Iot-based Smart Meter for Real-Time Electricity Load Analysis and Automation

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***Abstract*—In recent years, significant changes have taken place in the energy sector. Intelligent technology has played a major role in electricity generation to energy usage. The IoT sector has a lot of smart devices and smart home solutions. Similarly, there are smart energy meters that can be used as a solution in our homes. With advancements in technology, it is now possible for non-disruptive tracking - using smart electricity meters to control the power consumption of our home appliances. In this work, an IOT-based smart meter is used to calculate the power consumption for every room in a house by calculating how much electricity passes through a power line in real-time. After sensing the data, it is directly uploaded to a real-time database. This will allow the consumer to analyze, the appliances of which rooms are currently working and how much load it is consuming now. At any point, if the electricity consumption of a particular room exceeds the desired level set by the consumer, there will be an option to either cut off the power to that room or to send an email notification to the consumer. The consumer can remotely turn off the power to a particular room through internet connectivity, or even turn off the power to the entire house.**
Through these functionalities, the consumer will get an idea about the electricity consumption in his house and the consumer will get the control over the electricity usage, so he can save energy and money.

key Terms - IoT smart meter, ADC conversion, electricity usage, automation

I. INTRODUCTION

Technology has been developed to ensure the efficient use of energy. There is also a need for systems that can track, control, and automate electricity usage. Improvements have made our lives easier when everything has been made accessible. The solution is to develop new energy-efficient technologies to maintain the relationship between power supply and energy use.

The proposed system aims to provide power monitoring remotely which is cost-efficient, compared to previous systems. We plan to build a website so that the user can sign in and be aware of the power consumption of each room. A graphical representation of the power used by each room will let the user know if the power used by any exceeds a certain level, so the user can take necessary actions to save energy usage.

II. LITERATURE REVIEW

In this work, the conventional system of electricity meters affiliated with the power supplier of Bangladesh has been analyzed and there are many many difficulties and shortcomings were discerned. Here we have studied different systems that help to reduce the problems associated with reading meters. In India, Praveen Kumar et. al. (2015) proposed an energy meter system that is working based on GSM to work out shortcomings associated with the conventional systems of meter reading. This system included a digital meter based on GSM which was set up in each unit of the clients along with a billing process at the power supplier side. But, this system was unsuccessful to incorporate the places where there is no coverage of a reliable independent network of GSM.

III. PROPOSED SYSTEM

The methodology of this work comprises two sections. The first section is the system design and the hardware construction and the second is the Web-based system.

A. Hardware Design and Implementation

The IoT-based smart meter has been devised with Nodemcu which contains a built-in ESP8266 wifi module, current sensors, voltage sensors, Analog-Digital converter systems, and relay circuits. To measure the energy consumption, for each room a CT(Current transformer) is assigned and the data from each CT is collected through the serial port of the Nodemcu. For the entire system, we have a Voltage Transformer. On each second the nodemcu will read the data from the current transformer and the voltage transformer through PIC16F876 Analog to Digital converter IC. The PIC16F876 ADC converter has 5 channel digital input port. when we apply a digital signal ‘0’ to each channel, data from the corresponding sensor will be transferred to the

nodemcu. The nodemcu is working in 3.3v. so the digital value that is to be sent to nodemcu corresponding to the analog sensor value can be calculated using,

ADC reading = (Resolution of the ADC X Analog voltage Measured) / System Voltage

The Nodemcu is linked with the adjacent point of access utilizing its SSID and Password and also connected to a real-time database through the Authentication key. The power consumption taken by each room is calculated using Irms and Vrms values collected from the sensors by the given formula,

Power usage = Irms x Vrms

This power usage is uploaded to the real-time database along with the consumer_id, room_id, and timestamp. The hourly usage data is also uploaded to the database. The hourly consumption is calculated by,

hourly consumption = Irms x Vrms x 3600

For controlling the room, we create streaming with the database, where the room is controlled using a logic 1 or 0. If the bit is 1 the relay for the particular room will be turned on and if the bit is 0 then the relay for the particular room will be turned off. Fig 1 displays the flow diagram integrating the hardware design.

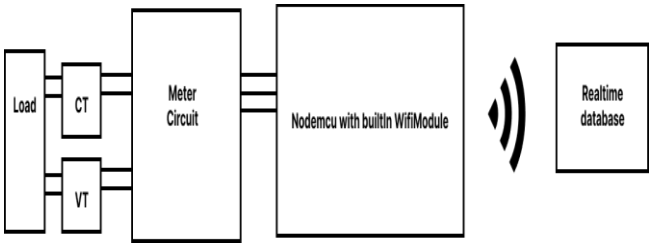

fig 1: Flow diagram of hardware system

A. Load

Load consisting of power supply to each room, Normally 220V power supply.

B. Meter Circuit

The Meter circuit senses the signal from the current sensor and voltage sensor and converts the analog sensor values to serial digital data, thereby transferring the data to the nodemcu when the appropriate control digital signal arrives.

C. Nodemcu

Nodemcu is an open-source low-cost IoT platform, which has an inbuilt ESP-8266 wifi module. Nodemcu reads the data from the meter circuit and applies necessary calculation and upload real-time data to the database.

D. Realtime Database

Here, we use Firebase Realtime Database, which is a cloud-hosted NoSQL database that let us store and sync data between users in real-time. The real-time database notifies the corresponding hardware about any data changes.

B. Web Application

A web application was developed for remote monitoring, controlling, and automation of electricity usage using the smart meter which reduces manual labor and keeps a record of the energy consumption of the consumer. Using, this web application, customers can monitor the real-time electricity usage by each room, and also the monthly usage through the dashboard. the customer can also control the room using the same dashboard.

The web application is developed using React.js as the frontend and node.js as the backend. As the database, we use google firebase's real-time database and MongoDB database. Since the web application is connected to the real-time database for real-time usage, changes in the database are notified to the web application on a real-time basis by the database. The MongoDB database stores the user details and the monthly usage data. The real-time database only stores the real-time electricity usage and also the room controlling logic bits. fig 2 shows the architecture of the system.

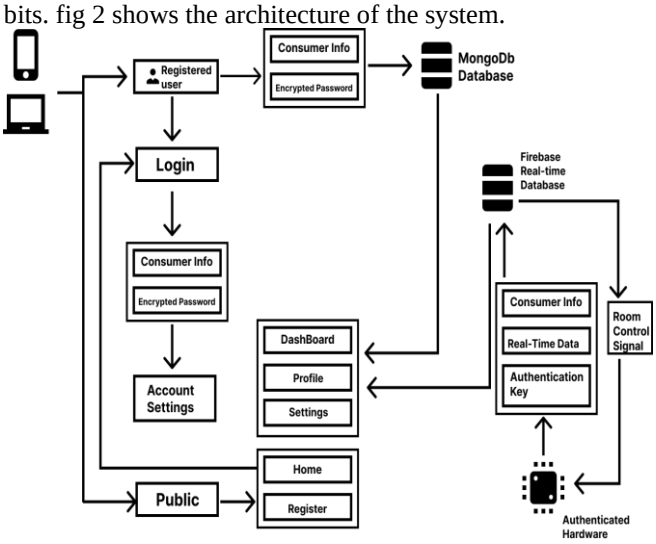

fig 2: Architecture of the smart meter

A. Public Module

It is the overall viewing end of a website. Anyone with the URL can access this module. It is public to any users, but cannot change or modify the information.

B. User Module

The registered users are the part of user module. It consists of 2 functionalities - user registration and user login. During the registration, the system collects the basic details from the user like name, consumer Id, email, password, phone number, and device Id. The password is encrypted and stores all the data in the MongoDB database. During the Login Phase, the user will give the consumer Id and password. It compares the given data with the data in the database and if the data are matching, then the user is allowed to enter into the system.

C. Account and Settings

The account and Settings module contains the client's records and different settings of the web page. There is a link between the account module and the user module. If the user completed the registration, then the account will be created on the database. Also, the user can change their password at any time. Automation settings, Device controlling settings, and other energy-saving feature settings are the other benefits. Furthermore, consumers can get warnings and alerts from this part.

D. Authenticated Hardware

This module is the hardware part of the system, which stores a key to authenticate with the database. The real-time energy usage data is uploaded in this part. This module is in the consumer part.

E. Databases

This module includes a MongoDB database for user data handling and a firebase real-time database to store and sync real-time data between the hardware and the application.
The automation process is done using an extra job scheduler application, that helps to monitor the total consumption of the room using the database value, and triggers the logic bits if the consumption is more than the desired level.

IV. IMPLEMENTATION

A. Software tools

The text editor used for this project is visual studio code. Visual Studio Code is a lightweight powerful source code editor, with built-in javascript support. It natively supports many programming languages, and functions can be attached by users with extensions.

The server setup is done node, its 'http.createServer()' method creates an HTTP server object and starts running the application. For the database, we use MongoDB Atlas and Firebase real-time database. The MongoDB Atlas is a multi-cloud database service, that deploys and scales MongoDB in the cloud. Firebase Real-Time database is a cloud-hosted NoSQL database that lets us store and sync and query data between users in real-time, and data is stored as a JSON and synchronized in real-time to every connected client.

The firmware for the microcontroller is created using Arduino IDE software. Arduino IDE is open-source software, which can be used to write and upload code to development boards. It supports C and C++ programming languages.

B. Hardware tools

Hardware requirements for this development are a laptop with an i3+ processor, 4GB+ Ram, and 2GB+ SSD space.
For the smart meter, we need a Nodemcu development board, Current Transformer, Voltage Transformer, PIC16F876 IC, resistors, diodes, potentiometers, etc. The nodemcu board is used to read the data and upload it to the database. The current and voltage transformers are used to sense the voltage and current usages and provide the necessary analog output. The PIC16F876 IC is a 5-channel 10-bit Analog-to-Digital converter, that helps to convert the analog output of sensors to digital serial output for the nodemcu to read.

V. RESULT

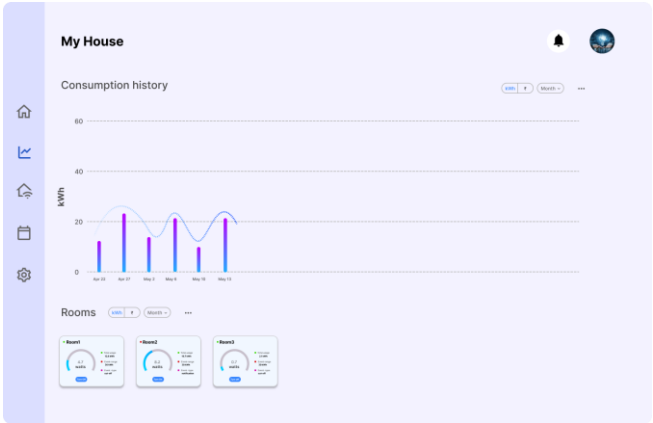

fig 3: Dashboard of the smart meter

The above image shows what the dashboard of the smart meter looks like. Consumer can see the total consumption history over the graph.
The consumer can use the control of each room separately, using the button given on the room card. also, users can see the status of the room and the real-time electricity usage of each room through the dashboard.
The dashboard also provides the monthly usage and automation based details.

VI. FUTURE SCOPE AND CONCLUSION

In this paper, we have discussed a method related to a smart meter for real-time electricity load analysis and control. Such a smart meter is needed in society to ensure and maintain the use of electricity through a low-cost intelligent energy metering system. Through this system, we can analyze, control and automate the electricity usage in our house.
We can also add machine learning algorithms to evaluate electricity usage and provide better electricity usage tips for saving energy.

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