Implementation of Smart Metering based on Internet of Things

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Abstract. From the aspect of saving energy, there is a continuous modification in communication technology and information in order to satisfy all customers demand. Today customers are demanding for accurate energy measurement, timely data and for good customer services. The best solution is smart grid system with various communication technologies which can be cost effective and electrical section to have a bidirectional communication in which information about electrical energy consumption is shared between consumers as well as by utility for remote checking. This paper describes the monitoring of energy consumption with Arduino Uno board and Ethernet using IoT (Internet of Things) concept. This proposed design eliminates human inclusion in the conservation of electricity. The consumer can receive the information about consumption of energy by using IP address on their devices. The web client code is uploaded for checking the client information such as location, content, connection, and disconnection to the web server. This proposed system gives reliable and accurate information regarding electrical energy management system (EMS) through Internet of things (IoT).

1. Introduction
Energy is fundamental need of our life because of mechanical development and urbanization. Energy catastrophe is the main issue confronted by our society. One of the solutions is to control, analyze and reduce of electrical power consumption in households. The purchasers must be encouraged by providing them with a perfect arrangement- i.e. the idea of using Ethernet communication via Internet of Things (IoT). In this modern period of Internet of Things, a physical world such as machines and sensors can be interfaced through the web. The things or items can be modified into smart things by providing it exclusive identification. The sensors and devices can communicate and share information through the web. We can analyze and control the sensors and devices at whatever time from any part of the world. IoT is an essential part of the smart metering/grid. An IoT is a twenty-first-century aspect in which consumers can be associated with the web page and establish communication between consumer and supplier through sensors and actuators. The IoT is a hybrid prototype which is developing in the area of remote media transmission.

2. Literature Survey
Currently, numerous system of Automatic Meter Reading (AMR) is implemented using Bluetooth, General Packet Radio Access (GPRS) and Global System for Mobile communication (GSM) [1]. Utilizing GSM technology remote sharing of information of energy consumption is possible. But there can be chances of missing SMS thus result in decreasing the reliability and efficiency of the system. GPRS is difficult to implement for long distance two-way communication between utility and consumers.
For automated billing system, communication is being done by the use of GSM and Ad-Hoc wireless routing protocol [3]. Each home is connected through the wireless system to central/utility office to access all the readings of energy meters using radio frequency system. The utility office receives continuous updates from energy meter about the units consumed by consumer and bill to be paid through GSM messages. The main disadvantage of this system is that it needs a human workforce to read a meter. If the customer is not available at home, the operator cannot able to read the meter.

Two-way communication has been an important function of the smart energy meters. Through wireless or wired connections such as GSM/GPRS, M-bus, and ZigBee, smart energy meter communication can be realized [4]. The different communication protocols used for two-way communication between consumer and supplier have been defined in terms of data rate, frequency, coverage range and limitations, stability, cost and their limitations and is shown in Table 1.

### Table 1. Comparison of different communication protocols

| Technology | Cost   | Communication protocol | Frequency                          | Coverage range | Limitation          |
|------------|--------|------------------------|------------------------------------|----------------|---------------------|
| GPRS       | Medium | Stable                 | 900-1800Mhz                        | 1-10km         | Data rates low      |
| 3G         | High   | Stable                 | 1.92Ghz-1.98Ghz, 2.11-2.17Ghz      | 1-10km         | Spectrum costly     |
| GSM        | Low    | Stable                 | 900-1800Mhz                        | 1-10km         | Data rates low      |
| WiFi-Max   | Medium | Stable                 | 2.5-3.5Ghz                         | 10-50km        | Not widespread      |
| PLC        | Low    | Very Stable            | 1-30Mhz                            | 1-3km          | Noisy channel       |
| SCADA      | High   | Stable                 | Up to 1.54 Mhz                     | Short distance | Expensive           |
| M-Bus      | High   | Least Stable           | 2.4-4.8Mhz                         | 1000m          | Expensive           |
| ZigBee     | Medium | Least Stable           | 2.4Ghz, 868-915Mhz                 | 30-50m         | Short range         |

The wireless embedded based AMR system is implemented using ARM7 Microcontroller [5]. The readings of energy consumption are sent to the utility by using RF link and then to the Web server through GSM. It also provides the facility of tamper detection and recharging of energy meter.

Advance metering infrastructure (AMI) based Smart Energy Meter are connected to each other by gateway presents an implementation and execution of Automatic meter reading system [6], [7]. By using PLC lines send data to utility computer and gateway communicates with utility computer via GSM. The power line communication is implemented by using LonWork bus technology.

The overview of smart grid technologies in electrical utility based on EMS and IoT has been discussed in [8], [14]. The different communication protocols used for energy management involves the two-way communication between supplier and consumers. Fig 1 shows idea about various different protocols of communication and technologies can be used.
For large and ordinary power consumers GSM based AMR has implemented called hybrid automatic meter reading [9], [11]. AMR is enabled by using ZigBee and GSM module in which ZigBee is interfaced with energy meter to collect data and GSM is used for transmitting message/SMS to the utility.

The better metering solution is developed with an energy chip and the measurement of energy through digital communication technique [12]. The information about energy is sent to the utility through ZigBee and a software is used for data management along with billing of total energy consumed.

The energy meter within home display based on GPRS has been developed [13]. The data is sent to the cloud through GPRS. LabVIEW is used for home display for the intelligent load scheduling of appliances with respect to time of use (ToU) pricing.

3. **Block Diagram Description**

The goal of this proposed energy metering system improves the customer demand for higher energy measurement, accuracy, and more timely data. The information of energy measurement can be used by the consumer as well as by utility. The block diagram consists of an Arduino Uno board, an energy meter, and IoT through Ethernet. This paper presents communication through Ethernet to send data to the server. The simplified block diagram of the system is shown in Fig.2.
4. Over view of Arduino and Ethernet shield

4.1. Arduino
Arduino is an open-source gadget simple-to-use for programming and hardware. It can influence devices, similar to motor, lights and different actuators by getting inputs from different sensors. All the activity performed by Arduino is modified and programmed by the microcontroller available on board by means of Arduino programming language. The projects of Arduino can communicate with other programming applications running on a PC and different types of hardware. The Arduino Uno board is shown in Fig. 3.

![Arduino Uno Board](image)

**Fig. 3 Arduino Uno Board**
The features of Arduino Uno microcontroller board is shown in Table 2.

| Feature                   | Value                                      |
|---------------------------|--------------------------------------------|
| Microcontroller           | ATmega 328                                 |
| Operating Voltage         | 5V                                         |
| Supply Voltage            | 7-12V                                      |
| Maximum supply voltage    | 20V                                        |
| Analog I/O Pins           | 6                                          |
| Analog I/O Pins           | 14 (out of which 6 used as PWM output)     |
| DC current per I/O Pin    | 40mA                                       |
| For 3.3 V DC current      | 50mA                                       |
| Flash Memory              | 32kB out of which 0.5kB used by boot loader|
| EEPROM                    | 2kB                                        |
| SRAM                      | 1kB                                        |
| Clock                     | 16MHz                                      |
4.2. **Ethernet shield**
The Ethernet shield can be connected to Arduino Uno board through a library of Ethernet. This shield is compatible with all former version which is W5500 chip. The Ethernet shield has authorized MAC address and an internet protocol (IP) address which is fixed using the Ethernet.Begin(). A MAC address of every device is unique globally for identification. The Arduino Ethernet shield Uno board as shown in Fig. 4.

![Fig. 4 Arduino Ethernet shield](image)

The features of Arduino Ethernet shield features is shown in Table 3.

| Table.3 Arduino Ethernet shield features |  |
|----------------------------------------|--|
| Operating voltage | 5V |
| Controller of Ethernet | W5500 with internal 32K buffer |
| Speed | 10/100Mb |
| Connection | Arduino on SPI port |

5. **Circuit Diagram & Its Working**
The hardware interface circuit consists of an Arduino Uno board, Energy meter, a Light dependent resistor (LDR), Ethernet shield, IoT such as Wi-Fi. The role of Wi-Fi is to share the energy meter information on the web page which can be achieved via IP address as well as on device also. The energy meter consists of LED which blinks continuously to indicate the unit and cost of energy consumption by customers. For experimental purpose, an LDR is placed on the LED of Energy meter. The voltage of LDR is set to receive the accurate result of energy measurement and the code is uploaded to Arduino board. The output is fed to the Arduino board at analog pin A0, 5V, and ground, and the energy is calculated. On serial monitor of Arduino board, the unit and cost of electrical energy consumed can be displayed. During two-way communication between customers and utility, if the web service fails while sending a message then it will be difficult to share or send data. The best solution to this problem is Ethernet communication. The initial cost of Ethernet is only required and communication is achieved by small bandwidth along with telephone /mobile network. The circuit diagram of smart metering based on IoT is shown in Fig. 5.
Two-way communication between customer and utility can be done by using IoT through Ethernet shield connected to Arduino Uno board. The communication part for sending the data of energy consumption to a web page through Ethernet communication with low cost. Web server program is uploaded for the two-way communication between the consumer and utility. This Ethernet communication enables consumer and utility to share information about the energy consumption through an IP address. The utility also receives the client's information using same IP address by web client program.

By using the Ethernet communication the customer and utility receive the real status of energy consumption with less cost as compared to other communication protocols. The information can be made private by using web client program uploaded in Arduino board to get the details of the client connected and disconnected to IP address for monitoring the electrical energy consumption. When the client is connected the information about the electrical energy consumption along with client information can be seen on the serial monitor of Arduino. This proposed system is cheap as compared to other communication protocols. This server system will be able to control and manage electricity usage by consumers.

6. Flowchart of Process
From the flow chart diagram, it can be seen that the energy consumption is continuously monitored by Arduino via Ethernet. LDR sensor which is used as a button state in this project checks the unit and cost of energy consumption by the consumer through the counter code uploaded in Arduino Uno board. If the LDR increases above the set voltage 550 then counter starts to count the pulses from the LED of Energy meter. With the counting of pulses by LDR, it gives the cost, unit increases with respect to time. If the LDR voltage is less than set voltage then there is no increase in unit and cost, it shows LDR off. The output of energy consumption is uploaded in web server and web client code through Ethernet. The utility/electricity board and consumer by using IoT through Ethernet can get the real time status of energy consumption only by IP address. The flowchart diagram is shown in Fig.6.
7. Hardware Implementation

In this proposed system LDR is placed on the LED of energy meter. The counter program is uploaded in Arduino Uno board for counting the blinking of LED. The counter continuously increased with respect to blinking of LED which is detected by LDR. The LDR is used as a button state to increase the counter to give the information about unit and cost of energy consumption. The total output of unit and cost of energy consumption by the consumer can be monitored. The implementation of proposed system hardware is shown in Fig. 7.

![Fig. 7 Proposed system hardware](image_url)

The data of energy consumption regarding unit and cost can be seen on Arduino serial monitor as shown in Fig.8.
8. Results & Discussion
The Ethernet has been used for the communication part and transmitted the information of energy consumption to a web page. The collected data of energy consumption is sent to a web page by uploading the web server code and web client code for clients connection in Arduino board connected with Ethernet shield. On Arduino serial monitor the unit and cost of energy consumed along with IP address have been displayed as shown in Fig 9.

The consumer can receive the information about energy consumption just by filling IP address on their mobile phones at anytime and anywhere. The customer can check the information from any edge of the world by using Ethernet communication called IoT. The consumer can receive the information about energy consumption just by filling IP address on their mobile phones at anytime and anywhere. The information of electrical energy consumption on mobile through IP address is shown in Fig 10.
After web client program code is uploaded for the monitoring of electrical energy consumption, the client information such as location, HTTP can be seen on the Arduino serial as well as on mobile phone for information security. When the connection is successful, the information regarding unit and cost of electrical energy consumption can be seen by the consumer as well as by utility. Fig.11 and Fig.12 show the web client connection and disconnection with the web page with their location and IP address used.

Fig. 10 Information of energy consumption on mobile

Fig. 11. Shows the web client data

Fig. 12. Shows output when client is connected
9. Conclusion & Future Scope
The goal of this project work was designed for the two-way communication of energy consumed in the home can send to the web server by using Ethernet communication (IoT). By using the Ethernet communication the customer and utility receive the real status of energy consumption with less cost as compared to other communication protocols. This proposed system is cheap as compared to other communication protocols. The collected data about energy consumption is monitored by consumer and supplier at anytime, anywhere from any part of the world.

Improvements can be achieved in the controlling and monitoring of energy online from any edge of the world.

References
[1] S. Male, P. Vethekar, K. Moore “A Smart Wireless Electronic Energy Meter Reading Using Embedded Technology”, International Journal of Engineering Research and Application, Vol. 4, No.1, pp.145-147, January 2014.
[2] M. Wei, S.H. hang, M. Alam, “An IoT-based energy management platform for industrial purposes”, Applied Energy Elsevier Limited, Vol. 164, pp. 607-619, February 2016.
[3] A.Vijayaraj, S. Saravanan “Automated EB Billing System using GSM and Ad-Hoc Wireless Routing”, International Journal of Engineering and Technology, Vol.2, No. 5, pp. 343-347, October 2010.
[4] M. A. Alahmad, P. G. Wheeler, A. Schwer, J. Eiden, and A. Brumbaugh, "A comparative study of three feedback devices for residential real-time energy monitoring," IEEE Trans. Industrial Electronics, vol. 59, pp. 2002-2013, Apr. 2012.
[5] N. Gupta, D. Shukla “Design of Embedded based automated meter reading system for real time”, IEEE Student’s Conference on Electrical, Electronics and Computer Science, pp.1-6, Bhopal, July 2016.
[6] S. Kim, E.Y.Kwon, M.Kim, J.H.Cheon, S.Ho Ju, “A Secure Smart Metering protocol over Power Line Communication”, IEEE Transactions on Power Delivery, Vol. 26, No. 4, October 2011, pp. 2370.
[7] M. Popa, “Data Collecting from Smart Meters in an Advanced Metering Infrastructure”, IEEE 15th International Conference on Intelligent Engineering Systems (INES), pp. 137-142, Slovakia, 23 June 2011.
[8] S. Jain, V. Kumar, “Survey on Smart Grid Technologies – Smart metering, IoT and EMS”, International Journal of Engineering Research and Application, pp.1-6, April 2014.
[9] A. Handoko, M. Y. Nayan, M. Awan “Hybrid Automatic Meter Reading System”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 2, No. 7, pp.361-365, Malaysia, July 2012.
[10] K. Gill, S.H. Yang, F. Yao, and Xin Lu, “A ZigBeeBased Home Automation System,” IEEE Transactions on Consumer Electronics, Vol. 55, No. 2, May 2009, pp. 422-430.
[11] Imran A. Zualkernan, A. R. Al-Ali, Mustafa A. Jabbar, Imad Zabalawi, and Ahmed Wasfy, “InfoPods: Zigbee-based remote information monitoring devices for smart-homes,” IEEE Transactions on Consumer Electronics, Vol. 55, No. 3, August 2009, pp. 1221.
[12] Maity, “Intelligent Online Measurement and Management of Energy Meter Data through Advanced Wireless Network,” International Conference on Devices and Communications (ICDECOM), pp.1-4, Mesra, 25 Feb. 2011.
[13] L.C.Saika, H. Das, N.B Dev Choudhry, T.Malakar, “GPRS enabled smart energy meter and automation of home appliances”, IEEE Annual India Conference, pp. 1-5, Bangalore, December 2016.
[14] H. Li, S. Gong, L. Lai, R. C. Qiu, D.Yang, “Efficient and Secure Wireless Communication for Advance Metering Infrastructure in Smart Grids,” IEEE Transactions on Smart Grid, Vol.3, No. 3, September 2011, pp.1540.
[15] S. Wang, L. Cui, J. Que, D. H. Choi, X. Jiang “A Randomized Response Model for Privacy Preserving Smart Metering,” *IEEE Transactions on Smart Grid*, Vol. 3, No. 3, September 2012, pp. 1317.