyed. Moreover there are various papers focusing on home automation and power metering, which will further help in implementation of in-home prototype in this paper [22-23]

III. Application of IoT in Smart Grid

The major objective of this paper is to focus on last meter smart grid and its communication system, related technologies, applications, challenges, issues and scope. The outline of this section is divided into three major sub-sections as smart grid and smart energy infrastructure, smart measurement and metering and communication technology. The present scenario as well as future directions of each sections is mentioned in this section.

A. Smart grid and smart energy infrastructure

As the name signifies, tradition grid produces electricity using fossil fuels, hydro or nuclear in centralised power plants. A conventional power plant generates electricity, transmit it using high voltage line and distribute it among the consumers. Thus it is considered as unidirectional flow of energy. For last meter smart grid, researchers should focus more on end user, for which smart grid has emerged as most promising solution. In smart grid every consumer is able to access their data uploaded in a web page or cloud server. Also smart grid facilitates each consumer to install low voltage generation plants and feed back to the grid, resulting in bidirectional flow of energy and information. The improvement of smart energy infrastructure requires smart measurement system, improved metering devices and efficient communication system. A smart grid viewpoint with its components is shown in below figure 1.

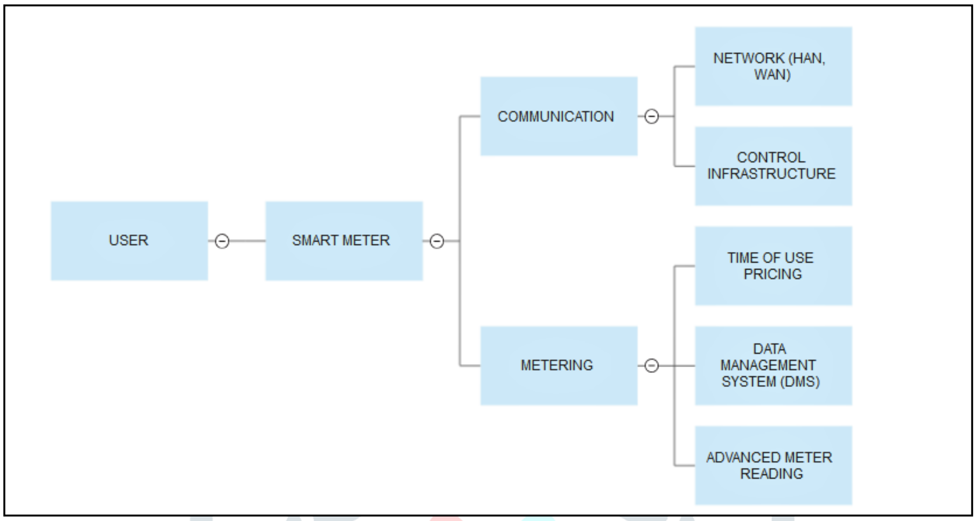

Figure 1 Smart grid perspective.

A. Smart measurement and metering

The measurement side of a smart grid includes energy management system (EMS). An energy management system is a computer aided system used by energy utilities to control, manage and optimize the performance of power grid by measuring and estimating active and reactive power. The EMS system is divided into two categories: centralized and decentralized. Centralized EMS consists intelligent algorithm and software whereas decentralized EMS uses logical operations. The smart measurement is executed by using smart meter. A smart meter is a device which captures the real time energy consumption by measuring voltage, phase angle and frequency. As shown in above figure 1, the smart metering comprises time of use pricing, data management system and advanced meter reading.

B. Communication network

The most crucial achievement of smart grid is involvement of communication technologies. In this section a extensive view of different communication technologies is discussed which will help in making improved judgement for the selection of applicable communication technologies. The whole communication technologies are divided into two main category- IoT and non IoT communication technologies. The non IoT technology is further divided into non IoT wireless technology (Bluetooth, Cellular communication, WiMax, Mobile Broadband and digital microwave) and non IoT wired technology (Powerline, Digital subscriber and optical) whereas IoT wireless communication includes Z-wave, 6LoWPAN, LoRaWAN and Zigbee. [24-26] Table 3 presents a summary of all each communication technology mentioned above.

The main objective of considering communication network technologies is providing some guidance on selecting satisfactory network as per need. The following table describes the characteristics and applications of the various communication technologies, which helps to understand which communication network is selected in which condition. After studying the table, it is observed that most of the technologies are focused in HAN i.e. Home Automation, while in IoT wireless section, only LoRaWAN supports NAN and WAN. Hence we can say for any system where long distance and low power communication is required, LoRaWAN will be preferred. Similarly, non IoT wired communication, DSl, power and optical communication requires high installation cost and hence are expensive for long distance communication as well as for rural, hilly and forest areas, it will be very difficult to implant. Thus it can only be used where high security and high communication efficiency is required. On the other hand, wireless technologies are economically good and free from complex structure, but they have bandwidth limitations, can be used for short distance only and also get influenced by interference issues. In summary we can say that no communication is best communication and are preferred according to the scenario.

Table 3
Various Communication Technologies

	PROTCOL	DATA RATE	RANGE	APPLICATION	CHARACTERISTICS
IoT Wireless Technology	Z-Wave	100 kbps	30m	Home automation (HAN)	Low latency, scalable , reliable
	6LoWPAN	250 kbps	10-100m	Smart metering, Home automation (HAN)	Low power, robust, support large mesh network topology
	LoRaWAN	.3-50 kbps	2-5 km	Online monitoring of transmission line and tower. (NAN,WAN)	Low power, long range, low cost, virtual channel, secure bidirectional communication.
	ZigBee	250 kbps	10-100m	Home automation, Energy monitoring, AMR (HAN)	16 channels with 5 MHz band width in 2.4 GHz spectrum, low deployment cost.
Non IoT Wireless Technologies	Bluetooth	721 kbps	1-100 m	Home automation,used in mobile and computer (HAN)	Low power consumption, short range low data rate communication
	Cellular	60-240 kbps	10-50 km	Monitoring &managing DER, SCADA (HAN, NAN, WAN)	Wide area coverage, improved QoS, network congestion due to high density.
	WiMAX	75 Mbps	10-50km	Real time pricing, AMR, outage restoration and detection (HAN)	Long range, high data, costly hardware, require leasing, trade-off between performance & distance
	Mobile broadband	20 Mbps	Vehicular standard	Electric vehicles, wireless Backhaul for SG monitoring (NAN)	High mobility, high bandwidth, high cost, infrastructure not readily available
	Digital microwave	155 Mbps	60km	Transfer trip between DER & substation (HAN, NAN)	Long distance, high data rate, prone to multipath interference and precipitation
Non IoT Wired Technology	Powerline	2-3 Mbps	1-3 km	Low voltage distribution, AMR (HAN, NAN)	Low installation cost, noisy and harsh medium, cost effective, wide availability
	DSL	1-100 Mbps	5-28 km	Smart metering (HAN, NAN, WAN)	High speed, low latency, high installation cost, long range.
	Optical	100 Tbps	10-60 km	Physical network (WAN, NAN)	Ultra high bandwidth, robustness against radio and electromagnetic interference.

IV. RESEARCH METHODOLOGY

In the uprightness of the above investigation, an in-home model for last meter smart grid implemented in an Internet of Things stage has been implemented. For better comprehension of the last meter smart grid, a point of reference model is set up so that it can exhibit the communication between energy utility and customer area. In this model, a smart meter is implanted to measure the power utilization of the customer and a server is introduced at service organization side. Raspberry Pi gets unit information from the meter, ascertains the units consumed and bill information and sends the gained information to server. This server in the transmission framework is associated with the cloud. After information is transferred reliably, the customer can get to this information globally. As the consumer knows about its energy consumption and can control the house load with the help of GSM, this strategy can likewise prompt increment in energy saving and can anticipate energy theft, therefore expanding system efficiency, reliability and security. Aside from these, there is an extra facility of giving safety by utilizing temperature and LDR sensor, which will consequently get enacted and informs the consumer in the case of emergency regarding fire crisis. The block diagram regarding the proposed model expressed above is shown in figure 2.

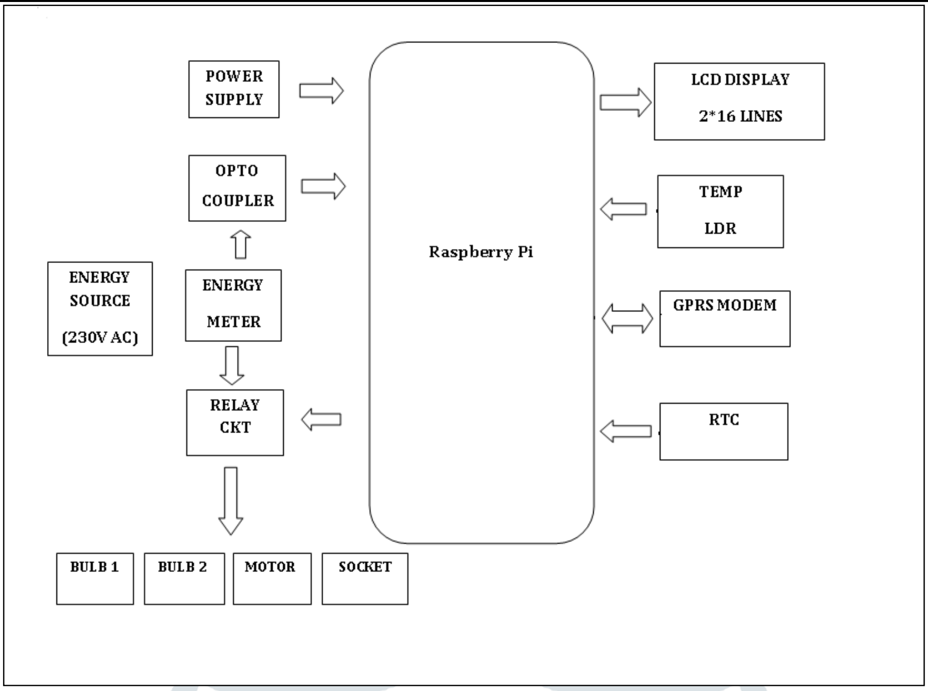

Figure 2. Block diagram of the proposed model.

A. Raspberry Pi

In the proposed model, Raspberry pi is used as an operating device, which can also be contemplated as Heart of system. Raspberry pi is a ultra-small, affordable single board computer which is capable of doing everything a modern computer can do except browsing internet. It is generally used to learn coding, build robots and creating projects. . It is a second generation model with an upgraded Broadcom BCM2836 processor, an ARM Cortex A7 based quad core processor running at 900 MHz. It also facilitates Ethernet, video and audio I/O, USB, GPIO connector, camera, JTAG, Display connector and memory card slot. A glimpse of specification of Raspberry Pi model used is shown in table 4.

Table 4 Specifications of Raspberry pi 2 model B

SPECIFICATIONS	
Chip	Broadcom BCM2836 SoC
Core Architecture	Quad core ARM cortex-A7
Central Processing Unit	9000 MHz
Graphics Processing Unit	Dual core videocore IV multimedia core processor
Memory	1 GB LPDDR2
Operating System	Boots from micro SD card and runs on Linux operating system
Dimensions	85*56*17 mm
Power	5V, 2A

A. Experimental Setup

The whole experiment procedure is divided into three sections i.e. consumer section, smart grid section and monitoring section An in-home prototype on the IoT platform is show below in figure 3.

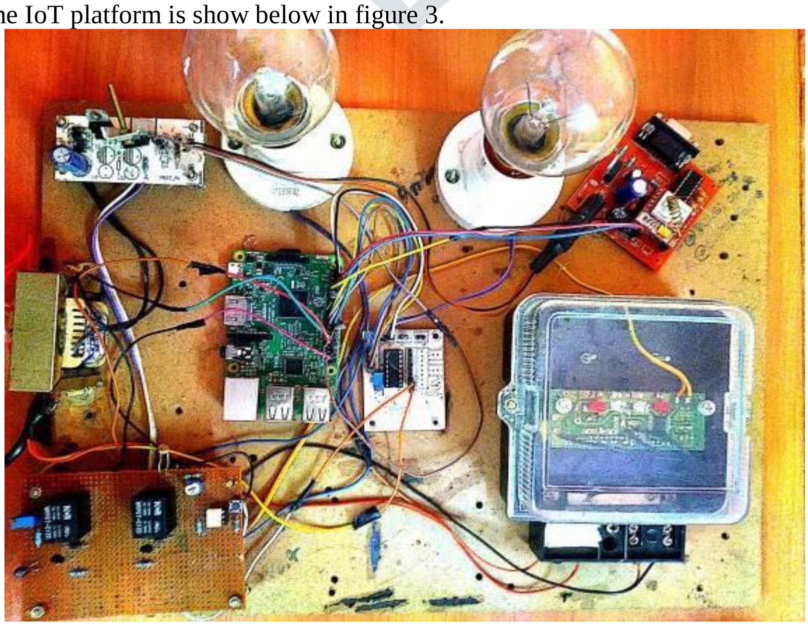

Figure 3 Smart Grid Prototype

A) Consumer section- In this section, smart meter is installed in consumer premises. Here the bulbs are utilised as home load. The main purpose of smart meter is to measure the number of units consumed and sent it to Raspberry Pi.Raspberry Pi constantly ascertains the unit consumed till the last utilization and transmits the data to smart grid server. Likewise, it also shows the readings captured by the numerous sensors such as temperature sensor and humidity sensor. The desktop of a Raspberry Pi model is shown in below figure 4. This method also encourages the consumer to screen their daily consumption day by day through their web. For future reference, a relay segment can also be implanted in the buyer side which will alarm the customer if there should arise an occurrence of over use, duty varieties and burglary.

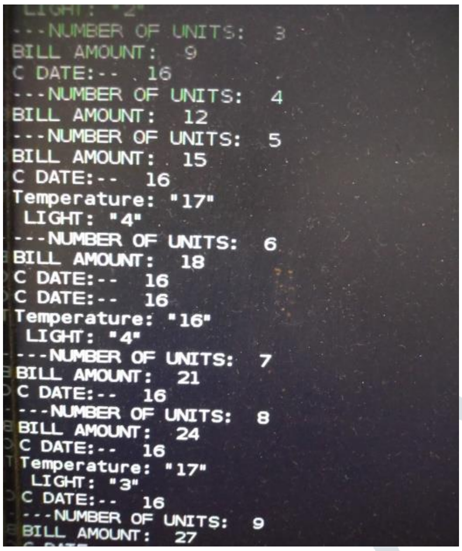

Figure 4 Raspberry Pi Desktop

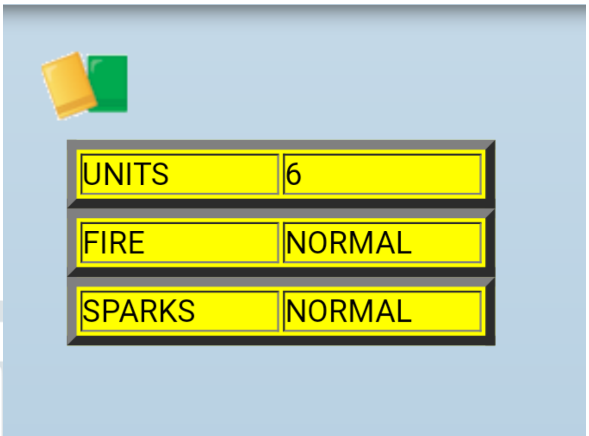

Figure 5 Web Page

B) Smart Grid – Raspberry Pi sends the data to the server with the help of various communication technologies such as ZigBee, WiFi, Bluetooth module etc. as listed in above table 3. In this in-home prototype model, WiFi communication network is used. To examine his record, a consumer needs to register and login the web page in which data is updated periodically. This web page displays the past information as well as instant value of units consumed and it also allows authorized consumers to manage their home load by sending commands. The web page after log in is shown in above figure 5.

C) Monitoring Section- Electricity board authorities and end users can screen the information once transmitted to the website. For better proficiency and reliability, end users are given an additional facility to control their load utilizing their smart phone with the assistance of GSM module in this model. In this in-home prototype, clients can on and off the home load according to their need as appeared in figure 6.

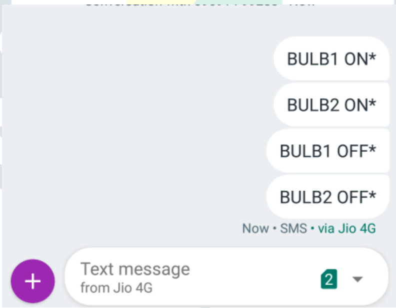

Figure 6 Message display for ON OFF of loads.

V. Result And Discussion

Continuous experiments are performed to verify the working method and reliability of the in-home prototype. The output in form of Raspberry Pi desktop, result in webpage and working principles is discussed above. Thus, we can say this in-home prototype successfully demonstrates the objective of last meter smart grid, also justifies the bidirectional flow of power and information between electricity board and end users. Furthermore, it also results in expand in reliability, increase in efficiency, reduction in cost and high security.

VI. Conclusion

After going through several observations, it is concluded that Internet of Things brings a great accord of upgrade to the last meter smart grid. The usage of WSN in smart network improves the presentation and guideline of the framework. End users can approach above web services and operate them to manage their home load. It also increases consciousness and involvement of non-technical end users granting them better interaction and control. With the increase in development, many new technologies will emerge which will make smart grid interoperable, cost effective and secure system.

ABBREVIATIONS

AMI	Advanced Metering Infrastructure	GSM	Global System for Mobile	PLC	Programmable Logic Controller
AMR	Automatic Meter Reading	GPIO	General Purpose Input Output	RTC	Real Time Clock
ARM	Advanced Reduced Instruction Set Computer	HAN	Home Area Network	WAN	Wide Area Network
CAN	Controlled Area Network	IoT	Internet of Things	WSN	Wireless Sensor Network
DSL	Digital Subscribe Line	JTAG	Joint Test Action Group		
EMS	Energy Management System	NAN	Near-me Area Network		

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