Towards Efficient Energy Monitoring using IoT

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***Abstract*—The purpose of this study is to monitor electricity consumption in dormitories, private rooms in hospitals, hostels and such buildings where the users are provided with the basic package that defines which electric appliances are allowed and which high wattage appliances (e.g. electric heaters, electric rods, hot plates) are not allowed to use. Efficient Energy Monitoring revolves around the idea of Internet of Things, which deploys smart monitoring concepts in existing electricity energy consuming environments. The system monitors the real-time electricity consumption of each individual room of a building, showing users the complete statistical reports of their consumption, notifying them if they are using any high wattage appliance that crosses the threshold set by their administrative authorities and do the predictive analysis to predict the future electricity consumption and thus visualize the analytics.**

Keywords—power consumption; FPGA; AMR; Internet of Things

I. Introduction

In today's world, everything is connected to the internet, communicates and exchange data in the physical environment and this defines the concept of Internet of Things (IoT). In our existing IoT enabled smart environment, the connected network of sensors and physical devices, each thing is uniquely identifiable by its universal unique identity, transferring information between them and controlling the specified subjects from any corner of the world.

Energy monitoring and consumption holds the prime importance in today's world because of the dilemma of the imbalance power production and power demand. Building sectors are consuming large amount of electricity and dormitory residential areas do not allow users to use high wattage appliances. Manual monitoring of electricity energy consumption at the individual level (e.g. each individual room of a hostel, each private room of a hospital) is quite challenging. To monitor the growing energy use of miscellaneous and electronic load, efficient energy monitoring focuses on developing a system that have capability to measure consumption at room level along with the user understandable statistical visualization reports and analytics of their usage.

Unlike smart meters, efficient energy monitoring provides complete web application that help its users to view their last month, week and day consumptions and calculate the charges or bills of their extra consumption.

Efficient energy monitoring is an IoT enabled monitoring system. The system is fixed with sensing module which contains ACS712 current sensors. Each room contains one current sensor which is connected to the main socket, and it sends the room data to microcontroller Arduino (Nano). A single Arduino represents a single floor of a building that further sends the data to microprocessor, which is a Raspberry Pi 3. Using cron job raspberry pi sends the data to Microsoft Azure cloud, from their respective users can monitor it using the web application. The other components of the system are Microsoft SQL database and Microsoft Azure ML studio. SQL database is used to store the values coming from hardware. Microsoft Azure ML studio is used to predict the future consumption so that users may control/lessen their electricity usage. Also, during the analysis of the stored data, notifications are generated from the cloud in case of any irregularity.

II. Related Work

There are different procedures accessible for estimating the vitality utilization of electronic devices and report this information. A predictive power monitoring system was implemented in [1] that can monitor the energy utilization of each individual, control the designation of energy for each powerline and efficiently predict the future utilization and the bills of each individual. The main tool they used for this is FPGA. Each electrical transmission line was associated with an electronic switch and power meter sensor, which was thusly associated with the FPGA. The FPGA was the one in charge of gathering and sending the information remotely to a PC using the ZigBee convention. All together for the user to screen his/her energy utilization, the PC will then show the received information using the application [1].

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In [3], creators have built up an AMR based system to detect the energy utilization. They have utilized an optocoupler sensor to detect pulse created by the LED shown on the smart meter. In view of the sensor yield, the energy utilization is calculated through a microcontroller. A comparative study is done in [4]; on the other hand, current and voltage transformers [2, 5] are utilized to analyze the meter. Utilizing coordinated chips, the power rate and power factor are calculated.

Kill-a-Watt [6] is a device created by P3 International is an exceptionally convenient and valuable device to monitor general power and the power utilization of a device connected to it when the device is not in use. It computes cost and predict the future cost by year, month, and even a single day. Alongside following utilization of device, the Kill-a-Watt additionally checks the nature of the supply. Plogg by Energy Optimizers Limited [7, 8] is a blend of a smart meter plug and a data logger. It utilizes ZigBee remote monitoring device and a metering chip. Plogg stores the deliberate power information and communicates this data remotely to a PC, a web connected Ethernet door, or a ZigBee introduced brilliant meter.

Every power consumption monitoring systems described above has recognizing favorable circumstances and highlights, however generally have restrictions, for example, constrained evaluations, no discovery for electrical variations from the norm. The EEM contrasts from these frameworks by giving the power monitoring at individual level, generating bills, alerts and do the predictive analysis in one system.

III. PROPOSED METHODOLOGY

The proposed architecture as shown in Fig.1 is divided into three section i.e. Current sensing circuit, controller, and Internet of Thing systems. All of these work as shown in Fig. 2.

A. Current sensing circuit

The first and foremost goal is to measure the power usage of each room individually. The Allegro™ ACS712 hall-effect based linear current sensor is embedded between supply source and the main switchboard of the room. The sensor measures the total current flowing through the room. The ACS712 gives practical and exact answers for AC or DC current detecting in commercial systems. The Hall effect principle states that the voltage could be measured at perpendicular angles to the path of current when the current flowing through the conductor is at right angle to a magnetic field.

Hall integrated circuit (IC) generates a proportional voltage when the flowing current apply through the conductor and creates a magnetic field.

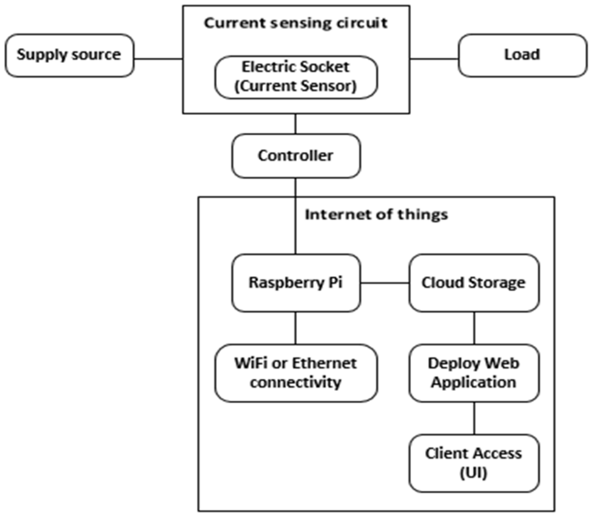

Fig. 1. Proposed block diagram.

B. Controller

Arduino Nano microcontroller based on ATmega328 is used in the proposed system. The 10-bit ADC microcontroller oscillates total 1024 counts. Arduino receives the input voltage and the total current data that is measured from current sensing circuit to calculate power. The Arduino receives the measured data on its analog pins and then send the data to raspberry pi. The microcontroller C programming is done in Arduino software (IDE).

First, the RMS volts is calculated using the conversion for a sine wave with a zero-volt offset using (1)

$$Vrms = (VCC/2) * 0.707 \tag{1}$$

The program is written and burn in microcontroller to calculate root mean square (RMS) value of the measured current according to the sensitivity of ACS712 current sensor using (2)

$$\mathrm{Irms} = (\mathrm{Vrms} * 1000)/\mathrm{mVperAmp} \tag{2}$$

Power is calculated as follows

$$power = V_{rms} * I_{rms} \tag{3}$$

C. Internet of things

Raspberry pi 3 is the key learning stage for IoT. Connect raspberry pi to the internet, login to raspberry pi and develop IoT platform. Microcontroller Arduino Nano sends the data to Raspberry pi through serial communication. The transmitter pin (Tx) of Arduino sends the real time data and the receiving pin (Rx) of raspberry pi receives the data. Raspberry pi further sends this information to cloud server via internet.

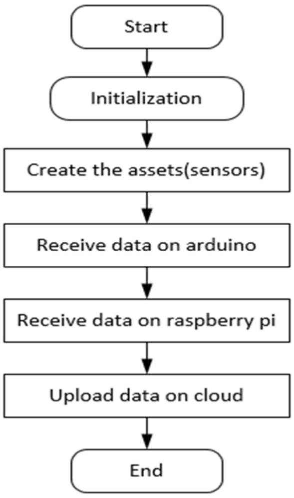

Fig. 2. Flow chart of proposed system.

1) Electrical appliances to be monitored are plugged in an electric socket.

2) Electric socket has a current sensor to measure the electric current flowing through the electric appliances.

3) Current sensors are coupled with Arduino Nano.

4) Arduino receives the current data on its analog pins sent by Vout pins of current sensors and calculate the power.

5) Arduino sends the data from its transmitter pin to receiver pin of raspberry pi.

6) Raspberry pi and Arduino serially communicate with each other.

7) Raspberry pi serves as a gateway to upload the data on Microsoft Azure cloud.

8) The receiving data on Raspberry pi resides in SQLite database.

9) Using cron job, raspberry pi sends the data to cloud after specified interval and change the status of the previous data that was sent.

10) The further calculations performed on that data is converting it into graphical form so that it can be visualized by the users.

Linear regression machine learning algorithm is applied on the real data set to predict the future consumption.

IV. RESULTS

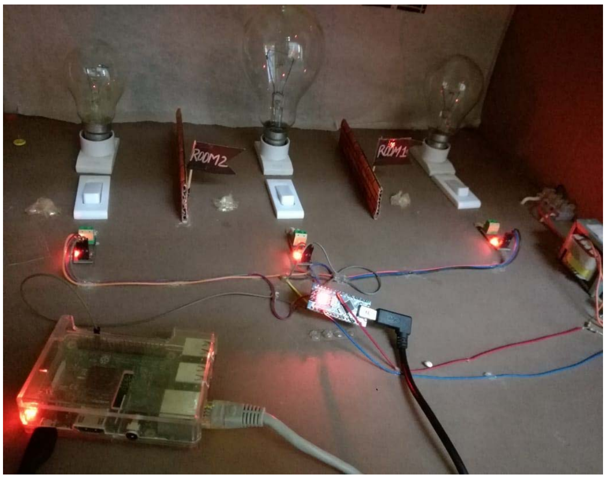

Fig. 3. Hardware setup.

The System was tested by using the light bulbs which are connected to the ACS712 current sensors. These sensors give the precise current measurement and are good for the overall monitoring of the power consumption. As shown in the Fig. 3 the sensors are connected to the Arduino, which is receiving the current values and after doing some calculations on the values, it sends the power values to Raspberry Pi. The Arduino calculations using Arduino IDE is shown in Fig. 4.

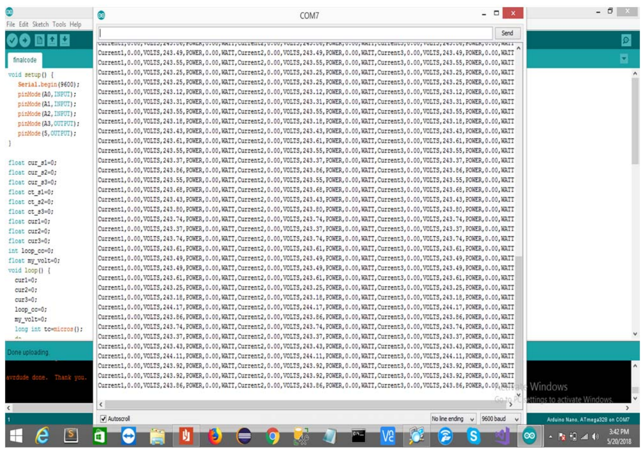

Fig. 4. Computations on arduino using IDE.

An authority in a building can see all the room's power consumption through the dashboard as shown in the Fig. 5. The graphs shown in the Fig is of monthly and weekly power consumption of all the rooms in a building. Authority can also select the specific room to view its daily, weekly or yearly power utilization and respective bills. The administrator sets the power's threshold so that when a user exceeds the provided power limit, an alert is triggered in the form of a notification which is send to both the administrator and the respective user.

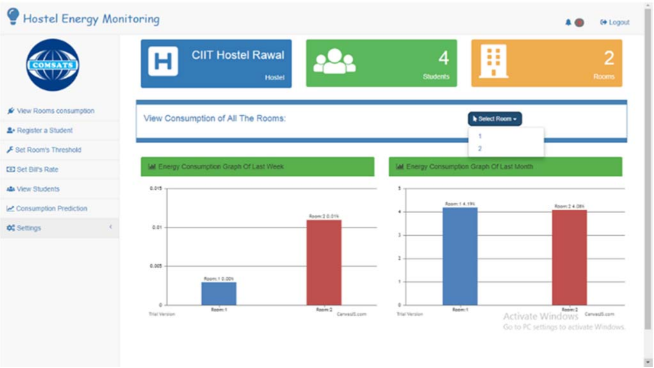

Fig. 5. All rooms consumption graphs.

The notification received by the administrator has complete detail about which room is exceeding how much power at what time. As our system also do the predictive analysis based on previous event that have occurred so that the user can control/lessen their consumption. Fig. 6 shows the graph that is depicting both the previous history and the future prediction of power consumption. The blue color represents the previous events/consumption of a room and the green color is representing the future prediction.

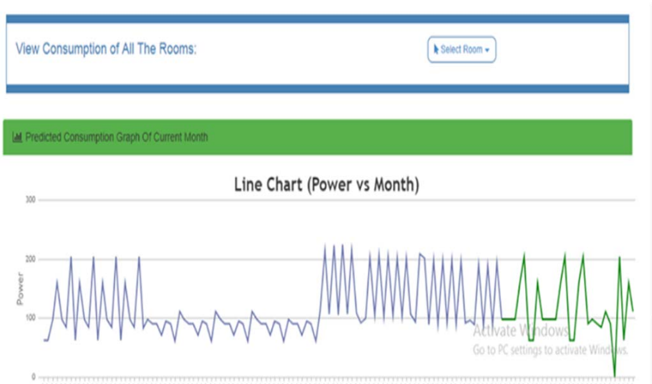

Fig. 6. Future consumption prediction graph.

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