Development of Small Scale Home Monitoring System Based on Internet of Things

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Abstract

Energy consumption is a vital issue in the house. Nowadays, people tend to ignore their energy consumption in their house. Its shows lack of awareness among the homeowner to the campaign on energy efficiency. Besides, the monthly bill only come up with the total cost and total energy consumed in the house. The homeowner is not able to identify which home appliance contributes the most to the energy usage. The main objective of this project is to develop a prototype of Internet of Things (IoT) smart home automation. The system consists of network architecture, MQTT protocol using ESP8266 NodeMcu development board, and provide the user interface for the user to monitor real-time data, based on the sensor with the internet connection. This project introduces the design of a controller that implement IoT concept where home appliances can be controlled remotely only by using smart devices such as laptop or smartphone. An infrared motion sensor is used to as a security system where it detect trespasser and will trigger an alarm. As a result, the prototype design is able to monitor real-time data from the sensor and control through the smartphone with internet connectivity. The significance of this project, the homeowner able to monitor energy consumption and control home appliance real-time from a distant location. A lot more field need to be explored to bring the concept of the IoT. Finally, with the utilization of the technology, it can be a benefit to the society and improved people's life for the better.

Keywords: *Internet of Things, Smart Home, Energy Monitoring, MQTT Protocol, Prototype*

1. Introduction

Internet of things (IoT) can be defined as the connection between the smart block which enables novel computing between them through the internet. The smart block is a combination of the internet with the emerging technology which is real-time localization, embedded system and near-field communication [1], [2]. Internet of things becomes significant in the 21st century and grows rapidly with the advance of modern technology. One of the reasons is the fast growth of mobile phone technology.

For the past decade, the mobile phone becomes essential in the daily life and a lot of features and function were added to the mobile phone so that everything can be accessed by fingertip on the device. With the emerging technology of the smartphone and IoT, many applications can be created to improve one life and give benefit to the society. Based on a survey by Atzori et. al, the data research domains and applications of IoT are shown in Figure 1 [3].

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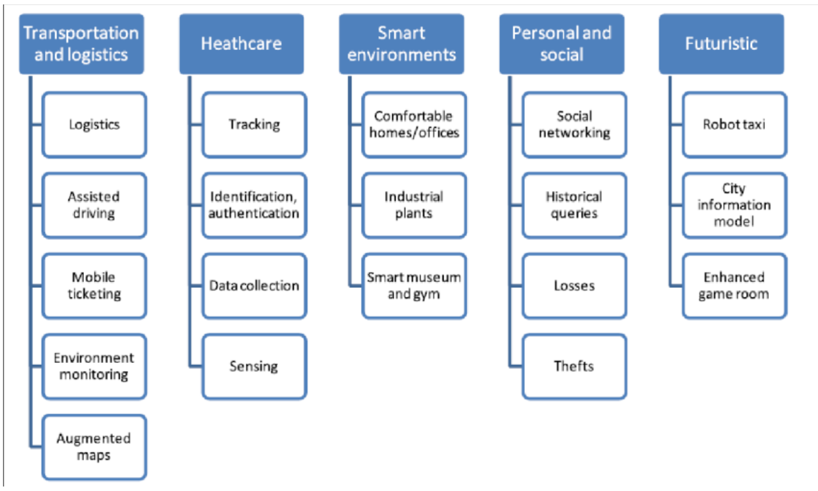

Figure 1. Application Domains and Relevant Major Scenarios of IoT [3]

The internet can revolutionize the sector of the smart home to provide intelligent, and comfortable environment to improve the quality of life [4]. Scalable computing and storage power are two main concerns offered by cloud computing for developing, maintaining and running home service. Besides, it also allows the user to access monitor or control home device anytime and anywhere [5]. Internet of things can be used for effective delivery of services without manual intervention in the more effective manner [6]. Figure 2 shows the basic concept of the IoT for home automation application.

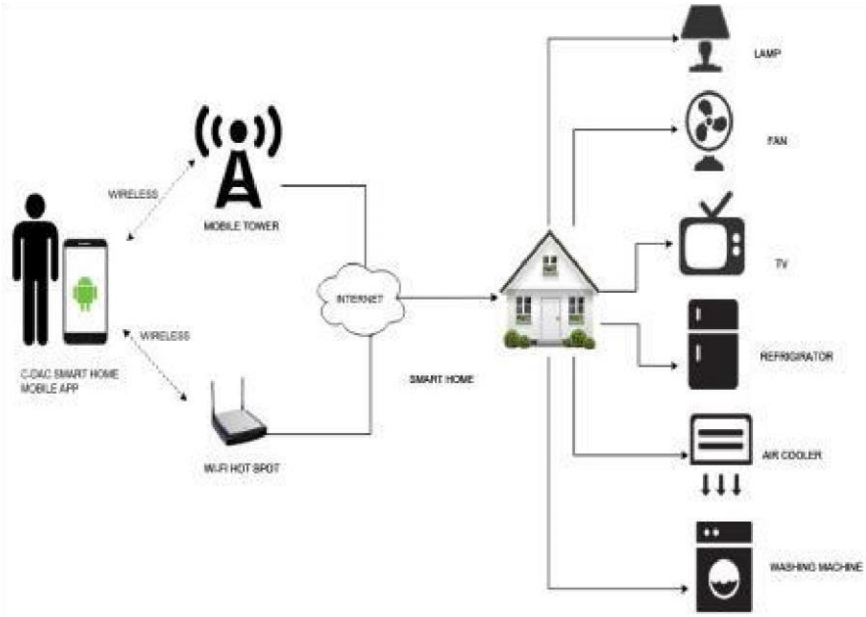

Figure 2. Internet of Things Concept for Home Automation [6]

The smart homes provide a better quality of life by introducing automated appliance control and assistive service. User comfort can be optimized by using context awareness and predefined constraint based on the condition of the home environment [7]. The smart home automation domain is characterized by an infrastructure that enables intelligent networking of devices and appliances that use various wireless and wired technologies to provide seamless integration, which facilitates ease of use of house systems while creating a personalized and safe home space [8]. The integration between energy efficient system and home automation provides the consumer with information about their energy consumption pattern and helps them to adapt to energy efficient behavior and offers consumer actionable information and control feature [9].

Nowadays people are talking about the energy efficient, but the reality remains the same, a lot of energy wasted every day or in other words, we have excessive of energy consumption. The real question is how does energy efficiency or energy saving can be implemented in the society. All parties should take initiative and responsibility on the issue. For example, the government should restrict the policy on energy efficient product, meanwhile, for the manufacturers must follow the guideline provided by the government and improved research activity on energy efficiency that is to be implemented on their product. The end users should be aware of the importance of the energy efficient by controlling and monitoring energy consumption in their house. A simple step taken can benefit millions of others.

Based on a psychological study by Seligman and Darley, it is proven that feedback as a mean of decreasing residential energy consumption. During feedback period, the electricity used was reduced by 10.5% as compared to average energy consumption by the house [10].

Most people tend to ignore the power consumption in the house, if the power supply is enough to generate the appliance in the house then just deal with it. At the end of the month, pay the electricity bill to the national utility provider. It shows lack of knowledge and awareness on the energy efficiency. Although, there are a lot of campaigns that had been done by the government agency to give awareness to the people about the importance of saving electricity and the effect of excessive energy consumption on the environment.

Furthermore, the electric monthly bill only comes up with the price and only displays total energy used in the house. Therefore, the homeowner is unable to identify which of the electrical appliances contributes the most to the total energy consumed.

The significance of this research is the homeowner is able to monitor the energy consumption by a single household appliance. The primary purpose of this research is to provide awareness to the homeowner about the energy consumption in their house. Hence, the homeowner can schedule and control the electrical appliances. Besides, they can identify which appliance contribute the most to the overall energy consumption in the house. Apart from that, this activity also supports the electrical energy conservation campaign which is to save energy as much as possible to lessen pollution and reduce greenhouse gas emission.

This project is to utilize the concept of the internet of things with advanced smartphone technology to the home automation to give awareness to the homeowner about their energy consumption in the house by monitoring energy consumption and control appliances in the house. A network architecture-based internet of things for smart home was designed. Besides, the project provides a mobile user interface or smartphone application for the homeowner to easily monitor the collected data in real-time with internet connectivity.

2. Related Work

Piyare presented Arduino based home control and monitoring system with Android smartphone. The proposed system consisted of three parts which are remote environment, home getaway and home environment. Ethernet module was attached to the Arduino to provide internet connectivity. The proposed architecture utilized RESTful web-based service as an interoperable application layer for communication between the remote user and the home device [11]. Meanwhile, Soliman et. al., proposed an integrated system the IoT between web service and cloud computing. The approach system consisted of embedding intelligence into sensors and actuator. Connecting the smart things is through ZigBee network technology. Besides, facilitate interaction between the smart things using cloud service to accessible from the different locations. JSON notation was used to improve data exchange efficiency [7]. Figure 3 illustrates the system architecture by Soliman.

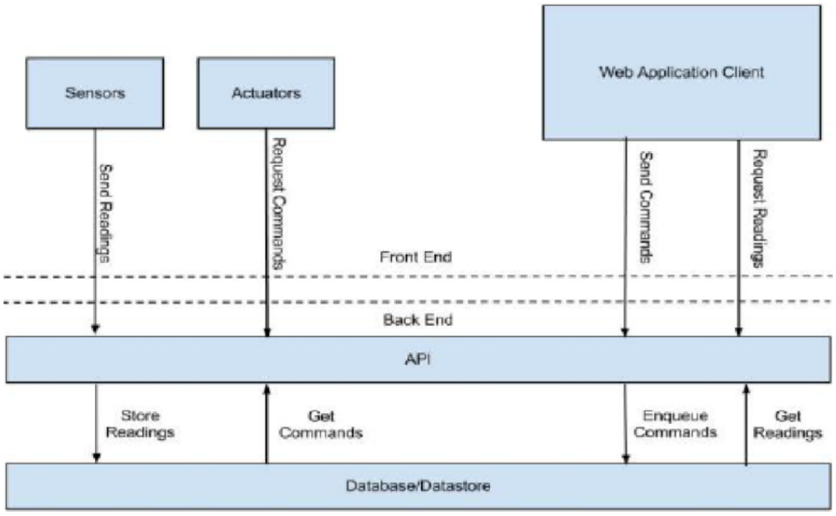

Figure 3. The System Architecture by Soliman [5]

Mandula et al presented mobile home automation system IoT based. Two types of connection were used which is Bluetooth for indoor environment and Ethernet for outdoor environment. They realized that Bluetooth communication technology can cover limited range area and only suitable for indoor environment [6].

Baraka et al demonstrated home automation system by using Arduino as central controller. Ethernet shield was mounted on the Arduino board to provide internet connectivity. Mobile device used to provide user interface with the system through a userfriendly application. A simple Web server application that runs on the Arduino communicate with the Web-based Android application through the HTTP protocol. They used wireless ZigBee and X10 wireless technologies for end device. The system highlighted on smart task scheduling by using resourceconstrainedscheduling algorithm [12]. Figure 4 shows the block diagram of proposed system.

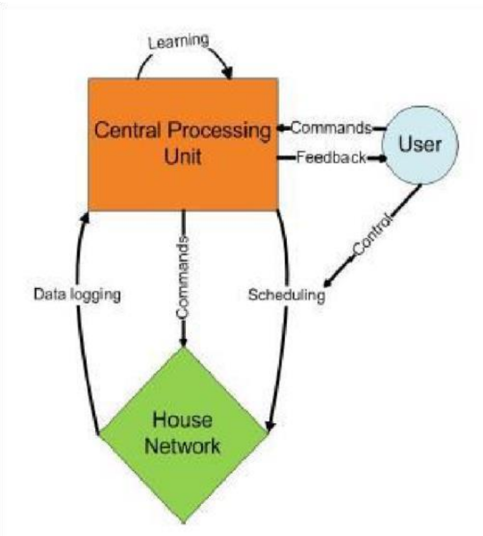

Figure 4. The Block Diagram Proposed by Baraka [12]

Thakare proposed a novel smart home energy system to sense the current values on real time basic, computes the instantaneous power and uploads the values to the cloud. The Wi-Fi module ESP8266 connected to the Arduino Nano to enable the

Arduino to upload the data to the cloud. PHP script is used for importing data from cloud and reverse process. JavaScript was used to represent the data graphically [13]. Next, Soumya et al proposed an IoT home automation system consisted Raspberry Pi that connect to various sensor and run by the python program. JavaScript application was used to control the relay and actuator [14].

Pavitra and Balakrishnan proposed home automation system, aiming to control home appliance via smartphone as user interface, using Wi-Fi as communication protocol and Raspberry pi as server system. The proposed system provided realtime home safety monitoring and control the home appliance remotely while protecting from accident by giving immediate solutions. One of the extra features of proposed system was the capability to detect smoke in event of fireplace, that associated an alerting message and an image is sent to smartphone and automatic phone call was made to the nearby fire station [15].

Crisnapati et al proposed a low cost and energy efficient system that fully operate for IP-based network known as Rudas. The proposed system consisted of several embedded sensors and networking devices connected to the Internet architecture. The system also implanted the fuzzy logic artificial intelligence to adjust the intensity of light and air condition in a room [16]. Chhabra el al proposed a design with implementation of Ethernet-based smart home intelligent system for monitoring the electrical energy consumption real-time at home using INTEL GALILEO 2nd generation of development board. The users also can remotely control the electrical device using an android based application. The proposed system focused on saving the electricity bill and home security [17]. Figure 5 shows the hardware and system architecture.

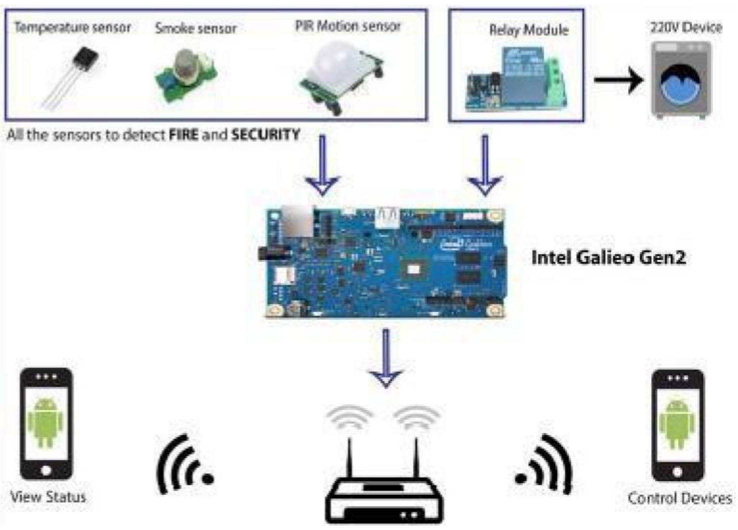

Figure 5. Hardware Architecture Overview by Chhabra [17]

Kamal et al proposed an efficient low cost supervisory system for smart home automation that can be managed using IoT. The proposed system based on Apriori algorithm and will help to monitor and control all the home appliances and electronic devices through a supervisory system in a most efficient and reliable manner. The consumer and supplier will get opportunity to manage the power distribution by monitoring the electricity consumption [18]. Hlaing et al proposed a design to implement a very low-cost wireless sensor network and protocol for smart energy and web application capable of automatically reading the unit and sending the data automatically for the power user to view the current energy meter [19]. **Table 1. Summarize Some of IoT Application for Smart Home**

Author	Year	Significant work	Methodology
Piyare [11]	2013	Home control and monitoring system Arduino based and Android smartphone.	Arduino and Ethernet
Soliman et. al., [5]	2013	An integrated system the internet of things between web service and cloud computing	Arduino with Ethernet and Zigbee network Technology
Baraka et. al., [12]	2013	Home automation system through mobile device. Highlighted on smart task scheduling by using resourceconstrainedscheduling algorithm.	Arduino and Ethernet
Mandula et. al., [6]	2015	Mobile home automation system internet of things based.	Arduino with Bluetooth
Pavitra and Balakrishnan [15]	2015	Home automation system, aiming to control home appliance via smartphone as the user interface.	Raspberry Pi
Thakare et. al., [13]	2016	Novel smart home energy system which senses the current values on the real-time basis, computes the instantaneous power and uploads the values to the cloud.	Arduino Nano ESP8266
Soumya et. al., [14]	2016	Home automation system-based internet of things	Raspberry Pi
Crisnapati et. al., [16]	2016	Energy efficient system that fully operate for IP-based network	Raspberry Pi, Arduino with Ethernet
Chhabra el. al., [17]	2016	Ethernet-based Smart Home intelligent system for monitoring the electrical energy consumption real-time at home.	INTEL GALILEO with Ethernet
Kamal et. al., [18]	2017	Supervisory system for smart home automation that can be managed using IoT.	Arduino with Wi-Fi module
Hlaing et. al., [19]	2017	wireless sensor network and protocol for smart energy and web application capable of automatically reading the unit and sending the data automatically for the power user to view the current energy meter	Arduino with ESP8266 Wi-Fi

3. Project Methodology

The objective of this project is to develop a network architecture for smart home using microcontroller ESP8266 NodeMcu development board. Secondly, to develop the communication protocol for interchange data communication. Finally, to design a user interface to the homeowner to monitor energy consumed by a single appliance.

Therefore, the approach starts with developing network architecture for the project using the platform provided by the IO adafruit. IO adafruit is a leading platform for the learning process and project development especially on the IoT project. This is followed by hardware and software selection of the proposed system for the prototype design. After building up the prototype, the prototype will be implemented with the real set-up environment. Configure the third-party application to provide a user interface. The methodology was divided into three subdomains which is network architecture, hardware, and software. Figure 6 shows the flowchart of this project from the start until getting the finished product.

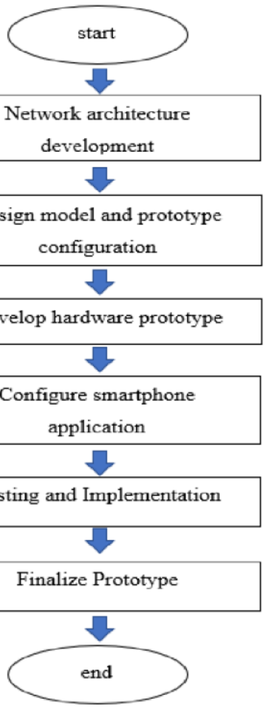

Figure 6. Flowchart of the Project

3.1. Message Queue Telemetry Transport

In this project, the network architecture that has been used is MQTT. MQTT is a Client-Server publish/subscribe messaging transport protocol. It is lightweight, open, simple, and designed to be easy to implement. These characteristics make it ideal for use in many situations, including constrained environments such as for communication in machine to machine and the IoT. MQTT enables resourceconstrained IoT devices to send, or publish, information about a given topic to a server that functions as an MQTT message broker. In this protocol, every client needs to connect to any addressess of the broker which is known as the topic to subscribe in MQTT. In a single broker, there can be multiple topics and the client can also subscribe to multiple topics of the same broker. Figure 7 shows workflow of MQTT protocol [20].

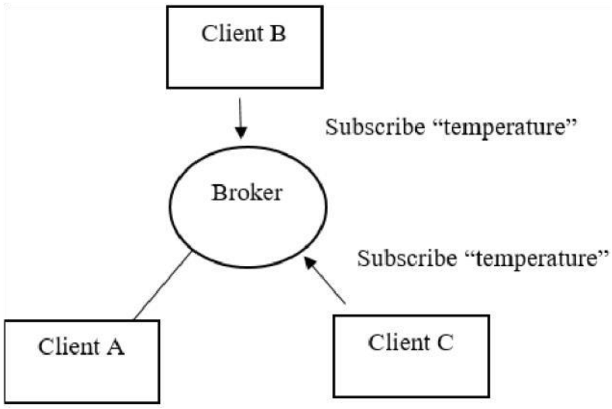

Figure 7. MQTT Subscribe Architecture [20]

3.2. Hardware

In this section, the detailed of the hardware specification was discussed. The subtopic is divided into 4 sections which is ESP8266 NodeMcu Development Board, sensors, hair dryer, and relay. Table 2 illustrates the detail of the equipment used.

Table 2. Equipment used for the Project

Equipment	Details	Image
ESP8266 NodeMcu Development Board	Key features of this development board are the ESP8266 Wi-Fi module embedded to this board with system on a chip. This development board is open-source, interactive, programmable, low cost and simple to be used and learned.	
LM35 temperature sensor	LM35 is a temperature sensor that is widely used in temperature sensing application from a simple project up to a complex project. The LM35 is the output voltage linearly-proportional to the centigrade temperature	
Light dependent resistor (LDR) sensor	The LDR is used to detect the presence of light in the environment. The relationship between the resistance and the light intensity level is inversely proportional. When the low resistance recorded, it means that light fall on the LDR is high, and the intensity level of light is high	

sound sensor	The sound sensor module provides an easy way to detect sound and is generally used for detecting sound intensity. It uses a microphone which supplies the input to an amplifier, peak detector, and buffer. When the sensor detects a sound, it processes an output signal voltage which is sent to a microcontroller that performs necessary processing.	
Hairdryer	The hairdryer was used in this project, basically to provide the change in the temperature. This also to ensure that the data obtained is based on the real data in real-time. The power supply for the hairdryer is ac ranging from 110 V to 220 V with 1400 W of power rating.	
Relay	The 5V relay module was used to enable control function in the prototype. In this project, the user can control the device (hair dryer) using the mobile application from the distance with the internet connection.	

3.3. Software

In this section, it discussed software that has been used in this project. The software is divided into two sections which is Arduino IDE and third-party smartphone application, MQTT dashboard application. Table 3 describes the details of the software used in the project.

Table 3. Detail of Software used in the Project

Equipment	Details	Image
Arduino IDE	Arduino IDE is an open source software to make easy to code and upload to the board. It can be used in many operating systems such as Windows, Linux, and Mac OS X. This software had been used to program the ESP8266 NodeMcu Development Board same as Arduino but in LUA script.	
MQTT dashboard	MQTT dashboard is the third-party application on Google Play Store. This application linked together with the MQTT broker that is provided by IO adafruit. The basic feature of the application is "subscribe" and "publish". The user needs to configure the information before using the application.	

4. Result and Discussion

This section discusses the result obtained from the project. The objective of the project is achieved when the developed prototype which contains several sensors is able to monitor real-time data on the smartphone application and website, from anywhere with internet connection. Figure 8 shows the live data from the sensor that has been displayed on website io.adafruit.com.

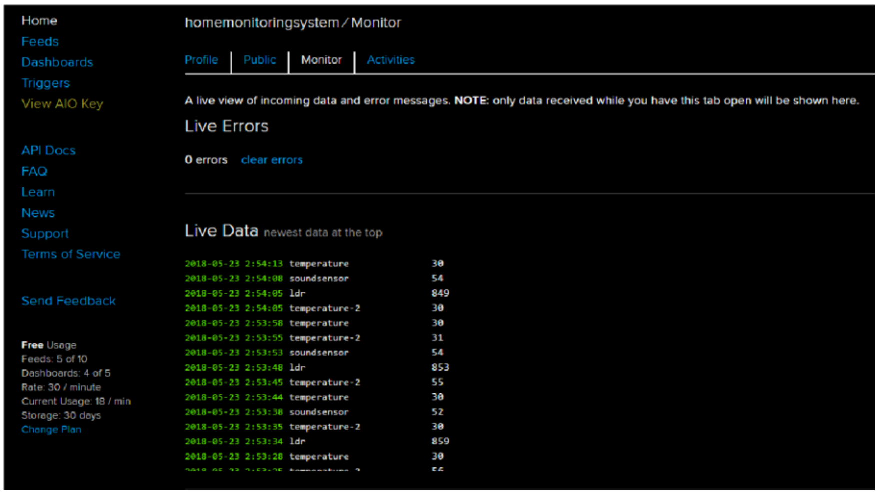

Figure 8. The Real-Time Data Obtained from the Website.

Figure 9. The Display on the Website

Figure 9 shows the sensor reading from the prototype which is the temperature sensor, light dependent resistor sensor, and sound sensor. The data obtained based on real-time environment. Meanwhile, Figure 10 and Figure 11 displays the userinterface which is third-party application that has been configured with the developed prototype.

The difference between Figure 10 and Figure 11 is the state of the hairdryer. Based on Figure 10, the temperature 2 recorded as 28℃ Celsius, at that time, the hairdryer is switched off. Meanwhile, Figure 10 shows the condition where the hairdryer is ON state. The temperature 2 reading is 68˚C. The temperature 2 shows significant change to the change of environment. The other sensors such as temperature, LDR sensor, and sound sensor do not show significant change to the change of the environment.

Figure 12 shows the data collection of the temperature 2 sensors in 60 seconds. There are three main parts of the graph. The first part shows the consistent temperature 2 reading ranging from 28˚C to 31˚C from the 1st second to 44th second where the hairdryer is switched OFF. The second part is on the 45th second, the temperature 2 started to rise, this is because the hair dryer is switched ON and the temperature 2 reading reach at the peak on the 49th second which is 70˚C. The third part is on the 50th second and onward the temperature 2 sensor reading started to decline. At that time, the hairdryer is switched OFF. Finally, on the 58th second, the temperature 2 reading gets back to the normal temperature which is 30˚C.

Figure 13 shows the graph of resistance against light intensity level. The experiment was conducted on three different conditions which is dark, dim light and bright light. Theoretically, the relationship between the resistance and light intensity level is inversely proportional. Based on the graph obtained, it shows that during the dark condition, the LDR sensor reading ranges from the 750Ω to the 900Ω which is the highest among other conditions. At the dim condition, the sensor reading drops to the 200Ω to 220Ω. At the bright condition, it shows the lowest reading as compared to the other conditions which is ranging from 100Ω to 130Ω.

Figure 14 shows the graph of sound intensity level against time. The experiment was conducted in one minute. The graph shows the variation of sound intensity level ranging from 43 dB to 60 dB. The sensor reading is compared to the sound level as of Table 4. For comparison between sensor reading on the graph and the value of intensity level table, it shows similarity when the slow radio shows 40dB and ordinary conversation which is 65dB. The setup experiment is a normal room condition. Figure 15 show the final prototype of the project.

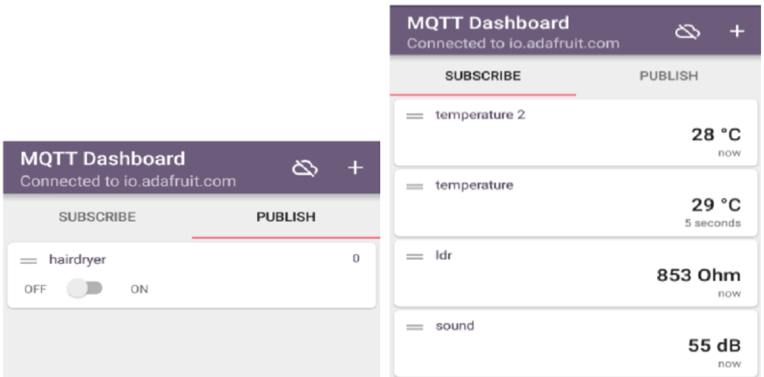

Figure 10. The Condition when the Hairdryer is OFF

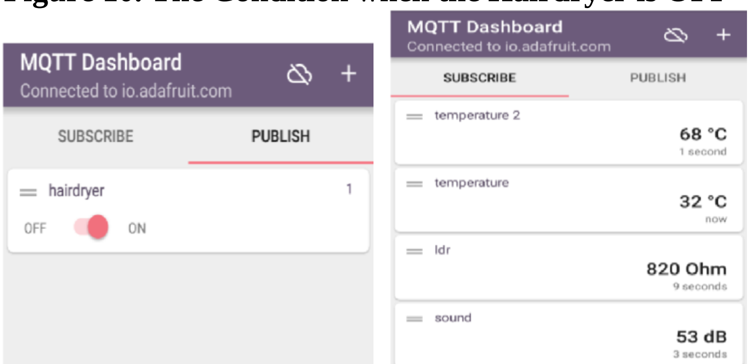

Figure 11. The Condition when the hairdryer is ON

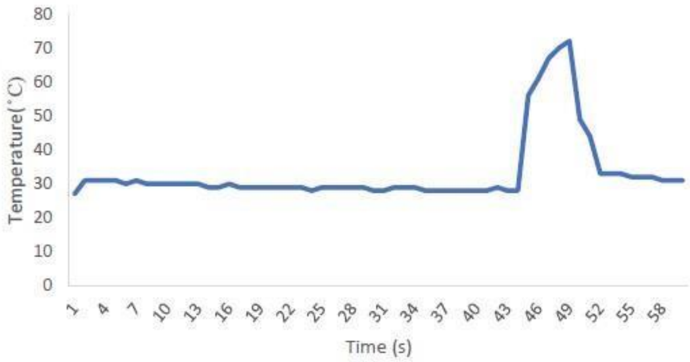

Figure 12. Result of Temperature 2

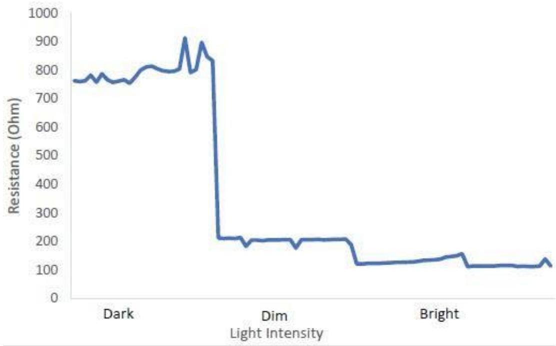

Figure 13. Result of Light Intensity Level

Figure 14. Result of Sound Intensity Level

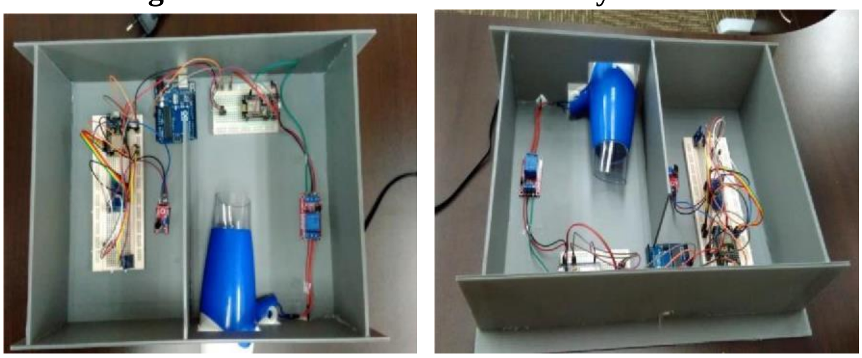

Figure 15. The Prototype

Table 4. Comparison of Sensor Reading and Sound Level

The Source of Sound	The intensity level (dB)	Intensity of Sound
Jet plane at a distance 30m	140	100
Threshold of pain	120	1
Loud rock concert indoors	120	1
Sirine at 30m	100	1 x 10 2
The interior of the car	75	3 x 10 5
Busy road traffic	70	1 x 10 5
Ordinary conversation	65	3 x 10 6
Slow radio	40	1 x 10 8
Whisper	20	1 x 10 10
Leaf rustling	10	1 x 10 11
Hearing limit	0	1

5. Conclusion and Future Work

As a conclusion, the objective of this project was achieved which is to monitor and control the sensor data from the distant by using smartphone application with the internet connection. The NodeMcu development board provide the opportunity to build the prototype of the internet of things project. The network protocol used in this project is MQTT. The importance of this project is to bring the IoT concept to apply to the home automation field. The main concern of the project is to monitor energy consumption by every single appliance in the house real-time by using smartphone application.

The prototype design should be improved and tested with the actual component. Besides, improved the function of the sensor, in which the sensor can react with the changes of environment like add-on artificial intelligent to the sensor. The NodeMcu is a great development board that needs to be explored in the new area (application) especially related to the internet of things project.

The concept of the IoT does not limit only to the home automation only, there is a lot of opportunities to realize the concept of the internet of things in today's world. At last, it can benefit the society and the people. Security and data privacy are the major concern when the issue addressed related to the internet of things because everything is connected, therefore everything can be accessed through internet connectivity. Hence, more research needs to be done especially on data security and privacy to give confidence for the people to utilize the concept of the internet of things in their life.

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