ENVIRONMENTAL CONTROL FOR CATFISH DRYING HOUSE USING RASPBERRY PI MICROCONTROLLER

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May 2018

This dissertation is submitted to

Universiti Sains Malaysia

As partial fulfillment of the requirement to graduate with honours degree in

BACHELOR OF ENGINEERING (MANUFACTURING ENGINEERING WITH MANAGEMENT)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree

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ACKNOWLEDGEMENT

It is a great opportunity and pleasure for me to express my gratitude towards all the individuals who directly or indirectly contributed towards the completion in this final year project. I am also overwhelmed in all humbleness and gratefulness to acknowledge my depth to all those who helped me to put these ideas.

Firstly, I would like to express my deep gratitude to my honourable project supervisor and my thesis advisor Associate Professor Dr Zahurin Bin Samad for his approach and outstanding supervision in my final year project. He always show me the right track when I need his help.

I would also like to thanks to technical staffs, Mr Hashim Md Nordin, Mr Mohd Ali Shahbana Mohd Raus and Mr Hazwan Mohamad for their supports and helps throughout completing this project.

Finally, I would like to express my lovely thanks to my family for their love, encouragement and personal support that I received upon the completion this final year project.

Thank You

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

RPi	Raspberry Pi
LAN	Local Area Network
WiFi	Wireless Fidelity
USB	Universal Serial Bus
UART	Universal Asynchronous Receiver/Transmitter
MQTT	Message Queuing Telemetry Transport
SSH	Secure Shell
ADC	Analog-Digital Converter
API	Application Programming Interface
I^2C	Inter-integrated Circuit
˚C	Degree Celsius
lx	Lux
V	Volt
AC	Alternate Current
DC	Direct Current
IoT	Internet of Things
T_L	Lower Threshold Value
T_H	Upper Threshold Value

KAWALAN PERSEKITARAN UNTUK RUMAH PENGERINGAN IKAN KELI MENGGUNAKAN PENGAWAL MIKRO RASPBERRY PI

ABSTRAK

Proses pengeringan ikan keli adalah salah satu cara pengawetan yang digunakan untuk memeliharanya sehingga ia dapat bertahan dengan lebih lama. Secara tradisionalnya, cara yang biasa digunakan untuk pengeringan ikan adalah dengan menjemur dibawah sinaran matahari. Walaubagaimanapun, cara tersebut adalah terhad dan terganggu oleh kerana keadaan cuaca yang tidak menentu seperti hujan. Bagi mengatasi masalah ini, projek pengeringan ikan ini telah dilaksanakan dengan menggunakan sebuah bangunan iaitu rumah pengeringan yang terlindung daripada persekitaran luar bagi meningkatkan proses pengeringan tersebut. Sebuah sistem perkakasan telah diperkenalkan dalam projek ini yang terdiri daripada bahagian pemantauan dan pengawalan yang dijalankan oleh sebuah pengawal mikro iaitu Raspberry Pi. Bahagian pemantauan adalah terdiri daripada penderia suhu dan kelembapan dan penderia keamatan cahaya yang disambung pada pengawal mikro tersebut. Penderia-penderia tersebut digunakan bagi memantau keadaan semasa di dalam rumah pengeringan tersebut selama 24 jam setiap hari. Kesemua maklumat yang diperoleh daripada penderia-penderia tersebut akan dihantar kepada pengawal mikro untuk dianalisa. Kemudian, data yang telah diproses akan diterbitkan melalui Internet dan dipaparkan dalam aplikasi *Cayenne* melalui komputer dan telefon pintar. Analisis bagi keadaan di dalam rumah pengeringan telah dilakukan berdasarkan data-data yang telah diproses tersebut. Keputusan menunjukkan bahawa suhu dan kelembapan udara adalah saling bergantung antara satu sama lain dan ia dipengaruhi oleh perubahan cuaca di luar rumah pengeringan tersebut. Bahagian pengawalan keadaan di dalam rumah pengeringan telah diperkenalkan bagi mengekalkan suhu dan kelembapan udara dengan menjana haba kepanasan menggunakan pemanas haba dan penyahlembap udara untuk mengurangkan kelembapan udara. Walaubagaimanapun, beberapa masalah telah dihadapi ketika kajian sedang dijalankan yang telah memberi kesan kepada keseluruhan sistem.

ENVIRONMENTAL CONTROL FOR CATFISH DRYING HOUSE USING RASPBERRY PI MICROCONTROLLER

ABSTRACT

Catfish drying process is one of the method used to preserve the fish to make it last longer than usual period of time. Traditionally, the most common method used is by drying the fish under the sun. However, this method is limited by unpredictable weather where sometimes the drying process is disturbed by the rain. In order to overcome the problem, this project is implemented by using a building protected from outside environment called drying house to enhance the drying process. A hardware system was introduced in this project which consists of monitoring and controlling part conducted by a microcontroller called Raspberry Pi. Monitoring part consists of temperature and humidity sensor, and light intensity sensor and connected to the microcontroller. These sensors are used to monitor the current condition inside the drying house for 24 hours daily. All the information gathered by the sensors was transmitted to the microcontroller to analyse. Then, the processed data were published via the Internet and displayed in *Cayenne* application through computer and smartphone application. The analysis for the condition inside the drying house was made based on the processed data. The results showed that the temperature and relative humidity is dependent each other and affected by the weather changes. The controlling part was introduced to keep maintain the temperature and relative humidity by generating heat using a gas heater and dehumidifier to reduce the air moisture. However, some problems were found during the experiment which affects the overall developed system.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

This research project is collaboration between Universiti Sains Malaysia (USM) and Northern Corridor Implementation Authority (NCIA) to enhance the economic growth for a catfish supplier which is Ceria Tok Salam Enterprise handled by Mr. Amran Bin Samsudin located at Pedu, Kedah [1]. The company has come out with another product instead of fresh catfish which is dry catfish. This product demand has increase until the company have to develop alternative way to increase the production.

Generally, the company uses ordinary way by utilizing the direct sunlight to dry the catfishes before selling out to the customers. This kind of process depends on the outdoor weather and other factors such as temperature, humidity, and solar intensity. The company does not have any expert workers to increase the production to fulfil the customer demands. From the collaboration, the company has been sponsored by government to build a solar drying house which can be operated for 24-hours daily and able to produce 150 kilograms of dry catfish in one cycle. The house is built using transparent roofs which allow direct sunlight enters to the drying house. This building also can protect the catfish from rain.

As the building is protected from outdoor environment, there must be a control system to maintain the environment inside the house. This is because both indoor and outdoor environment are different in terms of temperature, relative humidity, and solar radiation at daytime and night time [2]. As the building is not equipped with any control system, the thermal environment inside the drying house may become extremely unbearable at different weather at different time [2]. Therefore, the environmental control system which consists of sensors and heating devices must be developed to analyse and maintaining the environment inside the drying house.

In this project, Raspberry Pi (RPi) microcontroller will be used to collect the data required such as the temperature, humidity, and the solar intensity. The data are measured by using sensors which are connected to the RPi. The data are then analysed to determine which condition is suitable inside the house. The suitable condition will be setup based on the obtained data. Other devices such as gas heater, dehumidifier, and blower also connected to RPi. It will automatically activate the devices if the condition inside the house is below than the required setup data.

1.2 PROBLEM STATEMENT

Although the drying house has been built by the company, there is still no control system to maintain the indoor environment which can lead to the unstable condition during daytime and night time. Furthermore, it is hard for them to do the drying process during night time and bad weather, where the condition of low air temperature, illumination from the sun, and high relative humidity inside the house will affect the process. It is also a problem to the control system as there are no sensors to measure and record all parameters inside the house which can be used to make decision planning.

1.3 RESEARCH OBJECTIVES

The main objectives of this project are:

1) To design and develop an efficient control algorithm for an environmental condition inside the catfish drying house
2) To analyse the temperature, humidity, and illumination from the sun by using sensors connected to microcontroller inside the drying house
3) To study the performance of the developed system for catfish drying process

1.4 SCOPE OF PROJECT

This collaboration project is about designing an environmental controller for catfish drying process. RPi microcontroller will be installed together with temperature-humidity sensors, light intensity sensors, gas heater, and dehumidifier inside the drying house. The microcontroller is used to collect and send the data such as temperature, solar intensity, and relative humidity in the form of digital display via online transmission using cloud service. The data will be analysed before developing the programming code as instructions for the microcontroller to activate and deactivate the heating devices at required condition. Then, the performance of the system will be examined whether it need to be improved or otherwise.

1.5 THESIS OUTLINE

The thesis consists of five chapters which are arranged accordingly.

Chapter 2 presents about the literature review of the project which taken from selected research papers and articles that related to this project. The review covers about the environmental control system and the requirement for the system to function effectively.

Chapter 3 covers the project methodologies. All the working procedures are explained together with some figures and flowcharts. The methodologies also include the hardware, software, and the control algorithm.

Chapter 4 presents the results and discussions. The data analysis and the limitation of the project of the system are also included in this chapter. The discussions are explained based on the results.

Chapter 5 concludes the overall project from beginning until the end of the project. This chapter states the project successiveness, and the suggestion and recommendation to improve the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explains the review of the past researches. The information from the past projects is taken from the selected journal papers, research articles, and thesis. The information that gained from the reviews is taken for decision making in this project.

2.2 DRYING FISH

Fish drying process is a mechanism where the water content in the fish body is removed by means of heating. The drying mechanism occurs when the complex thermal process which are the unsteady heat and moisture transfer simultaneously [3]. Instead of freezing, the drying process also gives the same benefits which able to inactivating the enzymes, removing the moisture necessary for bacterial and mould growth, and preserving the fish [3]. Normally, fresh fish contains up to 80% of water [3,4]. In order to remove the water content from the fish body, the most possible way that can be used is the drying process. There are several types of fish drying process have been implemented nowadays. The most popular fish drying process is carried out traditionally by the open sun [3]. Most of the researchers are trying to find the best way for this issue to reduce the energy consumption and can be finished in a short time. This is because the dried fish is one of the most popular marine products where some countries such as Thailand, Malaysia, India, and United States make the dried fish as exported products to other countries [3].

As described in [3], the researchers study the drying kinetics of sardine fish (Sardine laurite) by using microwave heating. From the investigation, they obtained that the drying time is affected by the heating power provided by the microwave. The result of the drying process is shown as Figure 2.1:

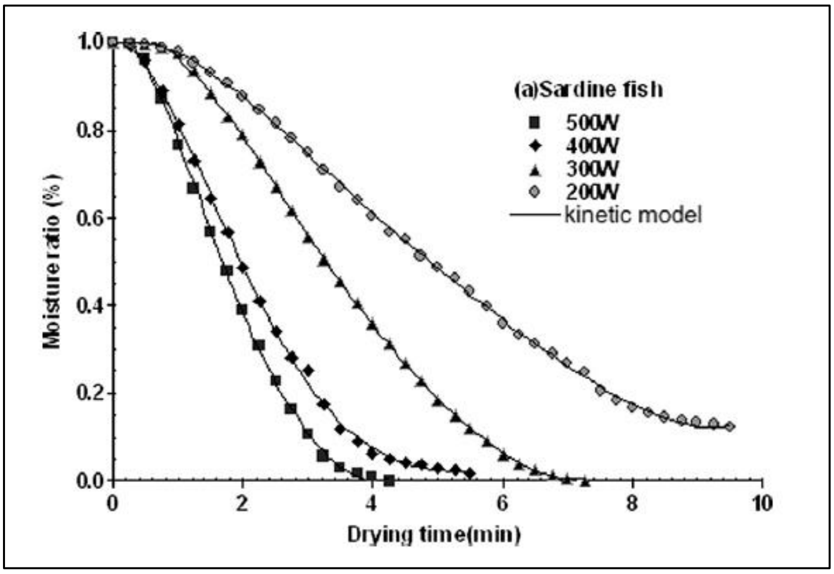

Figure 2.1: Difference between moisture ratios of sardine fish during the microwave drying process [3]

From the figure, it shows that the moisture ratio of the fish is dropped rapidly when the heat generated by the microwave is high. It can be said that when the heating energy is increased, the activity of water molecule diffused out from the fish is increased [3]. From that, the time can be reduced up to 51% as the power output is increased [3]. Table 2.1 also shows that the difference in diffusivity of sardine fish at different microwave output powers:

Table 2.1: Effective diffusivity coefficient value of sardine fish at different microwave power [3]

Power (W)	Effective Diffusivity (m^3/s)
500	3.048×10^{-7}
400	2.302×10^{-7}
300	1.758×10^{-7}
200	7.158×10^{-7}

The researchers in [4] studied the drying kinetics of chelwa fish and prawn under the open sun. The experiment is conducted under the ambient air temperature ranged from 32.5 to 42.5˚C and relative humidity ranged from 15% to 32% [4]. From the result, they obtained that both prawn and chelwa fish are dried in two and three sunny days respectively. This is due to the shape, size and nature of the two varieties [4]. The difference of drying time between prawn and chelwa fish is due to the difference in effective diffusivity and shown in Table 2.2. The drying rates of the samples are higher at the beginning of the drying process and decreased with decreasing moisture content [3,4]. The relationship between drying time and moisture ratio during the open sun drying process is shown as Figure 2.2:

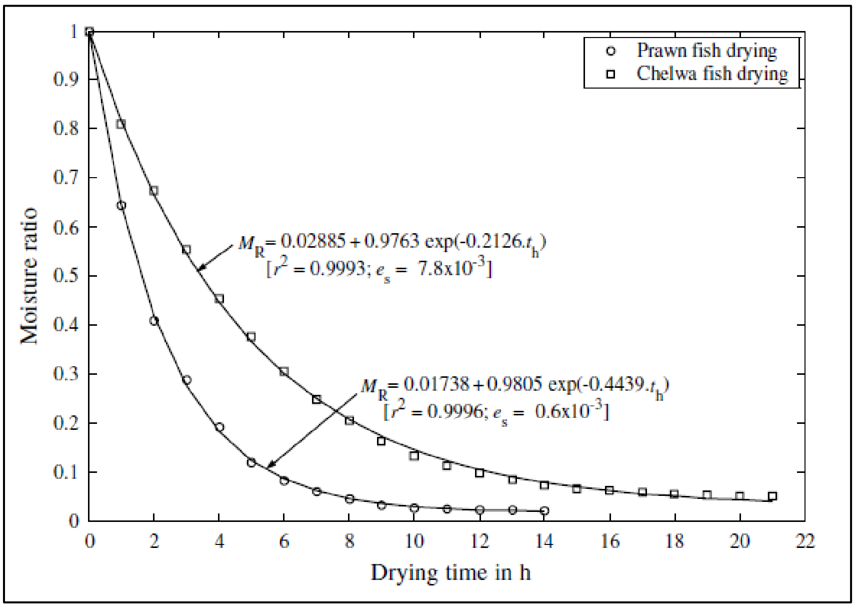

Figure 2.2: Relationship between drying time and moisture ratio of chelwa fish and prawn during open sun drying process [4]

Table 2.2: The effective diffusivity of prawn and chelwa fish [4]

Samples	Effective Diffusivity (m³/s)
Prawn	11.11×10^{-11}
Chelwa fish	8.708×10^{-11}

Instead of implementing preservation process by using open sun only, salt also can be an additional element to make the preservation of fish much more better [5]. This study has been conducted at Sri Lanka as this production is one of their important markets in marine products [5]. The aim of the study was to determine the use of combination of salts and spices to produce salted dried fish [5]. The drying process was carried out by using hot air dehydrator for 17 hours with temperature of 65-70˚C until the moisture of the fish dropped to 12%. There are five treatment parameters used for the fish sample which are 0% salt (T1), 5% salt (T2), 10% salt (T3), 1% salt with spices (0.2% turmeric, 0.5% chilli, and 0.5% pepper) (T4), and 2% salt with spices (0.2% turmeric, 0.2% chilli, and 0.2% pepper) (T5) [5]. These samples are then fried at temperature of 160-180˚C in cooking oil for two minutes for the purpose of sensory evaluation. The criteria for each sample such as colour, odour, texture, taste, appearance, and overall acceptability have been evaluated by the panellist [5]. The evaluation scale is shown as Figure 2.3:

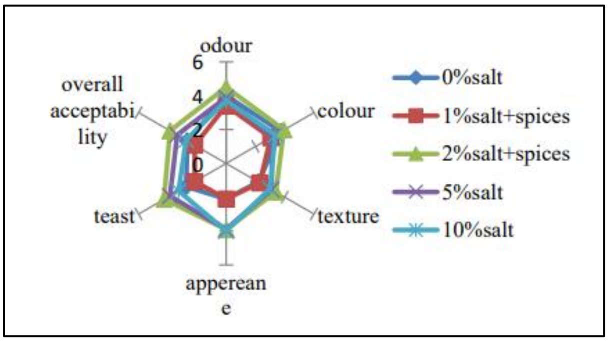

Figure 2.3: The sensory score for each fish sample treatment [5]

From Figure 2.3, it is observed that the sample treatment T5 (2% salt with spices) has the highest score followed by treatment T2 (5% salt). Between these treatments, the researchers had decided that the treatment T2 sample is the best among other samples [5]. This is because the T2 sample has preferable microbial attributes with aerobic plate count of 140 per gram and yeast and mould count of 1330 per gram whereas T5 has uncountable of yeast and mould count. The uncountable count of yeast and mould may cause from the contamination of spices used for the treatment [5]. 5% salt added sample also can be indicated as the best method to be used in dried fish production as the salt content for the dried fish is falls below the accepted maximum salt content preferred by Sri Lanka Standard (SLS) which is 12% of salt for dry basis samples [5].

From all the experiment conducted from [3], [4], and [5] that have been reviewed in this section, some of the methods can be applied in this project such as the drying time of the fish as mentioned in [3] and [4]. The drying time can be reduced by increasing the heat so that the moisture diffusivity of the fish can be increased together. This can lead to high production of dried catfish which can fulfil the demand from the customers.

2.3 DRYING HOUSE

Drying house is a building that uses heat as an element for drying process. The process can be done either naturally by implementing renewable energy such as the Sun or by using equipment like an oven to dry the product until it achieves the requirement level of dried product. For example, the requirement level of dried fish is about 12% [5]. The drying house is not only can be implemented for marine products only, but it can be used to dry certain type of vegetables such as cabbage, lettuce, and rhubarb [6]. The implementation of drying house especially in this project is to reduce the operating cost by using renewable energy and to increase the production of dried catfish. The studies and developments about the drying house have been made by some researchers from other countries. The review from the past project is explained in this section.

In order to make the drying house more effective, various researchers have studied the operation in the house. Some of researchers proposed that by making small-scaled drying house, the losses of solar fraction through the drying house wall is the most prominent loss [7]. As described in [8], the greenhouse dryer is classified into two types of structure which are dome shape and roof even shape. The dome shape drying house is used to maximize the utilization of solar radiation whereas the roof even shape drying house is used for the proper air mixing inside the house [8]. The structure of dome shaped and roof even shaped drying house are shown as Figure 2.4 and Figure 2.5.

Figure 2.4: Dome shaped drying house [9]

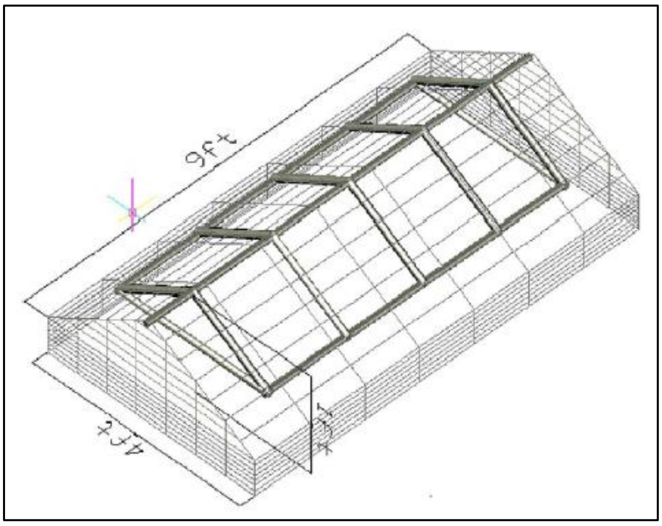

Figure 2.5: Roof even type drying house [10]

However, both types of solar drying house can be operated in either passive or active mode [8]. The passive mode is works when there is ventilation at the rooftop or the chimney of the drying house where the humid air can be removed by ventilator of exhaust fan inside the house [8]. The mechanism of natural convection mode (passive mode) is started by the movement of air from outside into the drying house at the bottom side and flows out from the opening of the rooftop. The mechanism can be shown as Figure 2.6 in a schematic view.

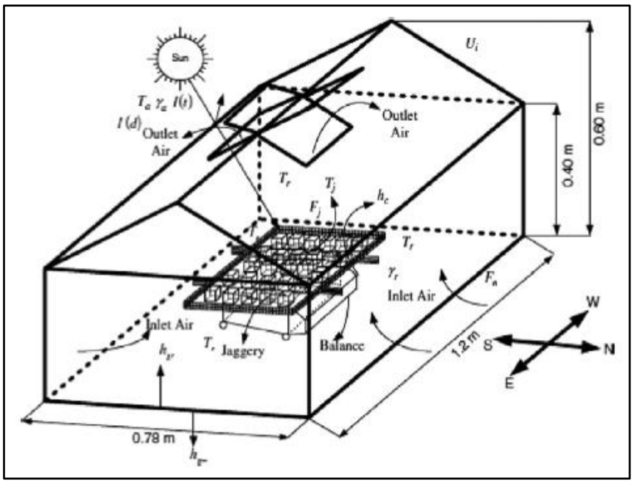

Figure 2.6: Schematic view of greenhouse dryer under passive mode [8]

For active mode (forced-convection) drying house, there are two factors that must be considered which are the air saturation deficit and the incident global solar radiation [8]. The air saturation deficit is known as the humidity index which is characterized by the difference between the saturation vapour pressure and the actual vapour pressure of a volume of air [11]. The air saturation is dependent to the temperature where the saturation will increase with temperature [11]. In this mode, two new concepts are proposed which are the generalized drying curve and the dryer performance curve. By improving the drying potential, the results show that the drying house with double platform is more efficient than single platform with the same area [8]. The double platform drying house is shown as Figure 2.7.

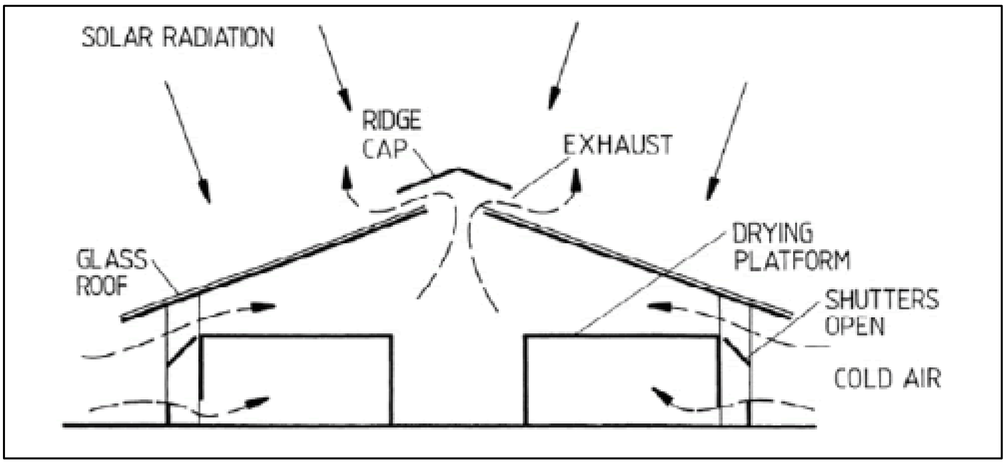

Figure 2.7: Double platform drying house [12]

From the review, most of the researchers in [8] and [10] found that the drying house with active mode is more efficient that the passive mode. The experimental results in [10] reveal that drying house operating in active mode is better than passive mode; forced-convection (active mode) is suitable for high moisture content crops while natural-convection (passive mode) is suitable for low moisture content crops [8].

In this project, the active mode drying house is implemented with some different concepts. As the drying house is built without any ventilation, dehumidifier and gas heater are proposed in order to absorb the air moisture and to increase the temperature inside the house until the optimum condition is achieved.

2.4 SYSTEM REQUIREMENT

System requirement is essential in order to monitor and control the condition in the drying house. This is because the condition inside the drying house is inappropriate for human beings for a long time. As the building can absorb the direct solar radiation from the sun, the temperature will rise rapidly. This condition causes the building become too hot. Therefore, this project is introduced to monitor and automatically control the environment inside the drying house. There are some requirements for the system development. Further reviews for the requirements are explained in the following subheadings.

2.4.1 MICROCONTROLLER

Microcontroller is the heart for the system where it can be used to develop a control or monitoring system as some projects has utilizing such hardware to monitor the condition in a building. There are some previous projects uses the microcontroller especially Raspberry Pi microcontroller as it is low in cost, maintenance and energy consumption [13]. Such hardware also can be used for variety of applications such as environmental monitoring system.

From previous research, Raspberry Pi (RPi) microcontroller has been used for development of environmental monitoring wireless sensor network system [14]. The system architecture includes a base station by using RPi microcontroller and sensor nodes. The sensor node consists of RHT03 temperature and humidity sensor, a microcontroller (Arduino), and ZigBee radio transceiver [14]. The sensor node component is shown as Figure 2.8. RPi was used in the base station as it can be used for connection to a local network area (LAN) through Ethernet cable or USB WiFi adapter, and can be directly accessed to SSH remote login [14]. The base station is connected to the XBee coordinator module through USB cable and USB-to-UART serial converter circuit. This is necessary for the functioning of the gateway application which programmed in Python of RPi [14]. The gateway application sends out the configuration and commands for data collection to the sensor nodes and records the data received from the nodes into the database [14]. Then, the web application is built so that the users can access the web interface. The web interface is used to visualize the data from the sensor node in the form of static and dynamic real time display [14]. The web interface display of the wireless sensor network system is shown in Figure 2.9.

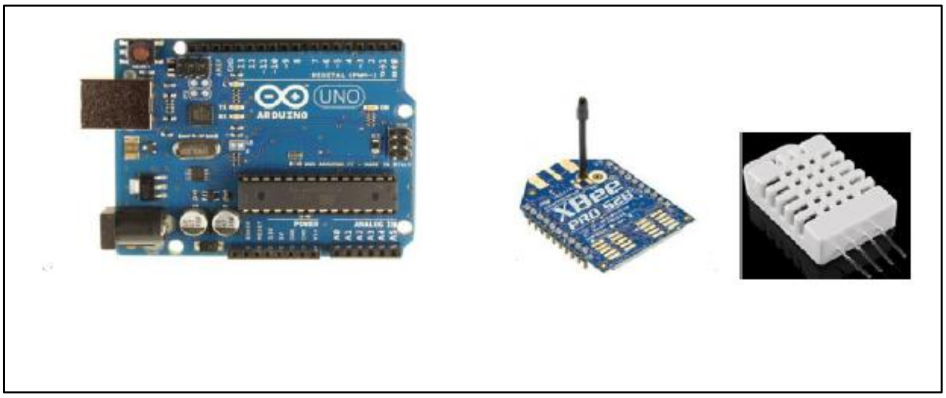

Figure 2.8: Sensor node components [14]

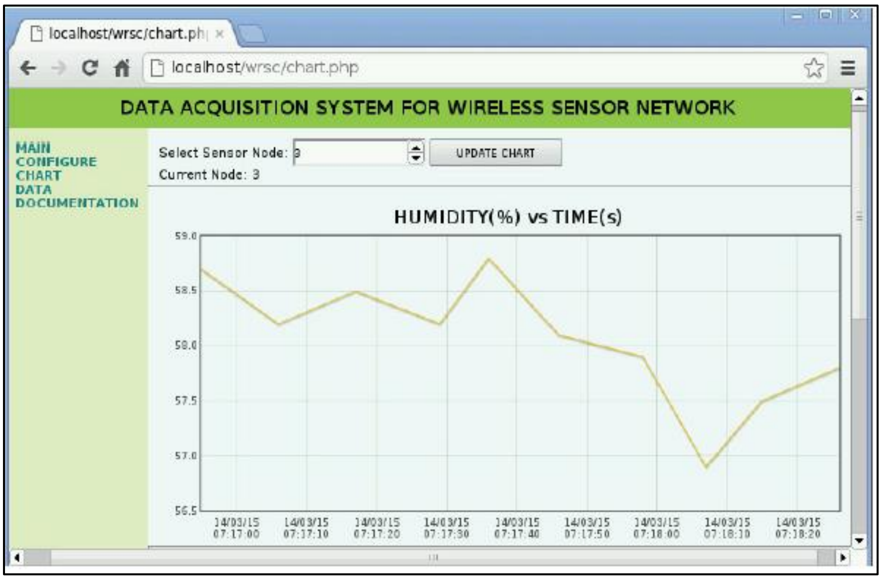

Figure 2.9: Web interface display of the wireless sensor network system [14]

Another study about the application of RPi microcontroller had been conducted for building monitoring system (BMS). The aim of this project is to reduce the maintenance and operating cost and provide user friendly experience with the data sharing [13]. The BMS proposed architecture is almost the same as proposed in [14], but there is a different in the sensor node from both applications. The application in [13] provide sensor nodes with the combination of sensors and a processing module to convert the sensor data from analog to digital data by using analog-to-digital converter (ADC) whereas the application in [14] provide sensor nodes with combination of sensors and Arduino microcontroller. However, both applications give same approach which is to convert the sensor data to metric unit format for user convenience [13].

The application using RPi microcontroller in monitoring system is better than using conventional system. The conventional system utilizes the power cables for laptops and personal computers which can lead to huge power consumption for the data collection and analysis purposes [13]. The differences between conventional monitoring system and the proposed monitoring system are shown in Table 2.3. In order to implement the Internet of Things (IoT) concepts, the proposed application in [13] and [14] are appropriate as all devices include sensors, actuators, smartphones, laptops and so on are connected each other for better relying of data.

Table 2.3: Comparison between conventional monitoring and proposed monitoring system [13]

Resources	Conventional Monitoring System	Proposed Monitoring System
Processor	Dedicated high cost Servers	Low cost Raspberry Pi
Controller	Dedicated Controller-Not inter-operable	Single-Controller-Interoperable
Display	Need a dedicated LCD or Screen for monitoring	Can be monitored using any laptop/mobile
Software	Licensed	Fully open licensed (free)
System Type	Occupy huge work space	Plug and Play (can be fit in wall)
Approximate Price	Average system costs RM2600 minimum	Average costs RM400

2.4.2 TEMPERATURE

Temperature is one of the important parameters that need to be considered for the fish drying process. It plays an important role in this project as it can measure the thermal condition inside the drying house. Temperature is also one of the parameters that can be controlled by using a microcontroller [15] where the temperature sensor must be integrated to the microcontroller so that the temperature reading can be recorded and can be used for the thermal controlling purpose. In order to achieve optimum thermal condition inside the drying house, heating system must be introduced to make temperature changes [16]. The heating system can be operated as the threshold value of the temperature is set at the optimum level. When the temperature inside the drying house is below the lower threshold value, T_L heating process can be started by the heating system with a constant thermal power until the temperature has reached the upper threshold value, T_H [16].

A study has been conducted to control the parameters include temperature inside an orbital motion shaker. To obtain the temperature reading, LM35 temperature sensor is used in the project [15]. The sensor is connected to the microcontroller so that the current data from the sensor can be used to compare with the set point (SP) value inserted by the user. The system can be operated in three mode selection; manual, programming, and maintenance mode [15]. For manual and programming mode, the SP value must be inserted in order to compare with the current data from the sensor. Whenever the SP value is greater than the sensor data, the heating system will be activated to heat up the environment inside the motion shaker. Whenever the SP value is lower than the sensor data, the cooling system will be activated to cool down the environment until it achieves the optimum condition. The working system flowchart is shown as Figure 2.10.

In this project, the temperature used is DHT22 temperature and humidity sensor. This sensor is capable to work in a harsh condition which is between -4˚C and 125˚C [17] as the condition inside the drying house is too hot at the midday. It is also can be used for long transmission distance with low power consumption between 3.3V to 6V DC [17].

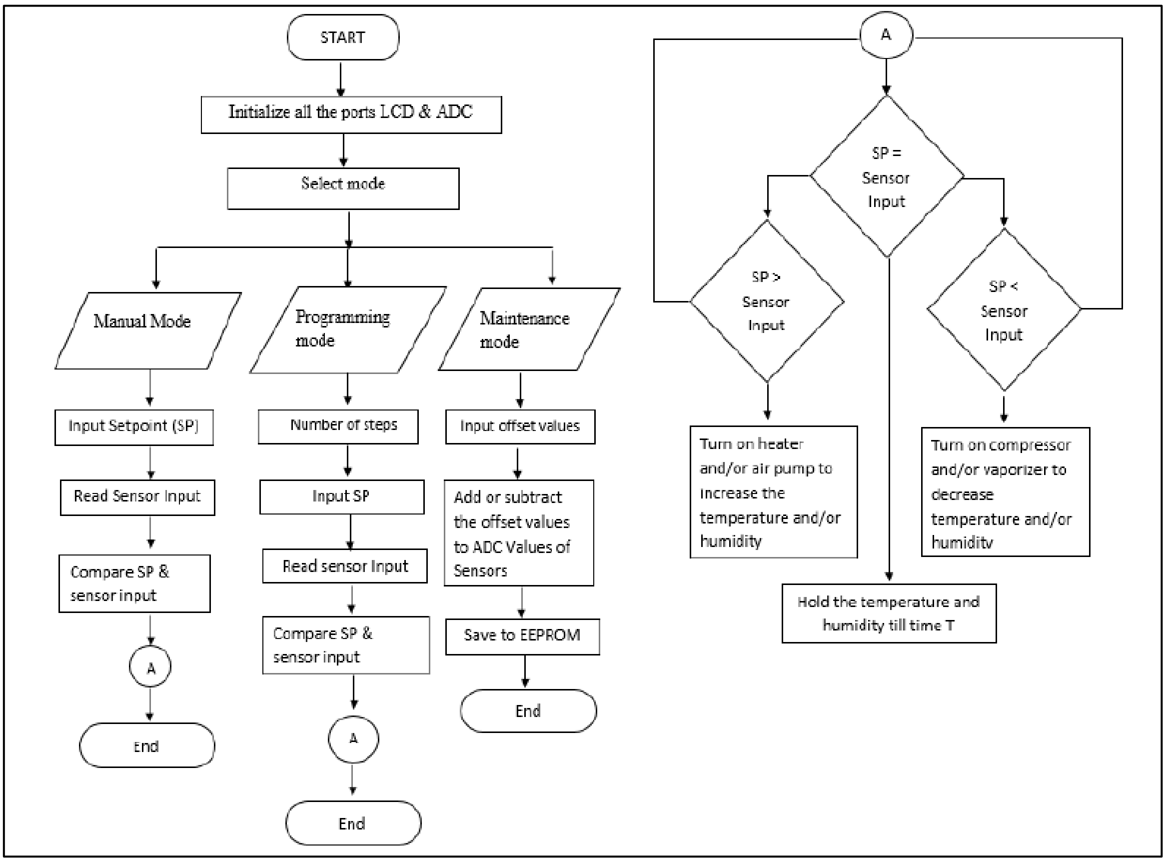

Figure 2.10: The flowchart of working system of an orbital motion shaker [15]

2.4.3 HUMIDITY

Humidity is a percentage of water vapour content in the room air relative to the total amount of vapour in the same room air may contain at given temperature [18]. Humidity is another parameter used after temperature for determining the indoor thermal condition in a building [19,20]. This is because both parameters are the dependent variables which can affect the amount of energy consumption in buildings [19]. The humidity reading in a building can be recorded by using sensors or thermal-hygrometers [19] and at same position with the temperature sensor [20]. It can be maintained at appropriate levels by optimizing the heating systems and carefully selected building materials and construction blocks [20]. The fluctuation of humidity is due to the human activities [20] such as breathing. For a building that have no human activities such as drying house, the fluctuation of humidity can be influenced by the material of the building itself. For example, researchers in [20] reported that hygroscopic materials can reduce the amplitude of humidity by up to 40%.

A study about the effect of relative humidity has been conducted on microwave drying of carrot. From the study, it is reported that the humidity can be controlled by means of different air flow rates during the drying process in the microwave [21]. The purpose of air flow is to evacuate out the humidity in the microwave. The different air flow rates affect the drying time where low flow rate causes the drying time longer compared to high flow rate [21]. The relationship between the different flow rate and the relative humidity can be illustrated in Figure 2.11. This study also consider about the relationship between the drying rate and the relative humidity where the result showed that when the sample is heated up to 70°C in the microwave, the relative humidity increases rapidly as the moisture content in the sample is evaporated [21]. This can lead to the decreasing in moisture ratio in the sample. The moisture ratio also is influenced by the air flows where the results showed that the drying time is reduced when the high air flow rate is implemented and the longer drying time when low air flow rate is implemented. The relationship of the moisture ratio and the drying time can be shown in Figure 2.12.

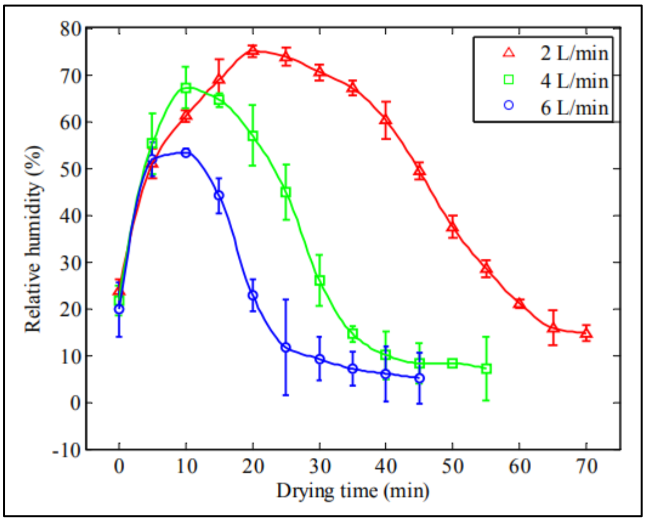

Figure 2.11: Relationship between drying time and relative humidity [21]

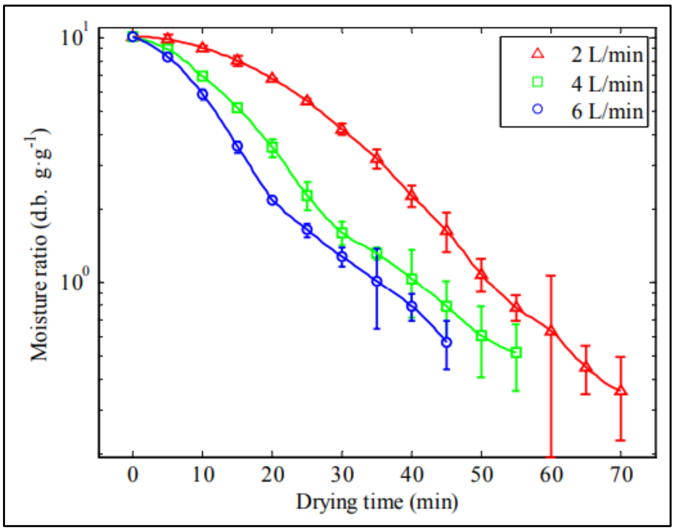

Figure 2.12: Relationship between moisture ratio and drying time [21]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discuss the procedures and system design that have been implemented in this project. The flow of the project, the components used, software development, and the experimental setup will be fully explained in this chapter.

3.2 PROJECT PLANNING

Project planning is essential in this project in order to manage the flow of the project. This is important to ensure the project flows smoothly. Figure 3.1 illustrates the process flowchart. The illustration also shows the steps that have been taken in order to complete this project.

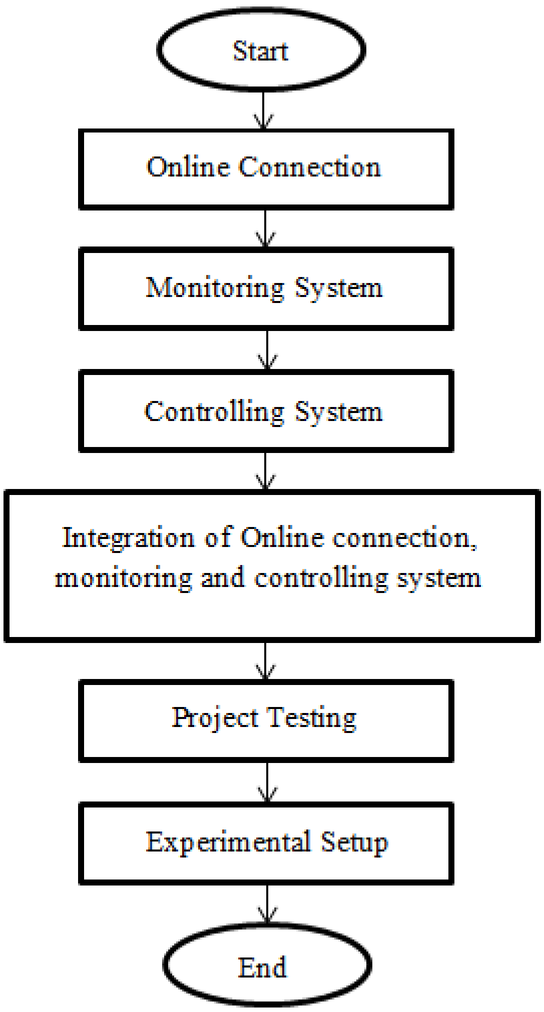

Figure 3.1: Project Process Flowchart

3.3 ONLINE CONNECTION

This project implements the online connection between the microcontroller itself which is RPi, the sensors and the Internet so that all the data recorded can be displayed in the form of graph. The online connection is essential for both monitoring and controlling the condition inside the drying house. Figure 3.2 shows the connection occurs between RPi, the sensors, equipment used, and the Internet.

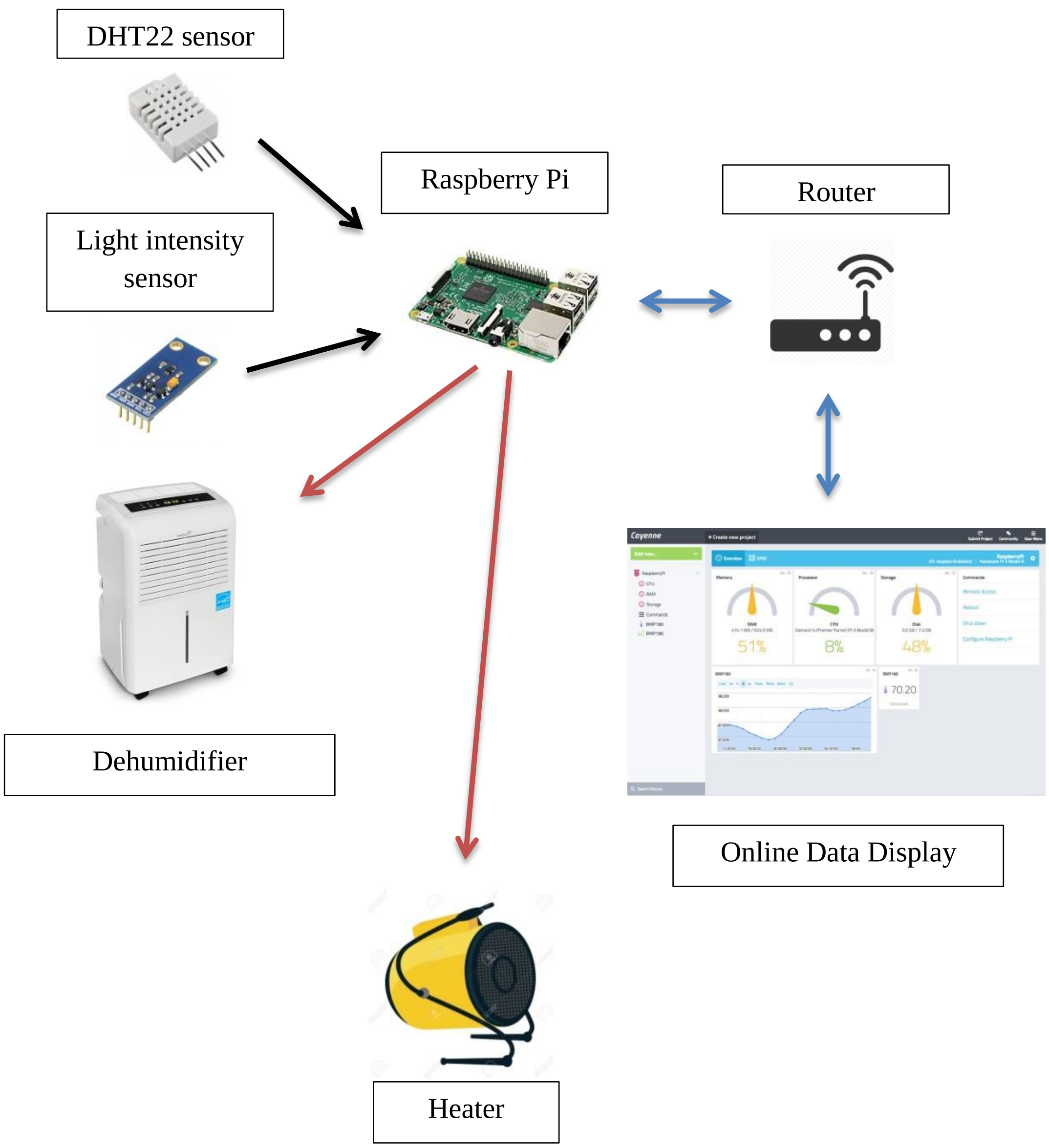

Figure 3.2: Connections between sensors, microcontroller, Internet and equipment

Before the connection can be implemented, the router must be operated primarily because it is acts as the bridge for the connection between the Internet and the microcontroller and the data display via online. The data display can be obtained by registering the *Cayenne* application account. Then, the application can be implemented by connecting to the RPi via online connection. Before this happen, there are some steps must be done in order to make the router to be operated. These steps are for activating the SIM card for data service from the local network service provider, OneXOX. The reason to implement the wireless connection instead of wired connection from local network service is because the drying house is located at the region where there is no Internet cable connection. The account registration to OneXOX must be done by signing up new account via the website https://selfcare.xox.com.my/SelfCare/Registration. Figure 3.3 shows the display from the website.

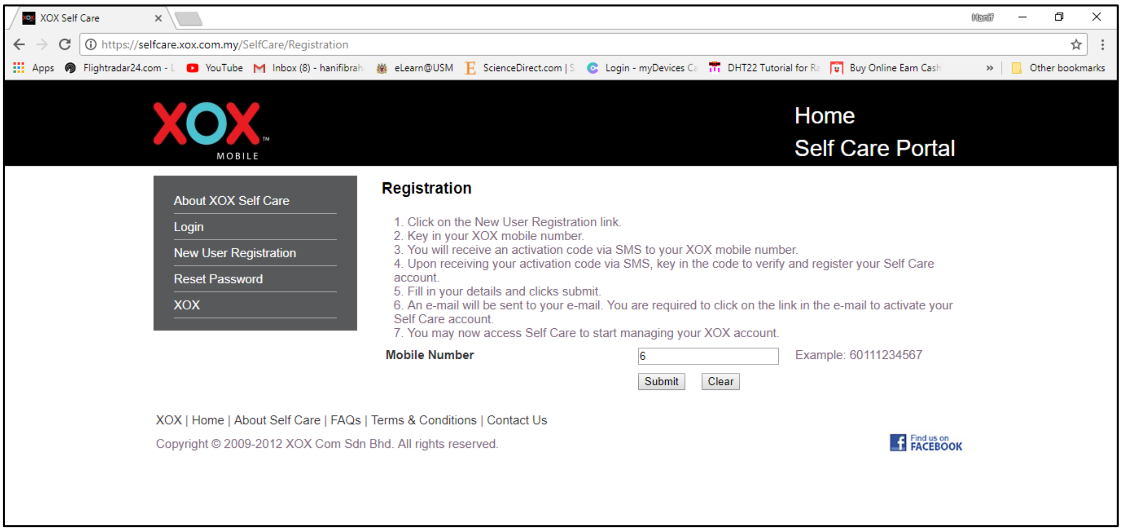

Figure 3.3: OneXOX online registration

By registering the mobile number, the account will be activated by the service provider. Next, an email and password must be included during the registration for login purpose. The email address and password for this account are kelipedu@gmail.com and *kelipedu2017* respectively. The account also can be login by using its Android application via smartphone. Figure 3.4 shows the display in Android application once the login is successful.

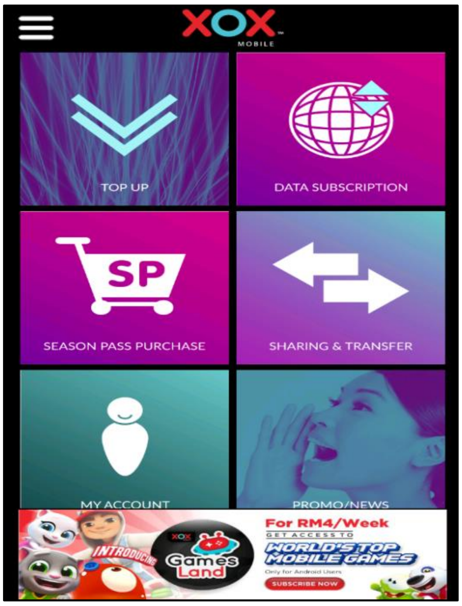

Figure 3.4: OneXOX Android application home display

By clicking the *Data Subscription* tab from the application, the subscription, upgrade plan, and additional data can be done. For new subscription, there are some of data plan available in the network service and the user must choose only one of the data plan. Once the data has been subscribed, the SIM card can be plugged into the WiFi router. The router used in this project is shown in Figure 3.5.

Figure 3.5: WiFi router used for Internet connection

To make an Internet connection with RPi, the network icon (red circle) as shown in Figure 3.6 must be clicked so that the network available can be seen. If the RPi is connected to the network, the network connected will be appeared at the top of the display with a green tick at the left side. This can be illustrated in Figure 3.7 where the connection of RPi and the WiFi router is successful.

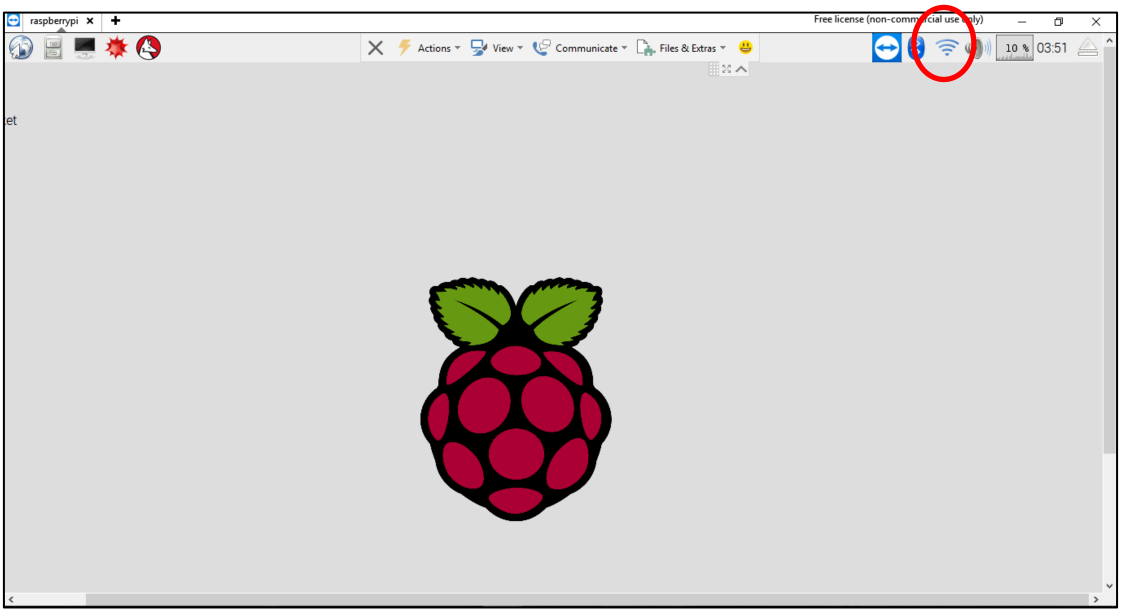

Figure 3.6: RPi home display

Figure 3.7: Connected network (RPi and WiFi router) and other available networks

As RPi is successfully connected to the WiFi router and the Internet, it can be linked together with *Cayenne* application via smartphone or desktop version. Before that, Cayenne MQTT Python Library must be installed by running commands using LXTerminal as shown in Figure 3.8. This library functions to connect the RPi and *Cayenne* easily. The library can be installed by writing the command into LXTerminal: *sudo pip install cayenne-mqtt*. It is also can be installed by using the repositories by writing to LXTerminal as shown below:

git clone https://github.com/myDevicesIoT/Cayenne-MQTT-Python
cd Cayenne-MQTT-Python
sudo python setup.py install

After that, a new *Cayenne* account must be created before the integration with RPi can be done. Once the account has been created, new device must be added by clicking *Add New* > *Device/Widget* > *Raspberry Pi* tab. The connection can be done by clicking *Raspberry Pi* > *Continue* > *Advanced Discovery Settings* tab and inserting the RPi Internet Protocol (IP) address as shown in Figure 3.9. The IP address must be inserted without the two digits number after stroke (/) sign as illustrated in Figure 3.10. Once the connection is successful, the details of RPi such as the Random Access Memory (RAM) used, the processor, remaining storage, network speed, and central processing unit (CPU) temperature will be displayed in the form of analog output (meter gauge). Figure 3.11 shows the display of the RPi details. As all steps are done, the other sections which are monitoring and controlling system can be implemented.

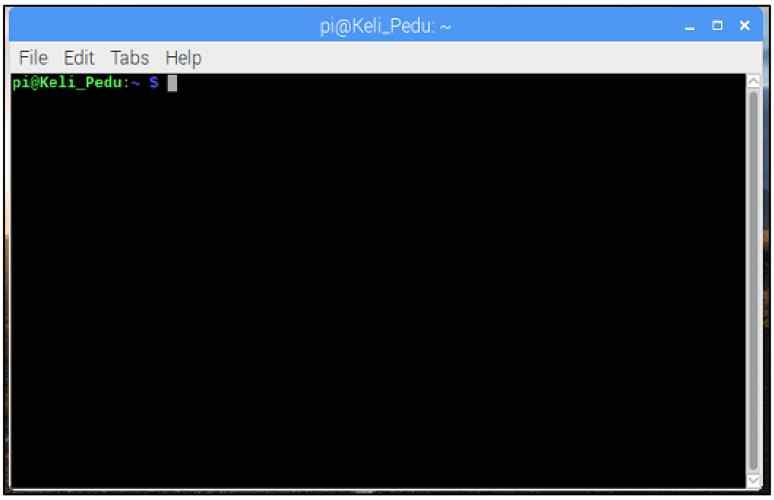

Figure 3.8: LXTerminal used for installing Cayenne MQTT Python Library

Figure 3.9: Advanced Discovery in *Cayenne* Android application

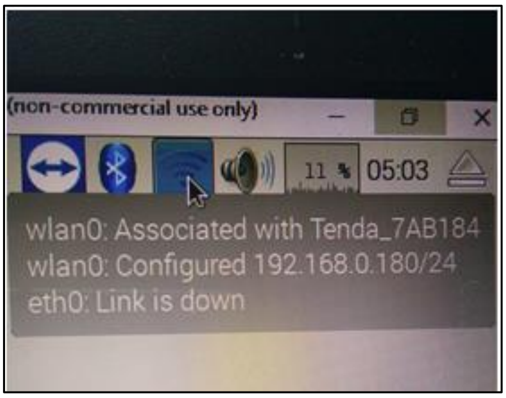

Figure 3.10: Configured IP address with WiFi router

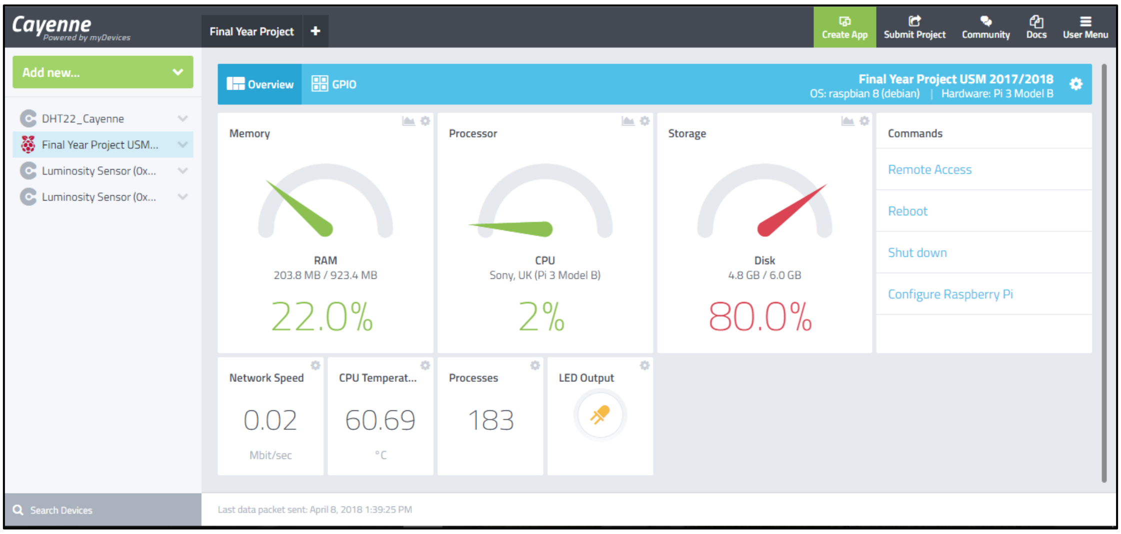

Figure 3.11: Cayenne application desktop display