Design and Implementation of an Innovative Internet of Things (IOT) Based Smart Energy Meter

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Abstract— Energy meter is very essential measuring instrument for measuring the power in domestic, industrial etc. environment. Correct and appropriate measuring of power without any error is important in order to calculate the total power consumption and then for tariff calculation. In view of this, in this paper design and implementation on an innovative smart energy meter is proposed. The proposed smart energy meter is based on Internet of Things (IoT) applications. The paper describes its design along with its working.
Keywords- *Internet of Things (IoT), Smart energy meter (SEM), architecture of IoT, Elements of IoT.*

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I. Introduction

The Internet of things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data [1]. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure [1]. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure [2], creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit in addition to reduced human intervention [3-6]. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, virtual power plants, smart homes, intelligent transportation and smart cities. Things, in the IoT sense, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, cameras streaming live feeds of wild animals in coastal waters, automobiles with built-in sensors, DNA analysis devices for environmental, food, pathogen monitoring [7], or field operation devices that assist fire fighters in search and rescue operations [8]. Legal scholars suggest regarding "things" as an "inextricable mixture of hardware, software, data and service [9].

In view of above this paper proposes the design and implementation of an innovative smart energy meter. The smart energy meter proposed is based on Internet of Things (IoT).

II. Literature review

A study based on context-aware computing, learning, and big data in Internet of Things was provided by Sezer et al. [10]. Na et al. [11] has proposed energy-efficient mobile charging for wireless power transfer in Internet of Things networks. Jin et al. [12] proposed an information framework for creating a smart city through Internet of Things. Wu et al. [13] develop a new paradigm, named cognitive Internet of Things (CIoT), to empower the current IoT with a “brain” for high-level intelligence. Xia et al. [14] proposed GPS-free greedy routing with delivery guarantee and low stretch factor on 2-D and 3-D surfaces. Ren et al. [15] proposed a technique for exploiting the data sensitivity of neurometric fidelity for optimizing EEG sensing. Yu et al. [16] developed a method for carbon-aware energy cost minimization for distributed internet data centers in smart microgrids. Abdelwahab et al. [17] discussed enabling smart cloud services through remote sensing: an internet of everything enabler. Khan et al. [18] discussed a design of a reconfigurable RFID sensing tag as a generic sensing platform toward the future Internet of Things. Zhang et al. [19] provided information about ubiquitous WSN for healthcare. Främling et al. [20] proposed a universal messaging standard for the IoT from a lifecycle management perspective. Sheng et al. [21] proposed leveraging GPS-less sensing scheduling for green mobile crowd sensing. Chen et al. [22] discussed information fusion to defend intentional attack in Internet of Things. Kantarci and Mouftah [23] proposed trustworthy sensing for public safety in cloud-centric Internet of Things. Lin et al. [24] proposes a protocol and a method of spectrum management that can guard against common types of security threats despite the limitations of the local processing. New and innovative IoT based applications and its basics were discussed in literature [25-30]. In this paper, a prototype of an energy monitoring device based on an open source concept is presented [31]. This architecture assures several advantages with respect to traditional energy meters, such as easy development of new applications making cost- and time-effective the migration to future smart grid infrastructures and simple adjustments to change in the relevant standards [31]. The development of the induction-type energy meter is discussed [32]. In this paper, measurement equipment for the calibration of energy meters is presented [33]. Its structure and metrological characterization are discussed [33]. To improve its performances without increasing its costs, two online digital compensation procedures have been realized and are shown: one increases the spectral purity of test signals and one corrects the transducer frequency response [33]. Experimental results relating metrological characterization have shown that the so-realized calibrator is suitable for the onsite calibration of energy meters [33]. A Comprehensive Review of Smart Energy Meters has been provided by Tiwary et al. [34].

III. Internet of Things: Architecture

Architecture of IoT [25] depends on various applications of IoT. Fig. 1 shows general 3 layer / 4 layer architecture for IoT. For e.g. consider two scenarios. Scenario-1: Let's consider smart devices for pollution, wherein sensors sense the amount of carbon monoxide, nitrogen dioxide, sound level etc. and sends these data continuously to the central database [1]. These data will be analysed by using analytical tools and gives information about amount of air pollution in that particular city to the traffic police. This information helps to take the precaution when it exceeds the normal level [1]. Here sensor layer indicates sensors will be continuously sensing the air and sends the data through Wired or wireless communication to the database [1]. This data will be processed and analysed and final consolidated result will be send to the user smart phone through the Air pollution control application. Hence four layers architecture is required [1].

Scenario-2: Let's consider a sensor is attached near the kitchen or gas cylinder with context to find the gas leakage. In this whenever sensor detects gas leakage it has to alert the surrounding immediately and then has to send the message to the owner. In this case analysing has to be done in the sensor layer itself [1].

IV. Internet of Things: Configuration

Essential components [26] which are required to build IoT are i) hardware components such as sensors, actuators, ii) Middleware components such as database for storage and data analytical tools iii) Visualization through different applications [1]. This section explains important IoT key elements which are used to build IoT as shown in Fig. 2.

Unique identification for each smart device [1]

IoT consists of huge number of smart devices. Each of this devices requires a unique identification for communication and also helps to control and access remote devices through internet. Ipv4 addressing supports limited number of unique addressing for smart devices.

IPv6 provides large set of unique address. Apart from this unique address, each of these devices also has object id. This object id is used to refer the smart device within the communication network.

Sensing devices [1]

Each object embedded with sensors continuously sense the data based on the context. Context may be sensing humidity or temperature or sound level, amount of air pollution or motion etc.

Communication [1]

Sensed data from smart devices are sent to the database through the communication technologies. This communication technology may be Radio Frequency Identification (RFID), Bluetooth, Near Field Communication (NFC), Wi-Fi, ultra-wide bandwidth(UWB), Z-wave, 3G, 4G and Long Term Evolution-Advanced (LTE-A).

Data storage and analytics [1]

In IoT smart devices produces large amount of data, which has to be stored in the storage device. These stored data has to be analysed to extract the meaningful information. To do this, analytics or analytical tool which incorporates intelligent algorithm has to be developed to extract the useful information from raw data. This analytical tool has to support interoperability with different platforms. In the IoT architecture middleware represents the both storage and analytical tools. A centralized infrastructure is required to support both Storage and analytical tools.

Visualization [1]

Nowadays the world has become smart with smart phones. By using smart phones or laptops user has to download the required application and through which user can interact with centralized database and get the useful information about the actual environment.

V. Block diagram and Working of IOT based smart energy meter

Figure 3 shows the block diagram of the IoT based smart energy meter.

The Internet of Things energy meter is a device fixed at the top of the conventional consumer energy meter that provides detailed information about the electrical power usage. Modern power meters have a LED blinking every time a watt-hour is used, the IEM detects these pulses using interrupts, counts them & the data is stored to the cloud. The model consists of an ESP 8266 wifi module which operates at 3.3V. It can be programmed through a serial port. The energy meter is connected to the controller through an opto-coupler MCT2E. A current sensor ACS712 is connected to the analog input (ADC) through a potential divider network since the maximum voltage to the ADC input is 1V. An organic led display is connected to the controller through an I2C interface and the load is driven through a triac BT136 under controlled from the opto - triac MOC3021 which provides isolation from the load to the controller. Input port of the system is 230V which is converted into 5V using SMPS and regulated into 3.3V using LM3117 regulator.

Theft can be detected using the current sensor ACS712. When the load is being consumed even though the pulses are not reaching the controller the current sensor sends a theft consumption signal to the controller and the controller breaks the circuit.

Figure 4 shows the experimental setup of IoT based smart energy meter in laboratory.

VI. ADVANTAGES AND LIMITATIONS OF SMART ENERGY METER

Advantages of smart energy meter:

1. There is no need of human operator to go to the consumers address to take down the reading. Hence extra labour cost is reduced.
2. The users can be aware of their electricity consumption.
3. Theft of electricity can be avoided by tamper proof energy meters.
4. The readings recorded can be used by the Research and development department.

Limitations of smart energy meter:

1. Security to protect the privacy of the personal data collected should be good.
2. There can be an additional fee for the installation of the new meter.
3. The Internet is not available in remote areas.
4. The IOT is a diverse and complex network.

VII. CONCLUSION

In this paper, an attempt has been made to design and implement practical model of Internet of Things based Smart Energy Meter. The proposed model is used to measure the energy consumption of the household, and even make the energy unit reading to be handy. Hence it reduces the wastage of energy and brings awareness among all. It will also deduct the manual intervention and will make the system smart and reliable.

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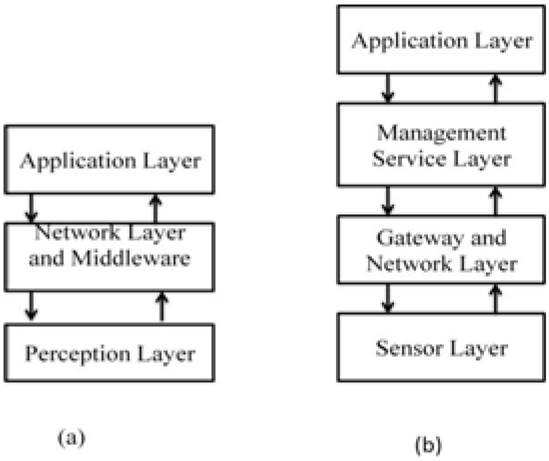

Fig. 1 General 3 Layer/ 4 Layer architecture for IoT [1]

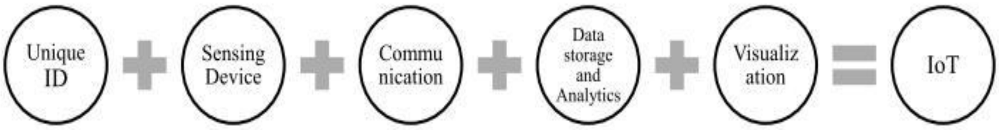

Fig. 2 Essential Key elements of IoT [1]

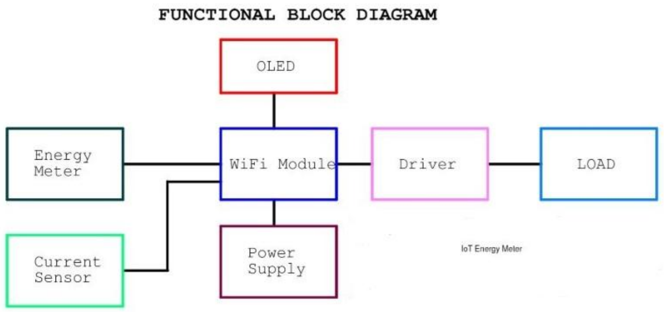

Fig. 3 Functional block diagram of proposed IoT based energy meter

Fig. 4 Experimental setup of IoT based smart energy meter in laboratory