The Development of Smart Home System for Controlling and Monitoring Energy Consumption using WebSocket Protocol

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Abstract. Energy consumption especially electricity is considered one of the most serious problems in households these days. It is because the amount of electricity consumed is more than the amount that people actually need. This means that there is an overusing which resulted from the inconvenience of moving to the switch to turn off the light or any appliances and it is often that closing the light is forgettable, for instance; in addition, there are no tools for monitoring how much energy that is consumed in residents. From this, it can be easily seen that people are having a problem in energy usage monitor and control. There are two main objectives of this study including 1) creating the communication framework among server, clients and devices, and 2) developing the prototype system that try to solve the mentioned problems which gives the user an opportunity to know the amount of electricity they have used in their houses and also the ability to turn appliances on and off through the Internet on smart devices such as smart phones and tablets that support Android platform or any web browser. Raspberry Pi is used as a microcontroller and the data is transferred to the smart device by WebSocket protocol which is strongly recommended for real-time communication. The example features on the device’s screen are user management, controlling and monitoring of appliances. The result expresses that the system is very effective and not difficult to use from users’ satisfaction. However, current sensors may be used for a more accurate electricity measurement and Wi-Fi module for more appliances to calculate its power in the future.

Keywords- Smart Home; WebSocket protocol; Monitoring; Controlling; Internet of Things

1. Introduction
Internet has been an important technology for today and undoubtedly the future. This is because it erases the border of cyber world between countries and each parts of the world. The statistic from Internet World Stats [1] has shown that the use of the Internet all around the world has been dramatically increasing shown in Figure 1. The ability to connect wirelessly has brought about the term “Smart Home”, the system that provides convenience and safety in residents. A smart home system or home automation is usually based on Wi-Fi in terms of data transmission between light bulbs and appliances to user’s smart devices such as smart phones and tablets; this means that to use a smart home system, smart devices are required for end users with the ability to install applications. The number of world smart phones use after 2013 was more than the use of desktop computer [2]. This trend of Internet use has implied us that people in the world are comfortable with these portable devices and any such device can connect the Internet in the future surely. Smart home comes with that trend, so called “Internet of Things” (IoT), the concept that everything can connect to the Internet giving it the ability to transfer its usage to the user for any purpose. Smart home with IoT together
means that any appliances in houses can communicate with the user through the Internet and the information from houses can display on screens of smart devices. Therefore, this study aims to create the smart home system in order to provide the convenience for monitoring the energy consumption in users’ home and controlling any electric devices via the Internet.

2. Related Works
Nowadays, there are many systems supporting the smart home concept. For example, Ramlee and their project mates developed smart home system using Android application [3]; but they use only Bluetooth connection among devices instead over the Internet. Moreover, Kumar developed the smart home system using Android as well [4]. That system uses REST protocol to transfer the data among devices via server. However, the communication among electric appliances and any client devices over the Internet is the big challenge point for researchers. There are many researches try to propose the best communication protocol. Pimentel and Nickerson [5] compared the latency of WebSocket protocol [6] among HTTP polling and long polling [7]. The result of their research shows that the average latency of WebSocket is better than HTTP and long polling. The possible protocols such as CoAP, MQTT, XMPP, RESTFUL, AMQP and WebSocket are strongly recommended for IoT application. In the survey on application layer protocols for the IoT application [8], they indicated that MQTT has proved to be more efficient for battery-run devices but it is not widely used as HTTP, and WebSocket is designed for real-time communication as MQTT but it is mainly used for client/server based architecture. Those protocols are recommended from them. Therefore, this study mainly uses WebSocket protocol for communication framework because the prototype application is based on HTML5, CSS and JavaScript as well as Data Center Unit (called as “DCU”) which is the microcontroller connected to the electric appliances supports WebSocket also. In addition, low cost ubiquitous sensing system was tested by [9] and the result shows that the reliability of sensing information transmission through the proposed integrated network architecture is 97%. That means we can apply any low cost sensors to the system with the reliability.

3. Methodology
First, the related works was reviewed in section 2 to acquire the possible solutions for developing the smart home system especially for real-time communication. Second, the system design consists of four parts including:

3.1. Designing Communication Framework
According to the Figure 2, it illustrates the overview of communication framework. The agent of WebSocket was built separately. There are three main parts of WebSocket agents including client, server, and device (call as “DCU”).
- First, when some clients wake up, then they will connect with the server using WebSocket agent; after that, do the handshake (see number 1 in the Figure 2).
• Second, when some DCUs wake up, do the same things as clients (see number 2 in the Figure 2). Actually, clients and DCUs must have their own ID to determine that who are connected to the server.

• This time, all active agents can send any message to each other. For example, if a client would like to turn on device 001, it just sends the message such as “please turn on 001” to the server (see number 3 in the Figure 2).

• After that, the server will receive the message. Next, server will send the message to DCU, which connects with device 001. The device 001 will turn on and send responding message back to related clients via the same path to confirm the result (see number 4-5 respectively in the Figure 2).

DCU is used as a microcontroller; in this research, Raspberry PI 2 model B [10] was used to control any electric equipment because it supports WebSocket protocol. Additionally, server WebSocket agent is used as a medium point to control the transmission messages in the system.
3.2. Designing System Features
The system features were designed using Use Case Diagram. In the diagram, it shows that which options the user can use and which options are for the system admin. The admin can manage user and appliances while the user cannot, see the Figure 3.

3.3. Designing System Architecture
System architecture has three parts consisting of:
- Client side, user can use any platform to access the application via web browsers. However, this study focuses on Android platform; that means we have the application on Android.
- Server side, all system information is kept in the database on the server as well as we also have rules and metadata to control users who interact with the system.
- DCUs side, it is the microcontroller, which directly connects with electric appliances.

As the mention above, three parts connect together via WebSocket protocol for real-time processing. Furthermore, we also use HTTP request for normal tasks such as manipulating with database, and call Web service that use JSON and XML for data exchange. See the Figure 4 that illustrates the overview of system architecture.

Figure 4. System Architecture

3.4. Constructing Home Model

Figure 5. All appliances on home model, four light bulbs and one fan can be tested on this model

According to the Figure 5, home model was constructed to prove the concept of smart home system in this research. We have four light bulbs, one fan and three electrical outlets. Relay modules are needed
in order to act as switches and bridges for working on 220V AC power system in Thai households and 5V DC power system on the Raspberry PI. After the system was completely built, it was tested its performance and we fixed problems that were found such as bug or hardware failure. On the end-user application on android smart phones and tablets, the screen and pages were designed. The result will be explained in the next section.

4. The Prototype System and Result
Once the user has logged in to the system, they are led to the main page called “dashboard”. In this screen, all the appliances status is shown, for example, the fan is off and all the three bulbs are as well off. At the top right, the cost of electricity used at that day is calculated real-time and will be shown on this corner as shown in the figure 6 (the right is shown on mobile device).

![Figure 6. Dashboard page on a normal screen (left) and mobile screen (right)](image)

The figure 7 (left) shows that users can use the GPS setting feature to control electrical appliances by the distance between their location and home location. For example, we can set the distance that if it is far from home more than 3 kilometers, every appliance will be turn off automatically. Moreover, the history of users will be recorded for every transaction as shown in the figure 7 (right) as the mobile screen.

![Figure 7. GPS setting (left) and historical usage (right)](image)

In fact, we also have more features such as user management, appliance setting, timer, and calendar setting for controlling electric appliances. The system also was tested on all of features and different devices with different screen resolution by users’ satisfaction, and the result express that the average satisfaction from users is in excellent level. Furthermore, the best display of the screen is in the case that it should be more than 800 X 1280 DP because user can see all information without any scrolling. We tested the performance and reliability of the system by running the application with 30 users simultaneously during one month to test fault tolerance, data accuracy, and response time. The result
shows that the system can run continuously without any error and the average response time recorded for data transferring to control appliances is 0.635 seconds.

5. Conclusion
After the system was built, it was tested its performance, stability, and functionality whether it met the research’s objectives or not. As mention before that one purpose of this system is to create a prototype that can assist the user in terms of energy consumption reduction and monitoring on Android devices, what we have found is that the system is easy to use because of smart devices can be touched on their screens. This creates a comfort to control each appliances or lights in houses. The ability to set a timer is very effective and useful in terms of solving the problem about energy overuse. It can be controlled by GPS in terms of calculate the distance between the device and the house and it can show the system status. The system status tells the user about how much they will pay at the end of each month and the cost of the electricity use will rise when the time goes by as they keep using appliances; this has shown that the user can monitor the price of electricity consumption in real-time. That means WebSocket protocol is suitable for this system in real-time data exchange.

In future works, the current sensor should be added to the system in terms of having a more accurate calculation of electricity use and cost. The Second suggestion, more Wi-Fi modules must be attached to each appliance to transfer data to Raspberry Pi because all appliances may not install in the same position and it is sometimes difficult to use cords for data transmission. All of these recommendations can function and cooperate with Raspberry PI and smart devices. The term “smart home” must come with the capability to automatically detect, calculate, and notify whatever it is programmed to do via Wi-Fi technology for providing its owners convenience and safety.

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