Real Time Power Consumption Monitoring Using Arduino

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***Abstract*-Due to the economic growth, the demand for electricity tends to increase every year and that can lead to global warming and climate change. The resources in the world are limited while the society has unlimited demands, so energy conservation, including effective energy consumption should be of great concern, and people should concentrate on it. Real Time Power Consumption Monitoring Using Arduino is using an Arduino platform as a microcontrollerto read the voltage and current from sensors and then wirelessly send the measured data to monitorthe results using a new Android application. An Android application used for monitoring the energy usage of small electrical devices. The users can visualize, control, and make plans for the energy consumption in each device or group of devices via the Internet. For the design, the Database System that consists of OLTP (Online Transaction Processing) for operational data transactions and OLAP (Online Analytical Processing) are used for historical data supports flexible and adaptable data and historical-data-repository reports.**

***Keywords*-Power Monitoring, Power Consumption, Arduino, OLAP, OLTP**

I. INTRODUCTION

Due to the economic growth, the demand for electricity tends to increase every year and that can lead to global warming and climate change. The resources in the world are limited while society has unlimited demands, so the ways of energy conservation, including effective energy consumption should be of great concern. For these reasons, our project, Real Time Power Consumption Monitoring Using Arduino, is intended to continue developing an application for monitoring electrical usage of each appliance. This developing application allows users to keep track of real-time and/or historical energy consumption in the form of the graphical views via an Android-operating system smart device. Unlike the prior related works, there are two major improvements and developments, which are the database system and the system administration.The main objectives of the project are to design a database system for recording the electrical power consumption of individual electrical appliances and groups of the multiple electrical appliances, classified by locations, power nodes and groups of device, from the power meter, to design and develop a database system to handle both the real-time data and historical data by applying the techniques of OLTP and OLAP, respectively, in order to analyze and compare the power consumption of the appliances, and to design a user interface for system administrators, so the database can be modified in the case of adding, deleting or changing any measured electrical appliances. This system uses sensors for measuring current and voltage. A general purpose micro-controller board (Arduino UNO) calculates the electrical parameters, Ethernet shield with an SD card and a WIFIRouter is used for offline storage and transmission of data wirelessly to the server (database) which could beused to notify the consumption information to the user through the internet.

II. LITERATURE REVIEW

To calculate the power we measure in a period of time, we normally use the integral formula to find the area under the graph of a function shown in Figure 1

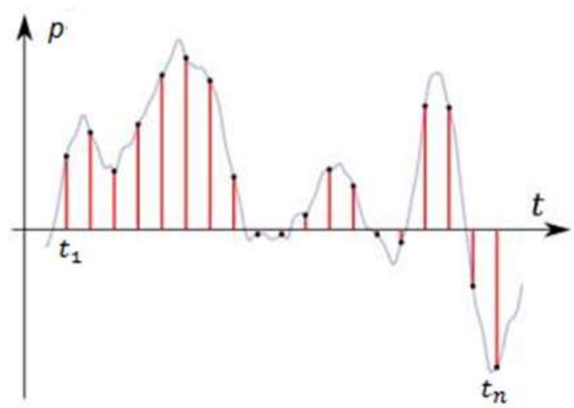

Fig 1 Sampling power at each time

The equation (1) calculate the area under the graph

$$E_{t_1-t_n} = \int_{t_1}^{t_n} P(t)dt \qquad (1)$$

$P(t)$: Power at time t

Energy can be calculated as in the equation (2)

$$E_{t_1-t_n} = \sum_{i=1}^{n} \left(\frac{P_{t_i}+P_{t_{i-1}}}{2}\right)(t_i - t_{i-1}) \qquad (2)$$

P_{t_i} : Power at time t_i

P_{t_i-1} : Power at time t_{i-1}

For our project, we did the sampling of the power at P_{t_i} when i>0 shown in Figure 2, then calculated the average power as in the equation (3).

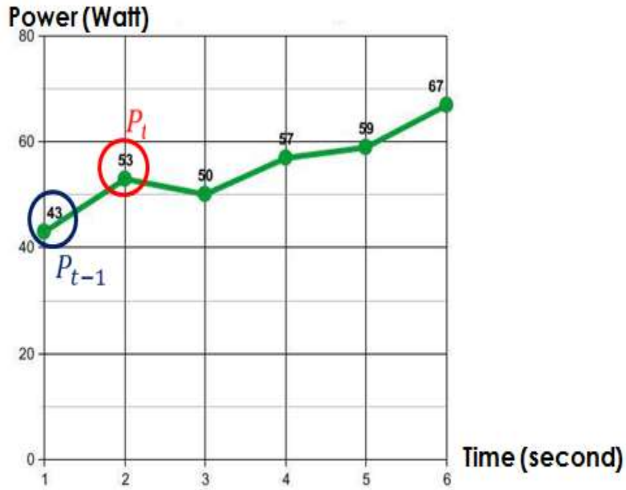

Fig 2: graphical power at each time

$$P_{avg,t_i} = \frac{P_{t_i} + P_{t_{i-1}}}{2}(\text{Watt})\ldots\ldots\ldots\ldots(3)$$

P_{avg,t_i}: *Average power at time* t_i

P_{t_i}: *Power at time* t_i

$P_{t_{i-1}}$: *Power at time* t_{i-1}

Energy can be calculated as in the equation (4):

$$E_{t_1 - t_n} = \sum_{i=1}^{n} E_{t_i}\ldots\ldots\ldots\ldots(4)$$

$$E_{t_i} = P_{avg,t_i} * \Delta t, \text{ Where } \Delta t = t_i - t_{i-1} \text{ ; } t_i > t_{i-1}$$

E_{t_i}: *Energy use at time t*

Δt: *Difference between time t and time t-1*

Online transaction processing, or **OLTP**, is used for operational data. OLTP is an original source of data that is normally supported by every database system. OLTP refers to the processing of online transactions (INSERT, UPDATE, and DELETE). The querying in OLTP is quite fast and OLTP applications are availability, speed, concurrency and recoverability. **Online Analytical processing** or **OLAP** performs an analyzing of multidimensional schemas analysis of business data and it refers to consolidation of data from the OLTP. OLAP is used for historical data that is stored in multidimensional schema. OLAP helps analyze the business data for decision making and planning. Table 1 shows the differences between OLTP and OLAP.

OLAP operations:

- Roll-up: it is performed on data cube aggregation by climbing up and dimension reduction.
- Drill-down: it is the reverse of Roll-up and is performed by stepping down and introducing a new dimension.
- Slice and dice: Slice will form a new sub-cube by selecting one dimension or more, but Dice will form a new sub-cube by selecting two dimensions or more.
- Pivot: it is the rotation of the data axes to provide an alternative view of data presentation.

Table 1: Comparison between OLTP and OLAP

OLTP	OLAP
Contains current data	Contains historical data
Operational data	Consolidation data
Fast processing speed	Processing speed depends on how much data is involved
Normalized with many tables	De-normalized with few tables
High performance	Highly flexible

Related work

1. Smart Home-Control and Monitoring System Using Smart Phone[4]

This paper, authored by Rajeev Piyareand and Seong Ro Lee, represents a low cost and flexible smart home control using an embedded micro-web server with the use of IP connectivity that helps controlling the home appliances everywhere and every time by using an Android smart phone.

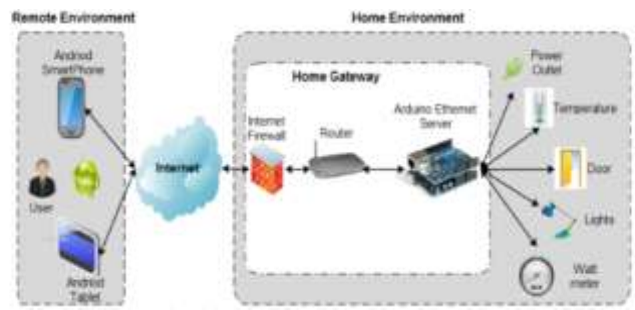

Fig 3: Overview of conceptual architecture

The system overview shown in Figure 2-3 consists of three main modules: a Web-server based on Arduino Ethernet, hardware modules and the Android application. This work also provides the remote connection to the Home Gateway for device control and monitoring, and schedule management.

2. Home Appliances Control System Based On Android Smartphone[5]

This paper, authored by Sachin Kishor Khadke, is used for the purpose of describing how to remotely control home appliances by using an Android smart phone so that the users can access anytime and anywhere unlike on a PC that is hard to manipulate and inconvenient to carry and limits monitoring. So, using an Android smart phone is more beneficial than using the PC. This application uses the wireless radio frequency to remotely control and monitoring the appliances. This paper focuses on lighting control of home appliances. Figure 4 shows the system overview of this paper and the graphical interface of light/fan controlling is shown in Figure 5.

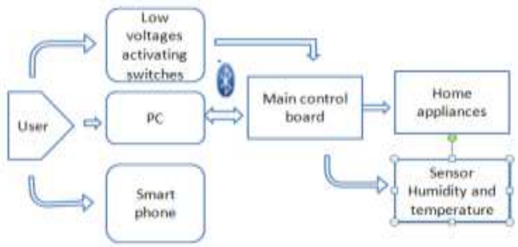

Fig 4: System Architecture

Fig 5: User Interface

3. Smart Home Automated Control System Using Android Application and Microcontroller[6]

This paper was authored by Mohamed Abd El-Latif Mowad, Ahmed Fathy, and Ahmed Hafez. The purpose of home automation and remote monitoring in this paper is to control the environment in the home, such as the humidity, temperature, fault tracking and management by using an Android smart phone. The authors also consider health monitoring. The system design is based on the Microcontroller (Arduino Uno), sensors and also a wireless Internet connection that is used for remote control. The objective of this paper is to help elderly and handicapped people to live a more convenient life. The ability of this application is lighting control shown in Figure 6, remote control shown in Figure 7, temperature sensing control shown in Figure 8, and security control.

Fig 6: Lighting System Controlling

Fig 7: Garage Door Remote Control

Fig 8: Outside Temperature Sensor

From researching other related works, we can see some functions that overlap with our project but there are some differences as follows.

1. Our project uses an Android operating system to create the application of monitoring the electric consumption of home appliances.
2. Our project can represent the current status of home appliances, so users can monitor the appliance status whether they are online or not.
3. Users can view the energy usage of home appliances in statistical and historical data.

III. SYSTEM DESIGN

The system design which has been separated into three main phrases as follow:

- The Front End, designed for smart phones running on Android operating systems, receives electrical power from the database to display on the screen via the Internet. Moreover, there are many functions so that users can search current electrical consumption and historical electrical consumption that is viewed by groups of devices and power nodes. Also, there is a system administrator for any change of appliances.
- The Database System is a database that stores the electrical consumption of the measured appliances from the Power Meter. This database system includes the techniques of OLTP and OLAP.
- The Power Meter is a system which includes microcontrollers, Arduino boards and Voltage and Current Sensors. Arduino will send energy data measured from the sensors to the database system via HTTP protocol.

System Architecture Overview

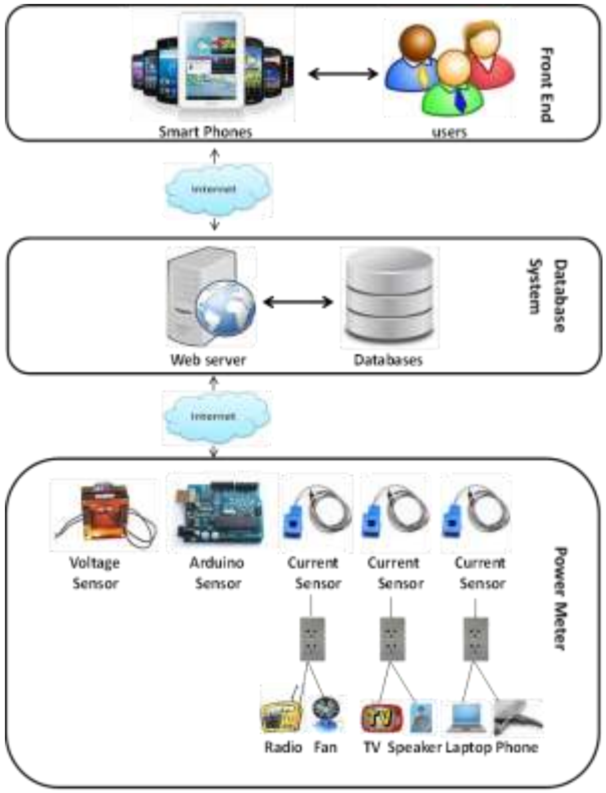

Fig 9: System Architecture Overview

Power Meter

1. *Voltage Sensor*

Voltage can be sensed by using an AC adapter, in order to scale down the output voltage to less than 5v a voltage divider circuit is used and DC bias is added to stabilize the signal. The adaptor voltage output (AC) implemented in the system was 9V for 230V input when it is loaded, in no load condition due to the transformer regulation it is 25 % higher which also depends upon the adaptor design conditions. The voltage divider divides the circuit voltage further so that the actual input to Arduino will be less than 5V.

2. *Current Sensor*

Measuring the alternating current source is not an easy task, very few devices are available formeasuring a great amount of load. Current Transformer (CT) sensors of split core are one such option wherewe can easily clip on to a phase wire and measure current proportionally that can be calibrated throughsoftware.A current transformer consists of a primary coil, magnetic core and a secondary coil, alternatingcurrent flowing in the primary coil produces magnetic field which induces current proportional to the primarycoil in the secondary coil. This current transformer is installed by clipping either the live or neutral wirecoming into the electric meter with the CT, when incase both the wires are clipped then the currents getcancelled as they flow in opposite directions. For this application system a typical CT transformer of modelno SCT-00-13 is used which can measure a load of 100A made proportional to 50mA

3. *Arduino Board*

Arduino is a general purpose micro-controller that can be programmed by using Arduino IDE software. It consists of a microcontroller with on-chip memory and pins for interfacing external devices. Arduino is both an open source hardware and software There are many variants in Arduino board.

- The one that used in this system is Arduino Uno. Microcontroller on the board is ATMEGA328.
- 14 digital input / output pins.
- Can be programmed using USB connection.
- 16MHz ceramic resonator.
- Operating voltage 5V
- Easy to attach libraries and program the board.
- Easy To interface External Devices.
- Serial Monitor in Arduino IDE can easily view sensor values on the screen.

Database System

In order to connect the data incoming from the Ethernet shield in to the database there should be aserver hosting the SQL database with the device IP. So the communication is established with the databasethrough the port address that should be programmed in the Arduino using SQL library.

In the implementation, a Wamp server which is an open source does this purpose. It has an apache tom catserver hosting the MYSQL database at the port address 3306 with authentic privileges of username and password.

Front End- Android Application Implementation

The user with the authenticity could view his electricity usage information, while he/she can even view the statistics of his/her usage as well. This can be established by hosting the android pages over the internet with a domain name and establishing a connection through JDBC between webpages and database by programming through servlets.

In the implementation we have two access privileges

1) Administrator

An administrator with authentic information of login id and password can register new users, modifyuser details, search for the user requests and assign user id along with his full details into the database.Admin will assign the user-id for the users whenever the users get registered in the website. After getting the user-id from the admin, users can login and check their electricity statistics in detail.

2) User

User could login with the authentic details of user-id and password. He/she can view his electricity usagedetails.

IV. RESULT

System Structure Chart

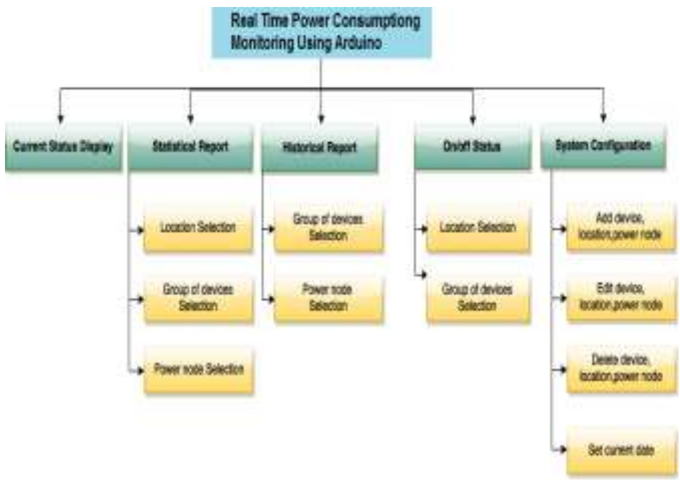

Fig 10: Structure Chart

From Figure 10, the detailed description of each subsystem is shown below:

1. Current Status Display–This subsystem shows the overall energy consumption, maximum energy usage categorized by group of devices, power nodes and location, and the number of on/off devices as shown in figure 11.

Fig 11: Current status

2. Statistical Report–This subsystem shows some statistical values, such as most energy, average energy and total energy, of this hour, today, this month and this year as shown in figure 12.

- Location Selection–This shows the statistical values by location.
- Group of devices Selection –This shows the statistical values by group of devices.
- Power node Selection –This shows the statistical values by power node.

Fig 12: Statistics

3. Historical Report–This subsystem shows historical energy usage by selecting date, month and year as shown in figure 13.

- Group of devices Selection–This allows users to select the group of devices to compare energy usage.
- Power node Selection–This allows users to select power nodes to compare energy usage.

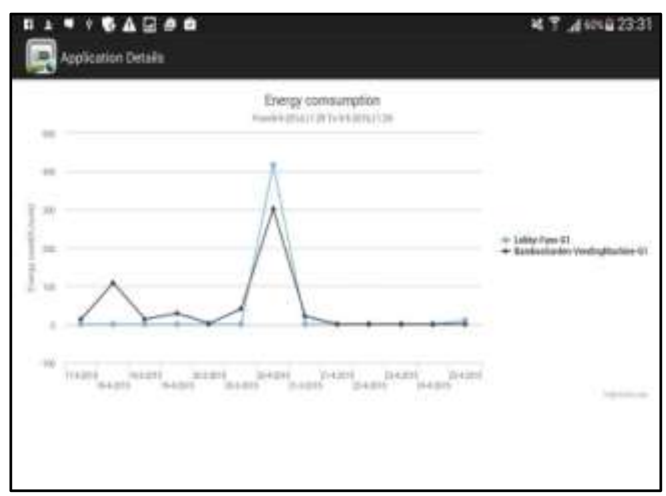

Fig 13: Energy comparison graph

4. On/off status–This subsystem shows the status of devices as shown in figure 14.

- Location Selection–This allows users to select location
- Group of devices Selection–This allows users to select group of devices to show the devices' status.

Fig 14: Show group of devices list

5. System Configuration – This subsystem allows administrators as shown in figure 15 to manage the system as shown in figure 16.

- Add device, location, or power node –This allows an administrator to add a device, location, or power node.
- Edit device, location, or power node –This allows an administrator to edit a device, location, or power node.
- Delete device, location, or power node –This allows an administrator to delete a device, location, or power node.
- Set current date –This allows an administrator to set the initial date.

Fig 15: Administrators Authentication

Fig 16:System Configuration

V. CONCLUSION

Real Time Power Consumption Monitoring Using Arduino is an Android application that is used to monitor the energy usage of appliances or locations by showing both current usage and historical usage. The users can compare the energy usage of the appliances when used at in different times and can use all the information provided in the application to make plans for electricity usage.Real Time Power Consumption Monitoring Using Arduino also provides the administrators function, so the administrators can manage the system by adding, editing, and deleting the appliances, locations, and power nodes.Real Time Power Consumption Monitoring Using Arduino has provided the benefits to the users and also project developers.The users can easily check the energy usage on their mobile devices. The users can make plans for energy saving strategies for each appliance.The users can see when their major loads are and in what locations they use the most electricity.The users can see the historical energy usage of the appliances.The users can compare the energy usage by the period of time.The users can check the appliances' status, whether it is on or off.Problems and Limitations is an Internet connection is a basic requirement, Real Time Power Consumption Monitoring Using Arduino is designed only for Android Operating Systems.Future Work, the application will be able to turn on or off electrical devices. The application can be applied with data mining for energy consumption analysis with the users' behaviors. The application will be used to calculate the electricity bill.

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