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Design and Implementation of Smart Energy Monitoring Systems Using Wireless Technology

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Abstract: The smart grid is the integration of electrical and information infrastructures. Here to improve the power communication between generation, transmission, distribution and consumer we required advanced information technology based smart energy monitoring system (SEMS). Hence the advanced information technology need fast and reliable communication protocol i.e. Zigbee, Internet of Things (IoT) and Cloud Computing. These are the communication devices which are used to develop the smart energy monitoring system (SEMS). In future using SEMS easily we can obtain the closed loop communication for developing smart grid. This paper presents the comparison among these three types of SEMS and also get the final solution in which communication protocol suitable for implementation of closed loop communication. The concept of smart grid is combination of smart energy monitoring system, smart energy management system and smart energy control system. In this aspect smart energy monitoring system is the important tool which is interface with the energy management system and energy control system respectively. Hence the SEMS provide the electrical information in real time to energy management system without any delay time; we can obtain the efficient energy management system.

Keywords: Smart Energy Monitoring System (SEMS), Zigbee, Internet of Things (IoT), Cloud computing.

I. INTRODUCTION

Electricity is the heart of the nation, to save the national environmental we should save energy. Hence to save energy, our energy system will get smart. Where as to implement the smart energy system (Smart Grid) we required power transmission, power distribution and power utilization in smart manner.

Here power communication is one of the major tool for making all the process as closed loop. In the proposed system, three kind of smart energy monitoring system (SEMS) discussed to achieve fast and reliable power communication. There are SEMS using Zigbee protocol, SEMS using IoT protocol and SEMS using Cloud Computing. These are the concept were discussed in real time.

The designed systems are using to reduce the energy wastage by continuously monitoring the power utilization. Among all the three types of SEMS, based on the application and performance level the best system will be analysed.

Zigbee protocol: Zigbee is low-cost and low-powered mesh network widely deployed for controlling and monitoring applications where it covers 10-100 meters within the range. This communication system is less expensive and simpler than the other proprietary short-range wireless sensor networks as Bluetooth and Wi-Fi [1].

IoT protocol: The internet of things is a network of ever growing physical objects (such as connected devices and smart devices), embedded with electronics, software, sensors and network connectivity that enables these objects to collect and exchange data. The Internet of Things (IoT) objects features an IP address for internet connectivity, and the communication that occurs between these objects and other Internet-enabled devices and systems.

Cloud computing: Cloud Computing is a general term for the delivery of hosted services over the internet. Cloud computing enables companies to consume a compute resource, such as a virtual machine, storage or an application, as a utility just like electricity rather than having to build and maintain computing infrastructures in house.

II. SMART ENERGY MONITORING SYSTEM USING ZIGBEE PROTOCOL

A. System Overview

Here the Smart Energy Monitoring system is developed by zigbee communication protocol for home and office energy savings [2]-[5]. The proposed concept uses to obtain the real time electrical parameters from

digital meter between distribution and consumption as shown in the figure 1. The proposed wireless monitoring system easily interface with our personal computer, laptop and mobile. So that consumer can know about their power consumption. Hence the proposed system implemented to stop unwanted power consumption and consumer can reduce power utilization by knowing electricity bill before the electricity board assessment.

Besides the function of wireless monitoring, the SEMS based on Zigbee wireless transmission proposed in this paper also possesses the important functions of intelligent energy management and power usage safety protection. For the convenience of applying the developed system onto buildings, the wireless transmission function is adopted in the system so that the system could be used and installed at any location within the interior space without any need of wiring, which realizes the intelligent power usage management, monitor and safety protection at any place and effectively improves the convenience of system utilization [6]. The system concept is as shown in Figure1. As shown in the figure, consumer end receiver board and distribution end transmitter board are plugged onto the designed intelligent outlet module.

All measured energy parameters are transmitted through the Zigbee wireless transmission module to the central monitor unit (personal computer) using Arduino controller. [7]-[10].

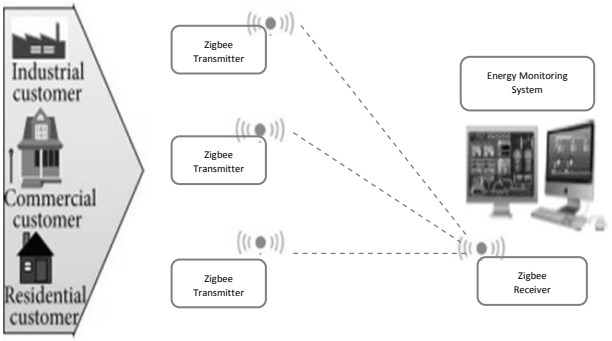

Figure 1. Configuration of Wireless Energy Monitoring System

The functional block diagram of energy monitoring device is shown in fig 2. This device consists of four main components, such as digital energy meter, power metering IC, Arduino Controller and zigbee transreciever 2.4G [11].

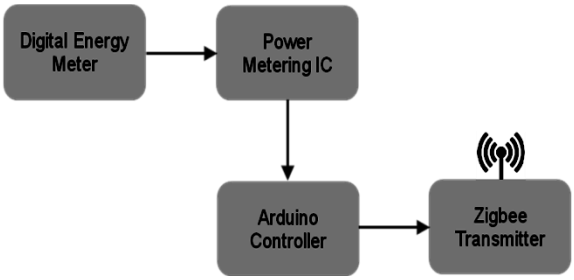

Figure 2. Functional block diagram of Smart Energy Monitoring system using Zigbee and Arduino controller

B. System Implementation

The energy monitoring consists of zigbee transceiver and user computer. This device has functions to display power consumption information and status information of Energy Monitoring System (EMS) and to set-up parameters of Energy Monitoring Device (EMD). This information is received or sent via the zigbee wireless communication between ESM and EMD.

The zigbee transceiver supports ZigBee 2006-stack and compatible to IEEE 802.15.4 protocol. Also the Zigbee prototype is 10m to 2Km.Compatibility with the arrange like Wi-Fi, Ethernet and GPRS is great and giving versatile systems administration arrangement makes it reasonable to use for checking and controlling application. Finally the computer (control server) displays monitoring parameters, such as power consumption value, voltage, current and frequency.

The zigbee prototype connected with Arduino uno, the Arduino uses to communicate energy meter values to zigbee protocol by developing the coding in embedded programming.

C. System Coding Used

The program is incorporated with "Arduino IDE".

```
#include <EEPROM.h>
#define CURRENT_SENSOR A0  // Define Analog input pin that sensor is attached
float amplitude_current;      // Float amplitude current
float effective_value;       // Float effective current
long voltage;
float unit=0;
void setup()
{    Serial.begin(9600);
}
void loop()
{    int sensor_max=analog
Read(CURRENT_SENSOR);
   if(sensor_max>0)
   {    Serial.print("Current(mA):");Serial.print(Amps);
Serial.println("");
   voltage = random(215, 230);
   Serial.print("Voltage(V):");Serial.print(voltage);
Serial.println("");
   float power = random(78, 90);
   power=power/100;
   Serial.print("Power factor(PF):");Serial.print(power);
   float frequency = random(48.2, 50);
   Serial.print("Frequency(V):");
Serial.print(frequency);
   unit = Amps*0.0001;
   unitlevel=value+unit;
   value=unitlevel;
   Serial.print("Unit:");
Serial.print(unitlevel);
   Serial.println("");
   } }
```

d. System Output Result

The implemented board of EMS transmitter end is shown in Figure 3 and the receiver end is shown in fig 4. The EMS is implemented by using several commercial chips and a personal computer. The EMS board is manufactured in four layers. Main parts, such as shunt energy meter, power metering IC are placed on top side of PCB and zigbee transceiver is placed on bottom side of PCB.

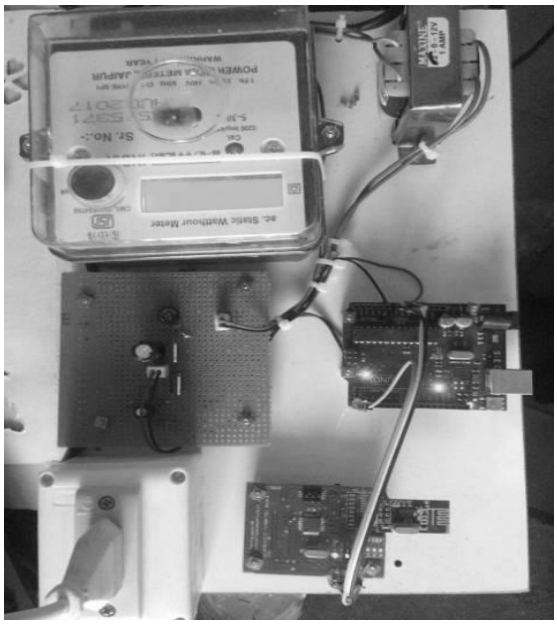

Figure 3. EMS Transmitter End

For function verification of prototype system, the power load emulator is designed and implemented. It contains two lamps, one is standby power consumption load and the other is normal power consumption load, and electric switches to emulate electric device's standby and normal operation. The test result of prototype satisfied all the function and performance requirements, such as power consumption monitoring, zigbee communication, AC voltage and current range, power monitoring range. Finally measured parameter displayed in the computer in notepad format as shown in the Figure 5. Here the delay time of data transferring obtained 15 seconds.

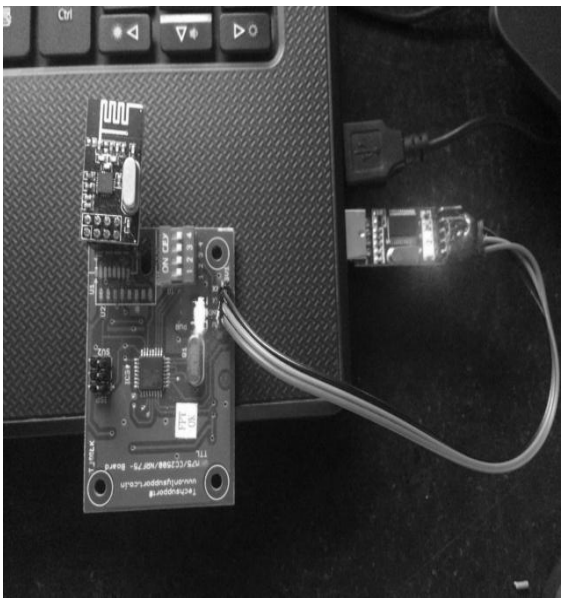

Figure 4. EMS Receiver End

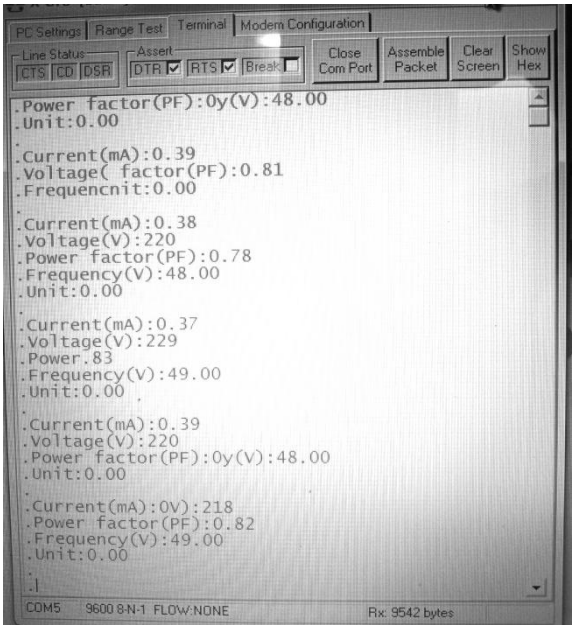

Figure 5. Collected Electrical Parameter – Displayed in Computer Screen

III. SMART ENERGY MONITORING SYSTEM USING IOT PROTOCOL

A. System Overview

Here the SMES using IoT Techniques is designed to continuously monitor the electrical parameters from the digital meter and to cut the power supply through wireless techniques, if any short circuit or over load utilization [12].

Data can be collected at each and every second's basis. As there is no human intervention in the entire process, there is no chance of human error and corruption. In the extremely bad weather conditions like heavy

snow, rain, storm, etc the system will not hamper on collecting [13]-[15]. Figure6 shows the difference between conventional energy meter and smart meter system.

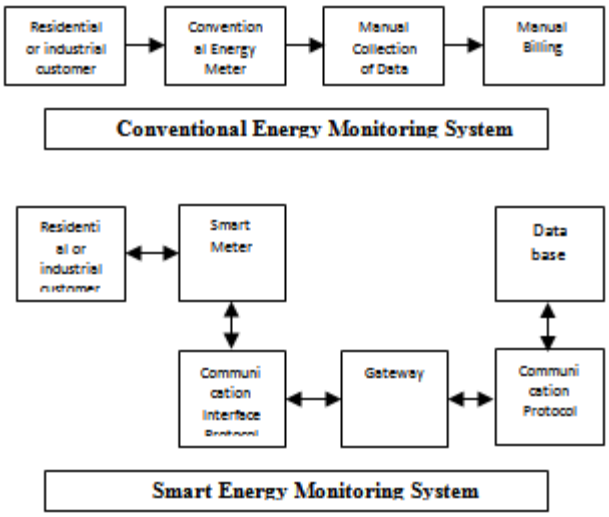

Figure 6. Comparison of Conventional and Smart Meter System

Advantages:

- Automation has been evaluated. So, the chance of human error and corruption will be reduced.
- In the extremely bad weather conditions like heavy snow, rain, storm, etc the system will not hamper on collecting.
- Illegal Social activity avoided (Power Theft).

B. System Implementation

IoT based SEMS functional diagram shown in Figure7. The IoT allows objects to be sensed or controlled remotely across existing network infrastructure, 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. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical system, which also encompasses technologies such as smart grids, virtual power plants, smart homes and smart cities. Each thing is uniquely identified through its embedded computing system but is able to interoperate within the existing internet infrastructure [16].

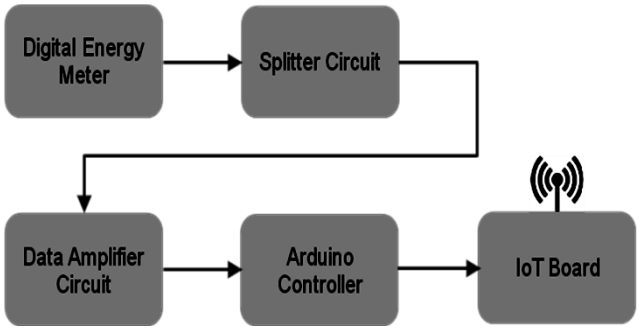

Figure 7. Functional block diagram of Smart Energy Monitoring system using IoT and Arduino Controller

When the various appliances of the household consume energy the energy meter reads the reading continuously and this consumed load can be seen on meter. We can see that the LED on meter continuously blinks which counts the meter reading. Based on the blinking, the units are counted. Normally, 3200 blinks is one unit. In our project we are trying to develop, a system in which Arduino Uno act as main controller, which continuously monitor energy meter. As per the blinking of LED on energy meter the Arduino will measure the unit consumption. The measured reading with the calculation of the cost will be continuously displayed on web page that we have designed. Threshold value can be set on webpage with the help of Wi-Fi, as per the

consumer's requirement. When the consumers reading will be near about to the set threshold value it will send a notification value to the consumer [17].

Finally the overall monthly bill with cost will be sent to customer as well as service provider in the form of text at first day of every month.

C. Software Used and Output Result

The Arduino Integrated Development Environment or Arduino Software (IDE) - includes a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus [18]. It connects to the Arduino and Genuino hardware to upload programs and communicate with them. The hardware of the SEMS by IoT shown in the Figure8 and measured parameter displayed in the system in Html File shown in Figure 9.

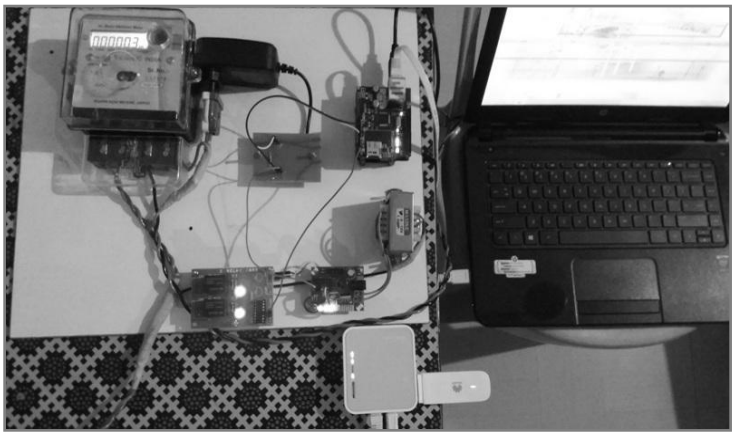

Figure 8. Monitoring Hardware Interface

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE) including complete error messages and other information. The bottom right-hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

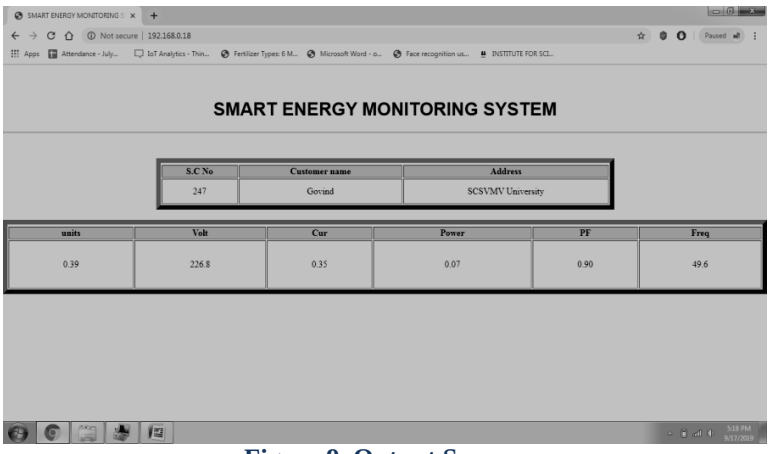

Figure 9. Output Screen

IV. SMART ENERGY MONITORING SYSTEM USING CLOUD COMPUTING

A. System Overview

This system designed and implemented to obtain the electrical information in online without any delay time between meter end to consumer end [19].

When compare with our developed zigbee and IoT based Energy monitoring system this cloud computing based smart energy monitoring system will provide more number of values and can obtain more data transferring coverage limit.

The main function of this concept is to achieve the process of collecting, storing, displaying real-time data from the smart meter to cloud server.

B. System implementation

Here the SATEC Power meter used to collect the data from main panel to consumer end. Hence we used GSM Based Communication gateway circuit. In the aspect of reducing delay time of data transferring, increasing wireless coverage distance lime and get more number of values form the meter this system has been developed.

In Zigbee based monitoring system, the power metering IC and Arduino controller used. Hence the system provides 15 seconds delay time in transferring data.

In IoT based monitoring system, Splitter circuit, data amplifier and Arduino controller used to collect the data and send the data to HTML file through WiFi Router. By IP Address accessing mode we can view the data in HTML file and in every 2 seconds once the data will be updated.

In order to achieve fast communication, reliable data, more number of values form the meter, increase the wireless coverage limit and to obtain the data storage unit the cloud based smart energy monitoring developed.

Hence instead of power metering IC and Splitter Circuit we used GSM Communication gateway circuit directly interfaced with the smart meter as shown in the figure 10. Communication gateway has will send the data to server and the data will be saved as per our customized programme in the cloud. so that wherever we can access the data and we can get the customized report without any difficulties.

Figure10. Smart Meter interfaced with Communication Gateway

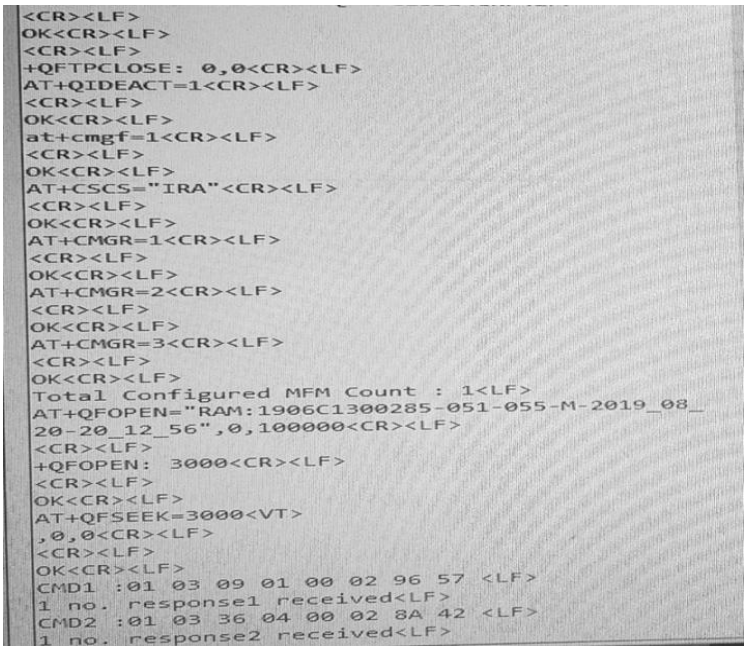

Figure 11. Sample Coding for the cloud based Energy Monitoring System

C. System output

It consists of Two way Digital Power Meter and used GSM Communication gateway to send the values to the cloud server directly. Here the transmission level is 14 Tbs without any delay time, because the coding developed for fully online system. It gives master report as shown in the Figure12 which can be customized. For the communication side coding developed with super java, for the data storage side coding developed with HTML [20].

Figure 12. Electrical Parameters Obtained by the Cloud Computing based Energy Monitoring System

V. COMPARISON OF SEMS

After analyzed all three concepts, the performance and application wise; SEMS by Cloud computing techniques concept providing fast and reliable communication between distribution, transmission and consumer. When compare other protocol, the cloud computing protocol gives the information to the server without any

delay time. So that the online report will be showing with in a second. This will be helpful to get better and smart communication. The Table.1 shows the comparison of communication protocol.

Table 1. Comparison of Smart Energy Monitoring System

Category	ZigBee	IoT	Cloud Computing
Development Timeline	2004	1999	2006
Operating Frequency	868 MHz	100 MHz-5.8 GHz	60 GHz
Channel bandwidth	2 MHz	200 kHz	10-100 GHz
Network Range	WPAN	LAN, LPWAN. Cellular and Cellular	VPN, ISP
Data Transfer Speed	250 kbps	2 Mbps	14Tbps
Data Transfer Delay Time	15 Sec	2 Sec	0.05 Sec

IV. CONCLUSION

We propose in this paper an advanced technology that can monitor the electrical information without any interval on the Internet In addition, an embedded system-based communication gateway that can be interfaced with cloud and set up easily made with domestic and commercial users. Moreover, the exact power consumption information are stored in a database server in the Cloud. Hence the stored information will be send as a report to the energy management system. And the control command from the far-end place, i.e., from the web server on the Internet, is first sent to the gateway and then transmitted to the IPS modules through the wireless communication protocol so that the remote control access can be achieved. With help of this concept, we actively reduce standby power consumption and the power outlet simultaneously through the communication gateway. Also the consumer can now about the power utilization before the monthly assessment. The proposed SEMS by Cloud Computing will be used to implement the closed loop power communication in order to develop the smart grid in future.

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