DESIGN AND DEVELOPMENT OF A WIRELESS INDOOR SMART ENERGY SAVING AND MONITORING SYSTEM

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ABSTRAK

Sistem Pintar atau Automasi Rumah telah menjadi terkenal dan pelbagai teknologi yang baharu. Sesetengah Sistem Pintar yang telah berubah mempunyai kualiti yang lebih baik dan pasaran yang hangat. Pengubahsuaian pada bangunan di tempat kerja sedia ada ialah satu idea dan cara untuk memudahkan Sistem Pintar digunakan di mana-mana tempat terutamanya di Malaysia. Penyelidikan ini menerangkan sistem yang berubah menjadi suasana tempat kerja yang lebih pintar. Sistem Pintar yang deperkenalkan ini boleh menyimpan tenaga. Kini, melalui analisis trend menunjukkan kegunaan bekalan elektrik semakin meningkat pada masyarakat ini. Isu kehilangan tenaga telah menjadi topik yang hangat. Selain itu, bahawa isu tersebut akan membawa impak yang besar dalam perhargaan elektrik yang meningkat serta kasilan kuasa yang menurun. Para pengguna tidak tahu sebab kehilangan tenaga. Dalam penyelidikan ini, sistem ini boleh mengurangkan pembaziran penggunaan kuasa di kawasan tempat kerja. Selain itu, sistem tersebut juga digunakan untuk mengawasi dan menganalisis kegunaan di setiap bilik pejabat di kawasan tempat kerja. Kebanyakan pengguna mencadangkan cara untuk mengubahsuai bangunan yang telah diwujudkan berbanding dengan membina bangunan yang baharu. Cara pengubahsuaian bangunan yang telah diwujudkan memerlukan kos yang lebih rendah dan mempunyai kualiti yang sama berbanding dengan bangunan yang baharu. Sesetengah pelengkapan asas yang berkos rendah dan mudah didapati telah digunakan untuk menghasilkan sistem tersebut supaya sistem ini dapat memaksimumkan penjimatan tenaga dengan kos yang paling minimum dalam kawasan tempat kerja. Pelbagai alatan yang digunakan termasuk alat pengawal yang diprogramkan, modul gabungan penerima dan pemancar, suis pengganti, sensor, dan lain-lain lagi untuk membina sistem tersebut. Sistem ini akan mengawal operasi peralatan elektrik yang berada di dalam tempat kerja. Sistem ini juga dibina dengan automasi dan tanpa wayar. Dalam konsep ini, sistem tersebut akan menghidupkan peralatan elektrik secara automatik jika ada sesiapa berada di dalam bilik pejabat. Sistem ini juga akan menutup peralatan elektrik jika tiada sesiapa di dalam bilik pejabat. Tambahan lagi, sistem ini mudah dialihkan ke mana-mana tempat. Konsep ini dapat menjimatkan tenaga di kawasan tempat kerja. Bahagian sistem pengawalan memainkan peranan yang penting untuk mengawasi suasana setiap bilik di kawasan tempat kerja dan juga mengawasi kehadiran setiap staf pada setiap masa. Sistem ini mempunyai teknologi yang canggih dan maju berbanding dengan sistem yang telah diwujudkan di pasaran. Di samping itu, sistem ini juga boleh membuat analisis data berkaitan dengan masa kerja setiap hari. Melalui analisis data sistem ini juga boleh menunjukkan perbezaan sebelum dan selepas digunakan di kawasan tempat kerja. Dalam keputusan perbandingan yang ditunjukan, aplikasi sistem amat sesuai digunakan di kawasan tempat kerja. Perkara yang harus diperhatikan semasa memasang sistem ini adalah lokasi yang sesuai, identiti pengguna yang sesuai, dan juga jangka masa untuk menggunakan sistem tersebut. Akhir sekali, dalam keputusan sistem ini, jumlah tenaga yang digunakan telah menurun. Sebagai contoh, jumlah tenaga yang digunakan di dewan telah berkurang sebanyak 18kWh. Sistem ini dapat menjimatkan 50%. Keputusan ini telah membuktikan system ini sesuai dan boleh digunakan oleh para pengguna di kawasan tempat kerja. Justeru, sistem ini telah mendapat pengiktirafan ramai dan mempunyai permintaan yang tinggi di dalam pasaran bagi menjadikan kehidupan manusia menjadi lebih selesa dengan menggunakan sistem yang berkos rendah dan kehidupan yang berkualiti.

ABSTRACT

Smart Homes or Home Automation becomes famous and different new technology begins to emerge recently. A number of improvements make Smart Home better quality and marketed to the public. To allow the Smart Home system more reliable to any places, modification of an existing work building becomes an idea in the society especially in Malaysia. This research describes a system to convert a conventional into an intelligent working area. A Smart System is introduced to reserve energy. Nowadays, the trends show that highly demand electricity in the society. The issue of rapid energy losses has been discussed around the corner. Energy losses bring the impact of soaring prices of electricity and power production reduces. All the consumers have no idea about the reasons of energy losses. In this research, the design of a wireless and reliable indoor smart power saving system is to minimize the energy losses for the work stations area. Not only have that, the system is able to monitor and analyse the power consumption specialised in each of sections in work building. Modification of an existing work building is highly recommended compare to rebuild a building. The cost is lower if apply a system in existing building and brings out an equivalent standard compare to a new building. Some basic equipment which easily to get and purchased with a lower price to produce the system and apply in the work area, to minimize the cost using and maximize the energy saving. A variety of equipment are used include a programmable controller, transceiver module, relay switches, sensors and others to build up the system. The system will control the operation of electrical appliances in work building based on the conditions of offices. The system works also in fully automated and wireless. When there is someone in the office room, the system will turn ON the appliances immediately. However, when there is no one in the office after certain time, the system will turn OFF the appliances. On top of that, the system is portable to use in anywhere. This concept brings the conveniences and easily to save the energy in any work building. The Monitoring System plays a role to monitor the condition of every office room in work building. This monitoring concept is able to detect the occupancy of the staff in real time during working hours. This shows that the valuable and more advances compare to the technology already in market in this research. Moreover, the system will make data analysis according to the results collected in daily working hour. The data analysis will shows the different between before and after the system is applied in work area. From the comparison results, the application of Smart Energy Saving and Monitoring System is reliable to be placed in work area. The requirement to install the system is according to different locations, different identity of user and the period of using the system. Lastly, the results showed that the total energy used was reduced. For example, the total energy used in lecturer hall had reduced 18kWh. A higher percentage of total energy estimated saves up to 50% was showed after the system was applied. The results proved that the system is applicable and reliable to the user in work area. Thus, this system takes into account the architecture of human cognition and it is highly demand in market to achieve a lower energy usage at the same with high quality and comfortable life.

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LIST OF SYMBOLS

GWh	Giga-watt hours
J	Joules
kWh	Kilowatt hours
TWh	Terawatt hours
W/m^2K	U-value

LIST OF ABBREVIATIONS

AC	Alternating Current
ASEAN	Association of Southeast Asian Nations
CO_2	Carbon dioxide
DC	Direct Current
ECHO IV	4th Electronic Computing Home Operator
EHR	Electronic health record
ESP	Enforced Sub Populations algorithm
GHG	Greenhouse gas
GSM	Global System for Mobile Communications
IDTV	Interactive Digital TV
IEA	International Energy Agency
IHU	Intelligent hardware units
IoT	Internet of Things
LCEA	Life cycle energy assessment
MHP	Multimedia Home Platform
OAP	Open Access Plan
OSGi	Open Source Gateway Initiative
OWL	Ontology Web Language
OWL-OS	OWL-OSGi
PIR	Passive Infra-Red
PLC	Programmable Logic Controller
PMV	Present Market Value
RF	Radio Frequency
RIDE	Robotics Integrated Development Environment
SHEMS	Smart Home Energy Management System
SI	International System of Units
SMS	Short Messaging System
SPI	Serial Peripheral Interface
WHAS	Wireless Home Automation System

CHAPTER 1

INTRODUCTION

1.1. Background of Research

It is well known system that some of household features, activities and appliances are function automatically and control by electronic, called as home automation or Smart Home. The first smart homes were ideas but not in actual structures. The actual smart homes were only introduced a short while although the idea of home automation has been around for some time. In the early 19th century era (1900-1945), before the home appliances are being "smart", the incredible achievement of home appliances was first engine-powered vacuum cleaner in 1901. After two decades, the coming inventions followed by refrigerators, clothes dryers, washing machines, irons, toasters and others. In the middle age of that century, ECHO IV was the first smart home device which is able to compute shopping lists, to control the temperature at home and to turn appliances ON and OFF. In the late 19th century era, Gerontechnology had been proposed which combines gerontology and technology to improve the life of older person. In the early of 20th century, Smart Homes or Home Automation has becoming famous and different technologies began to emerge. Smart Homes became a more affordable option for the consumers based on the viable technology. Nowadays Smart Homes are sustained and able to avoid expending unnecessary energy. Current trends in Home Automation include remote controlling, automated home appliances, scheduling appliances, mobile/email/text notifications, and others. In this residential extension of building automation, various control systems are utilized. A number of improvements make Smart Homes famous and marketed to the public, including better security, organization, energy conservation and the overall achievement of an easier life. It is easy how a Smart Home might be particularly attractive for every busy family, or a solitary Open Access Plan (OAP) with

complicated medical needs to provide health care. The Figure1.1 has shown the statistic of market size of the smart home market worldwide from 2016 to 2022. The source forecasts the global smart home market to grow to around 40.9 billion U.S. dollars in 2020(Friedrich Schwandt, 2018).

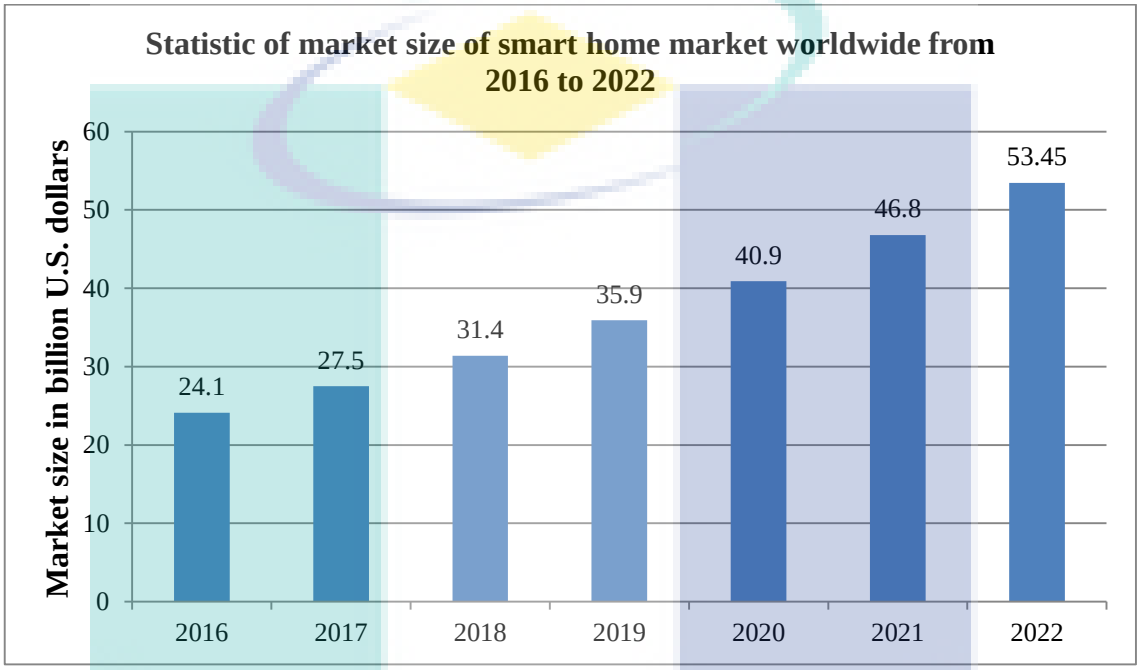


Figure 1.1 Statistic of market size of smart home market worldwide from 2016 to 2022

Source: Friedrich Schwandt (2018)

Smart home allows to control and monitor different devices in the home, including the heating, lighting, security, and entertainment, automatically and sometimes remotely via the Internet (Eun-young, 2017). The system drives two ways automatically either via the existing electrical wiring of the house, or using a wireless network. A well-designed smart home system consists of fundamental components include a computer (Lee, Kwon, Lee, & Kim, 2017) with the appropriate programming, the various devices and systems to be controlled, interconnecting cables or wireless links, a high-speed Internet connection, and an emergency backup power source for the computer, its peripherals, and the essential home systems. According to the news in AsiaToday, smart home market, related products and investments are growing rapidly and are being made actively in Asia. It has more than a decade to have a smart home

system in developed countries and it will be trends in Asia by 2030 according to the related report.

To make Smart Home system more reliable to any places, a lot of researches are driven to develop better performance, types of controlled equipment and different communication ways. This would make the concept of Smart Home apply in anywhere including work area in building or industry area, especially in Malaysia. According to the South-East Asia Energy Outlook Report (Birol, 2013), Malaysia was the third largest energy consumer in ASEAN region. On top of that, the demand of electricity would projected to double by 2030 and probably increasing further to just over 300THh (terawatt hours) in 2035. Generally, up to 50% of the energy we use is being wasted in worldwide. The vice president and head of Internet of Things at Xchanging (Shankar, 2015) stated that the most effective way to control energy consumption is to reduce wastage and manage how energy is being used especially in building. Buildings are energy guzzlers and require heavy energy supply. Government and private sectors are working on transforming the traditional buildings into 'smart' building with the installation technology of monitors, controls, and automated system to build a comfortable, safe and better environment for the occupants. On top of that, this management gives result in terms of energy efficiency, cost reductions, a lower carbon footprint, a healthier life for occupants, and labour reductions from eliminated manual work on the departments.

A smart building is using automated processes with any structure to automatically control operation in building including heating, ventilation, air conditioning, lighting, security and others (Tracy, 2016). Besides that, smart building is able to collect and manage data, in order to helps owners, operators and facility managers to improve the asset reliability and performance in any business function and services such as reduce energy use and minimize the environmental impact of buildings. In a smart building with integrate operation system equipped with sensors to react and respond to real-time conditions changes, energy consumption is able to reduce up to 30%. There are two ways to develop the smart building, which is to build and integrate smart technology into newer buildings at the point of instruction, or to modify and convert an existing building into smart building with installing additional wiring and devices. However, both of the concepts have the same concept which is to make the buildings connect to a network with intelligent and adaptable software.

According to Navigant Research ("Smart Buildings and Smart Cities," 2017), the smart building technology market will generate the global revenue from $4.7 billion in 2016, up to $8.5 billion in 2020, and the growth rate shows 15.9% over the forecast period. There are several types of smart buildings exist causing the great impact of raising revenue around the world including smart office buildings, health care facilities, hospitals, educational facilities, stadiums and others. Through the smart building technology, it is gives better control over energy consumption in daily operations. For an instance, the employees have forgotten to switch equipment off before they left the office area, the equipment would be switch off either by automatically or by remotely. From this phenomena not only reduce energy consumption, but also decrease carbon emissions which bring cost saving purpose.

1.2. Problem Statements

Recently, the news relates to natural disaster or ecosystem imbalance is spreading widely in the moment. The planet's natural ecosystem had been destroyed and caused the severe impact to us like emission of CO_2 or causing the disaster occur like global warming and haze. Figure 1.2 has shown the total world energy consumption according to International Energy Agency (IEA)(*World Energy Statistics* 2016). This shows that the demand of energy consumption is increasing yearly.

Most citizens already have an idea to make their home becomes more intelligent. This topic is starting to gain awareness in public which around us. Save the planet to be a better place in future start from our action now which is to apply additional methods in people daily housework to decrease the need of energy consumption. One of the good choices to reserve energy is to convert their original home into an intelligent one or known as "Smart Home".

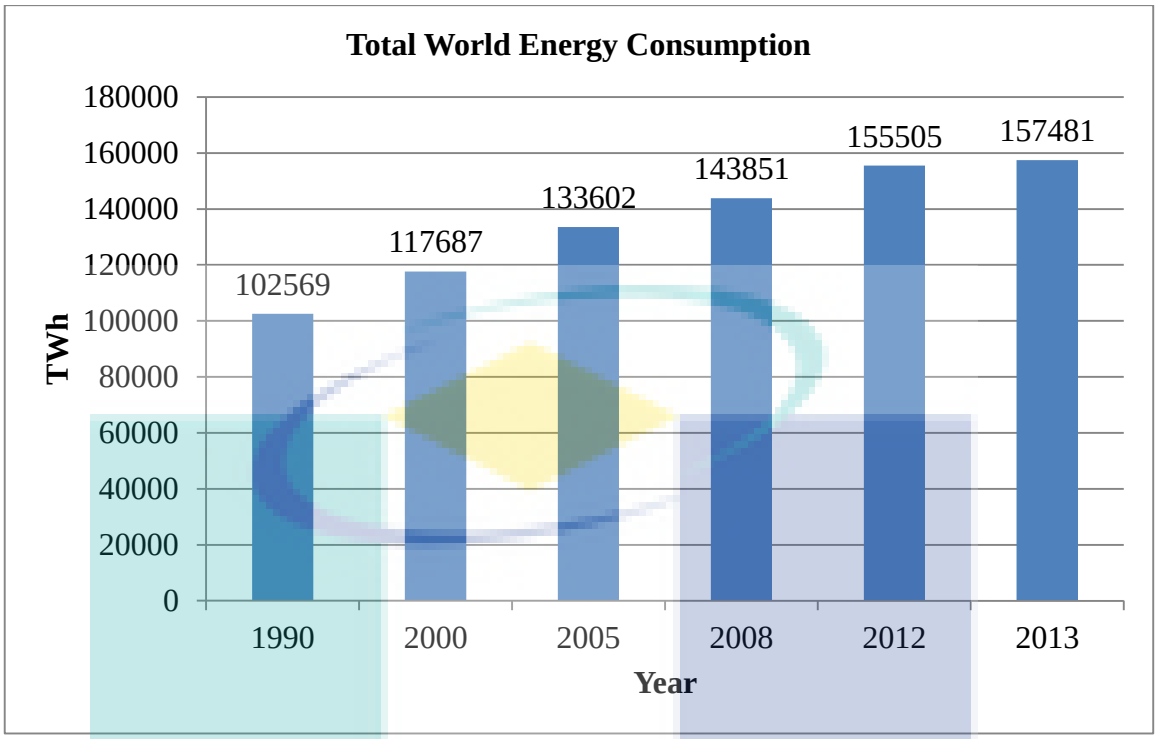


Figure 1.2 Total world energy consumption in different year

Source: International Energy Agency (IEA) *World Energy Statistics* (2016)

Besides than the housing area, generally the buildings in cities around the world are involved approximately 30% of global GHG emissions and 70% of energy consumption. Thus buildings play a role in helping to achieve smart building technologies goals. This technology will bring the changes of facilities management that is able to reduce the wastage of energy consumption for climate and sustainability goals to improve public health and protect the natural resources. Smart building technology is built with the aid of Internet of Things (IoT) technologies to lead the automation and become truly smart in the complex network of smart cities. According to Navigant Research ("Smart Buildings and Smart Cities," 2017), the growth of the global smart buildings for smart cities market is expected from $3.6 billion in 2017 up to $10.2 billion in 2026. This Navigant Research report was provided through an analysis of the market issues, including regional trends, case studies at the city level, and market drivers and barriers to examine how smart buildings market growth encouraged by the smart city agendas and the contribution of smart building technologies to smart city goals.

In the previous research state the reasons and solutions in related issues of energy losses rapidly in nowadays. According to (Abhay Kumar, 2015), one of the reasons causing energy loss is the absence of user in every room and sometimes forget to switch off the light or the electrical equipment. This will bring the wastage of energy resources and creates lots of chaos and tension after accumulate a long period. One of researchers (Joo & Choi, 2017) states that the important for users to reduce their electricity costs and maintain the efficiency of appliances, are the deployment of energy management in work area. It is one of the key solutions to maintain efficient and economical management of the residential and commercial building energy usage of the electricity grid.

Thus, this research is to design and implement a Wireless Indoor Smart Energy Saving and Monitoring System at offices in building. This system is able to solve the problem of highly demand electricity, by minimizing the power consumption in maximum usage, and reduce the power loss to the lowest in building. The principles of the system are working fully automated and fully wireless to control the operations of electricity supply when the user presence in working area. These principles are able to ensure the electricity to be used wisely. Besides that, the user is able to monitor the conditions in every office occupied by staff during the period of working hours. This monitoring method is able to discover out the reasons of highly demand electricity.

1.3. Objectives

1. To design a wireless and reliable indoor smart power saving system and develop the hardware to minimize the energy losses at work station areas.
2. To analyse the power consumption specifically at each office of the work building.

1.4. Significance of Research

Smart energy saving system has greatly increased in popularity over the past several years. This smart energy saving and monitoring system is designed to fit all the conditions for the users and mainly at indoor for the offices in building. Wireless data communication using transceiver module in this system is to achieve a simple connection of the network of micro-controllers and also reduce using wire for a long

distance connection. In addition, it is able to avoid the power dissipated with wires, and it also collects more than one data more precise and high accuracy from the sensor network.

Smart energy saving and monitoring system is functioning fully automated to control the electrical appliances. It can be operated when there is no Internet or Wi-Fi provided because it uses an RF communication in the system to send the signal. It will be easier for the user since it operates automatically anytime without the concern of checking every moment. The principles of this system are set; it will OFF all the switches when sensor detects no one in the work area after 10 minutes, whereas it will ON all the switches when sensor detects someone enter the work area after 5 seconds. The user does not worry if any forgotten for the switching purpose in the work area.

Moreover, this system helps to improve the efficiency of power consumption by reducing the energy usage and also minimized dissipated in daily life. This system only allows consuming power when users have activity in the room of work area and it achieves the concept of energy saving in all the time. For instance, the system only allows consuming power during working hours from 8am till 5pm, and also it will cut the power supply off when detects no one during working hours in the office. In addition, it also helps to reduce the cost of electricity billing and sustain longer life span for the devices in the work area.

The system helps to collect the data for analysis purpose and also to monitor the condition of offices through the monitoring system. Data analysis allows the user to calculate how much of power has been saved in daily activity. The data collected and data shows will display to the user regarding how much of working hour fulfil by every staff time by time.

The design of indoor smart energy saving and monitoring system can be mainly applied in office or other workplaces. It is applicable to a modification of existing building into smart buildings. One of the advantages in this smart system is not only applicable in the office, but it is a portable system which can be easily to be applied at any indoor offices. Moreover, this smart system is easily to use and it is lower cost compare to other existing energy management system. This is a reliable system which consist the function of consuming power efficiently, high quality, to build up the system

with lower cost, and suitable to use in any indoor environment. It is a better choice to have this smart system in any workplaces to save the energy.

1.5. Scope of Research

In this research, the smart energy saving and monitoring system helps to control the power consumption in the work area in building and also prevent energy losses as waste. However, there are some requirements need to be considered in this research. High efficient of energy saving which is more emphasize and suitable to apply in offices in building rather than housing area while install the system. This is because the checking system is mainly apply in working area to prevent any work delay regarding on the attitude of staff and to maintain the high quality of giving output in work. This system has two status which are Active status and Away status. When there is someone is working in the office, it is known as Active status. Conversely, there are two situations for Away status. For the first situation, when there is no one in the office; for the second situation, when the staff in the office has no movement within 10 minutes. For example, the staff is taking nap or sleep during working hours. Additionally, the smart energy saving and monitoring system is built with a concept of fully automated and wireless to avoid any influence of data collected in workplace. This concept build up a more efficient tool to achieve the goal of maximizing the energy saving. The only microcontroller electronic platform used in all the sub-system is using Arduino board as a platform to send the instructions to the microcontroller. Besides that, the distance between all the sub-systems up to 50 meters without any obstacle and up to 40 meters with obstacle. The signals will be transmitted and received in between the sub-system to make operation and analysis data. When install the whole system, every sub-system must be placed in the same floor in a high building to ensure the signals are able to transmit smoothly.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction of Smart Home

Nowadays, issues energy losses rapidly have been became a famous topic to discuss with. According to (Malinauskaite et al., 2017), the society of European has grown wealthier and affordable to spend and grab in everything for personal interested therefore more waste is produced than ever before. The energy consumption is increasing also due to the reasons of the growth of population and rising standards of living over the world. Based on this fact, it shows that high consumption of energy leads to waste increasing generation. On the other hand, (P. V. Krishna, 2017) state that more pressure has put on demand for better provisioning of utility like electricity due to the increased dependency on fusion of heterogeneous technologies, to preserve the over-utilized natural resources energy. Additionally, (S. Misra, 2013) state that the present electricity distribution is been facing challenges due to population increased and also their increased use of energy for various system, even the provided electricity grids that serve consumers have evolved more than 100 years. This cause power consumption by end-users has increased manifold and coupled with the impact of soaring prices of electricity, the reduction in power production, and an ever increasing debt.

The trends of applying smart home have gradually increasing due to the issues related. Based on (Chen & Lin, 2016) state that the related demand and products to perform energy saving is build up a smart home electric energy saving system by combining various of smart devices to check total power consumption information ,and also control energy saving of appliances. Moreover, (Schweizer et al., 2015) found that the method to allow smart homes to autonomously achieve energy savings is to make the usage patterns and preferences of inhabitants can be learned efficiently. A

recommender system based on developed algorithm help users to reduce their energy consumption without reducing their comfort level. Apart from that, a very high chances to enhance energy efficiency and also reduce the actual energy demand to expected with the proper energy management of buildings (Capozzoli et al., 2018). There are a lot of researchers have study about the smart system using different concepts and methods to achieve the same goals. At the same time, the research make improvement and produce more advance for current system become a better quality compare to existing system.

2.2. Energy Saving

Many studies have been conducted by researchers to save energy without any technology applied. One of the authors challenge the widely held view that using green roof technique as current building regulations to affect annual building energy consumption (Castleton H.F., 2010). Green roof is a cooling technique which prevents solar radiation from reaching below building structure and this showed the benefits in winter heating reduction as well as summer cooling. In other words, (Castleton H.F., 2010) emphasizes that the potential of green roofs offer in relation of saving energy and also greatly reduces the proportion of solar radiation. Many studies have been conducted that the green roofs assess the extent of energy savings with reduce annual heating and cooling loads due to the poor insulation value of green roofs, and also assessing their potential in other factor such in the context of building use and environmental education to the community. Table 2.1 shows that energy saving potential based on different levels of insulated buildings with different room conditions. The collected model used to compare the internal temperature with insulated versus non-insulated building, both compare with green roof and without green roof. The insulation thickness is specified with U-value in existing insulation of the original roof structure. The results showed that a very small annual saving is made for well insulated buildings whereas a substantial saving is made for less well insulated buildings. When the green roof applied, the result showed that largest saving for winter heating rather than for summer cooling, which give an impression that green roofs are predominantly seen as a passive cooling technique.

Table 2.1 Energy saving potential of green roof on low, moderately and heavily insulated buildings in Athens, Greece.

Roof construction	U-Value without green roof (W/m^2K)	U-Value with green roof (W/m^2K)	Annual energy saving % for heating	Annual energy saving % for cooling	Total annual energy saving
Well insulated	0.26-0.40	0.24-0.34	8-9%	0	2%
Moderately insulated	0.74-0.80	0.55-0.59	13%	0-4%	3-7%
Non insulated	7.76-18.18	1.73-1.99	45-46%	22-45%	31-44%

Source: Niachou (2001)

A broader perspective has been adopted by (Oyeshola F. Kofoworola, 2009), who argued that activity of recycling building materials is able to contribute additional energy savings as priority to builds the life cycle energy assessment (LCEA) and also the operation of other life cycle phases. In (Oyeshola F. Kofoworola, 2009), it utilizes the existing building energy codes with appliances standards, and labeling and information of programs can help reduce energy consumption. It has shown that using set-point temperature close to 26^{o}C, practicing load shedding, using appropriate sized windows, employing glazing with lower heat transfer coefficients, all of this simple energy efficiency and no-cost energy conservation behavior may prove effective in reducing the energy consumption during operation. On top of that, the energy efficiency is able to contribute in reducing a building operating energy profile, and reduce using natural resources due to recycling the building materials. Table 2.2 shows that the analysis of energy saving strategies in different phase includes operating and manufacturing phase. This will improve in terms of energy performance of buildings and also conserve energy and natural resources by utilize the use of recovery and recycling of building materials.

Table 2.2 The analysis of energy saving strategies in different phase.

Strategy	Phase affected	% Energy saved (in phase)
Chiller replacement	Operating	17%
Periodic load shedding	Operating	12.50%
Set-point temperature adjustment	Operating	7%

Table 2.2 Continued

Strategy	Phase affected	% Energy saved (in phase)
WWR reduction (0.5-0.45)	Operating	2%
WWR reduction (0.5-0.35)	Operating	6.20%
High performance glazing	Operating	3.70%
Recycling of building materials	Manufacturing	8.90%

Source: Oyeshola F. Kofoworola (2009)

2.3. Indoor Energy Management Systems

A number of researchers have reported an indoor energy management system which is using indoor set-point standard of air-conditioned spaces as a tool to control electrical energy consumption in Thailand (N. Yamtraipat, 2006). It will control the indoor set-point temperature at a certain range of values to assess the assumption of electrical energy and environmental saving potentials in Thailand. It shows the concept is proposed due to some factors which are highly consume electricity energy by different sectors such industrial, commercial, residential and others, greenhouse emission causing warm the atmosphere, and CO_2 emissions to the environment caused by office building depend on direct and indirect factors. Table 2.3 shows that this energy saving is likely to reduce the electricity generation from power plants and is able to estimate the reduction of CO_2 emissions from fuel used by the power sector after the room air temperature is set at 26^{o}C. The results showed that the overall electric energy consumption saving is 804.60GWh which will affect a corresponding reduction of 579.31ktons CO_2 per year. This regulation measure has big effect on reduce energy consumption and less GHG emissions.

Previous studies of energy saving have not dealt with smart home system, in (Rune Vinther Andersen, 2007) shows the concept of reduce energy consuming and simulate energy efficient behavioral mode is manipulated by keeping the thermal indoor environment close to neutral. The aim is to keep the Present Market Value (PMV) within predefined limits to make the control. A simulation is applied with different control actions such control the heating system, lighting system, windows, table fan, blinds that reduce the solar heat gain and direct energy transmission relate with clothing insulation values, metabolic rate and infiltration rate. In Table 2.4 shows that two behavioural modes, the environment controlled by an energy expensive manner (naïve

occupant) represent behaviour mode 1 whereas the controls operate with efficient way by rational occupant represent behaviour mode 2. PMV index set with +/-0.2, +/-0.5, and +/-0.7 according to quality categories A, B, and C respectively. In Table 2.5 shows that building higher energy consumption is based on occupant behavior and it will affect building lower energy consumption with control criteria. It is very important of appropriate occupant behavior to reduce energy consumption to acclimatize buildings.

Besides that, a proposed project was designed and constructed by using a microcontroller-based Automatic Light Control to reduce the usage of electrical energy in a room as study (Adelakun, 2014). This project controlled the room light to switch on and off automatically by using passive infrared sensor to detect the presence of human being which placed near to the door in the hall. The concept of controlling the sensor was the PIC16F84 microcontroller via a relay. A pilot test was carried out and the result was obtained in Table 2.6. The result showed that a 15% saving in energy consumption for the active working hours of different lighting types used. However, this operation only achieves 50% accuracy based on the premise manual control switches.

Table 2.3 Total energy saving and CO_2 reduction estimation based on room air temperature as 26^oC

Room air temperature set at buildings (±0.5ºC)	**20**	**21**	**22**	**23**	**24**	**25**	**Total Energy saved at 26**
% of buildings set at above temperature	2.57	3.88	6.25	13.16	28.49	23.29	
Electricity consumption by air-conditioning (GWh)	187.55	283.14	456.10	960.36	2079.07	1699.60	
Increase in room set-point of temperature (ºC)	6	5	4	3	2	1	
% Electricity saving	36.84	30.70	24.56	18.42	12.28	6.14	
Total annual electricity saving	69.09	86.92	112.02	176.90	255.31	104.36	804.60
Total CO_2 emission reduction (ktons/year)	49.74	62.58	80.65	127.37	183.82	75.14	579.31

Source: N. Yamtraipat (2006)

Table 2.4 Setup of the simulations

Criteria	Behavioural mode 1	Behavioural mode 2
A (-0.2<PMV<0.2)	Simulation 1A	Simulation 2A
B (-0.5<PMV<0.5)	Simulation 1B	Simulation 2B
C (-0.7<PMV<0.7)	Simulation 1C	Simulation 2C

Source: Rune Vinther Andersen (2007)

Table 2.5 Energy consumption in the simulations. The primary energy was calculated by multiplying electricity consumption by 2.5 according to the Danish building code.

Energy consumption per year (kWh/year)	1A	1B	1C	2A	2B	2C	No control
Heating	2532	2372	2346	923	768	720	1812
Fan	380.1	423.6	431.0	1.4	0.3	0.1	0.0
Circulation Pump	13	13	13	3	2	2	13
Lighting	174	172	171	187	189	189	131
Primary energy for heating, ventilation and lighting	3948	3891	3882	1400	1246	1198	2171

Source: "Danish Building code" (1998); Rune Vinther Andersen (2007)

Table 2.6 Comparison of PIR Sensor Module with Manual Switching (50% Negligence in manual swithing)

		PIR Sensor Module		Manual Switch	
S/N	Time (3Hours)	ON	OFF	ON	OFF
1.	2.00-2.30		X		X
2.	2.30-3.00	X			X
3.	3.00-3.30		X		X
4.	3.30-4.00	X		X	
5.	4.00-4.30		X		X
6.	4.30-5.00	X		X	

Source: Adelakun (2014)

2.4. Smart Systems Benefits in Different Specifications

According to (Su-hong Shin, 2013) in Korea, a study of smart power control system using RF communication in Smart Home Environment is made. The system

includes the used of current booster, an AC/DC converter, and a DC/DC converter to operate lights and to implements the concept with using standby power and RF communication as smart power control system among smart home technologies. Figure 2.1 shows that the scenario of the smart power control system. It shows perception in solving the security problem due to unsecured protocol and vulnerable security areas will be attacked by hackers. Therefore, wireless network environment is brought out to minimize the possibility of data losses in sensor network. It serves the system wireless networking technologies using RF as a medium to transmit and receive data. It also suggests a method to solve inefficient energy management problem. Basically, it uses standby power to make operation with the help of multiple-trans connection in series and it extracts a current from each Trans. As a result, the extract current helps to control the light switch through RF communication. Before it receives the power directly, the system will convert an alternating current into a direct current. Figure 2.2 and 2.3 show that the design of inner and outer of the system. Besides of implementation of using RF communication to control light switch, it also implement monitoring system and Smartphone application to make user easier to use. Figure 2.4 and 2.5 show that a window of main program and screens of the smart power control application respectively. In conclusion, it proposed that this services not only apply in home network but also a factory, a commercial building and others to save energy by control the electric light system. It is needed to test safety when apply in gas valves, door locks and others in future work to perform a quality life.

An integrated and low cost home automation system with flexible task scheduling concept based on idea of researchers in (Joaquin Lopez Fernandez, 2014). It contributes a Home Automation System using Robotics Integrated Development Environment (RIDE) in design, implementation and maintenance. In this system, integration is important for different kind of devices used in open system. Internet of Things (IoT) devices in the system could be connected directly and is also able to provide a gateway from other network to internet which adapted to the Modbus interface. Figure 2.6 shows that the overview of home automation system. Besides that, RoboGraph in Petri Nets tool is proposed to use to complete a flexible task like programming and debugging(Fernandez, Sanz, Paz, & Alonso, 2008). Figure 2.7 shows that Petri Net debug a main window. Secondly, it can be used to check the behavior and properties of modeled system and monitoring in the system. It also capable to analyze

the data logged during execution. A prototype model has made with several sensors and actuators and also Modbus module interface with the Arduino. Figure 2.8 shows that Modbus module to test the transaction in between building devices and central control system. In this combination of the system, it allows the user to monitor the house devices to achieve the main target and also create new behaviors to increment the number of devices in the system in future work.

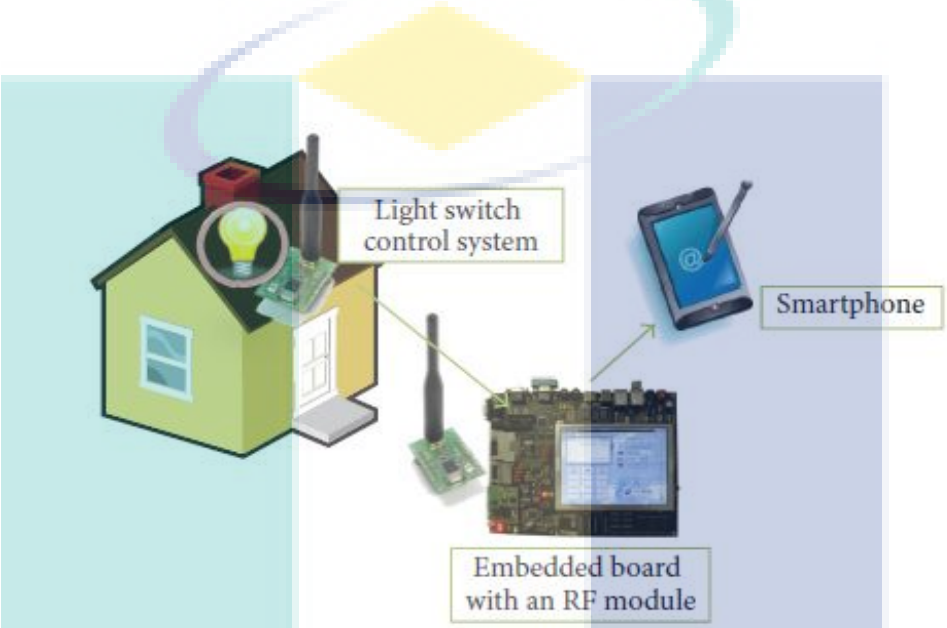


Figure 2.1 A scenario of the smart power control system proposed.

Source: Su-hong Shin (2013)

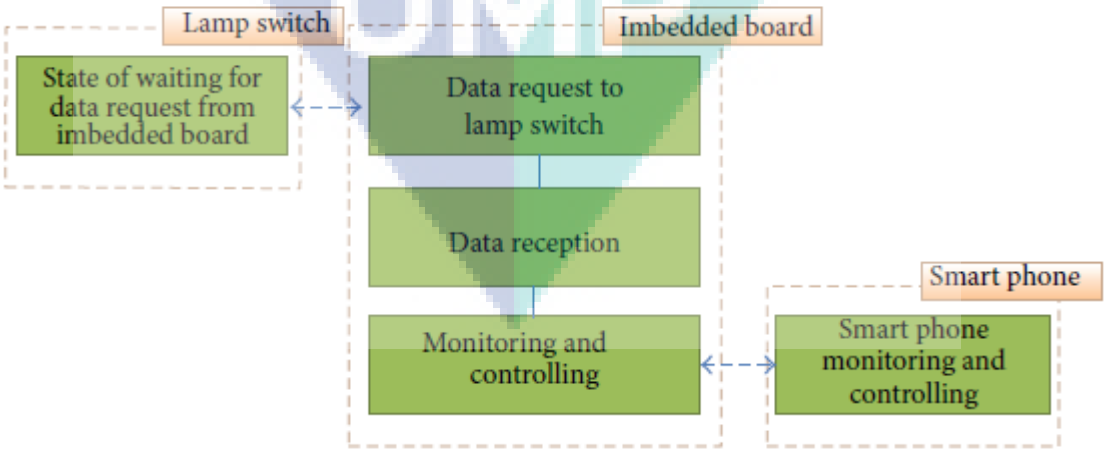


Figure 2.2 Inner action of the main program.

Source: Su-hong Shin (2013)

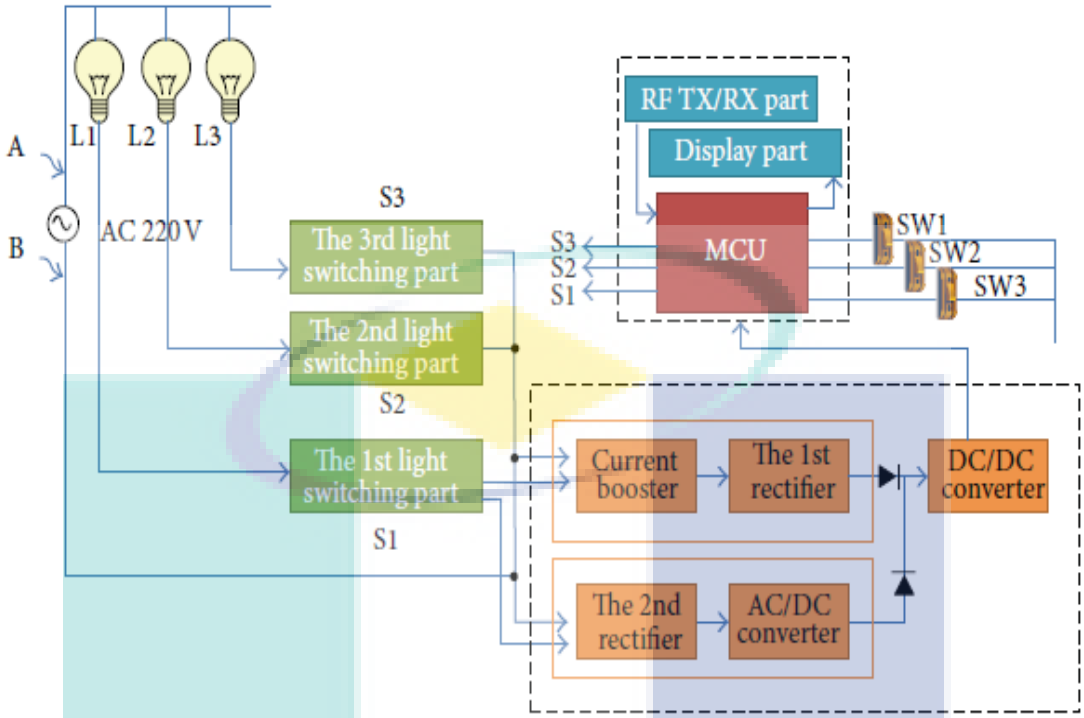


Figure 2.3 A diagram of the RF light switches system.

Source: Lim (2016)

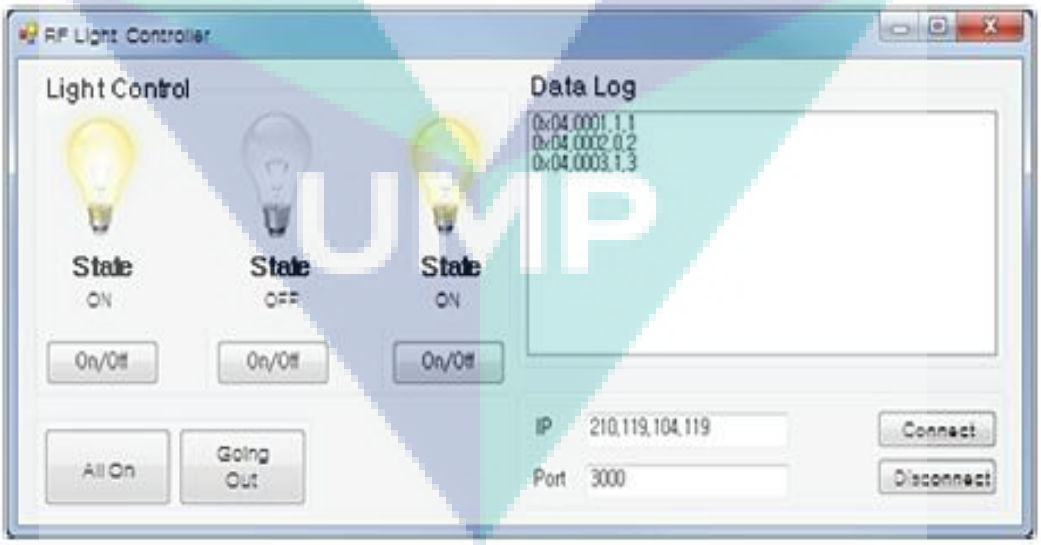


Figure 2.4 A window of the main program.

Source: Su-hong Shin (2013)

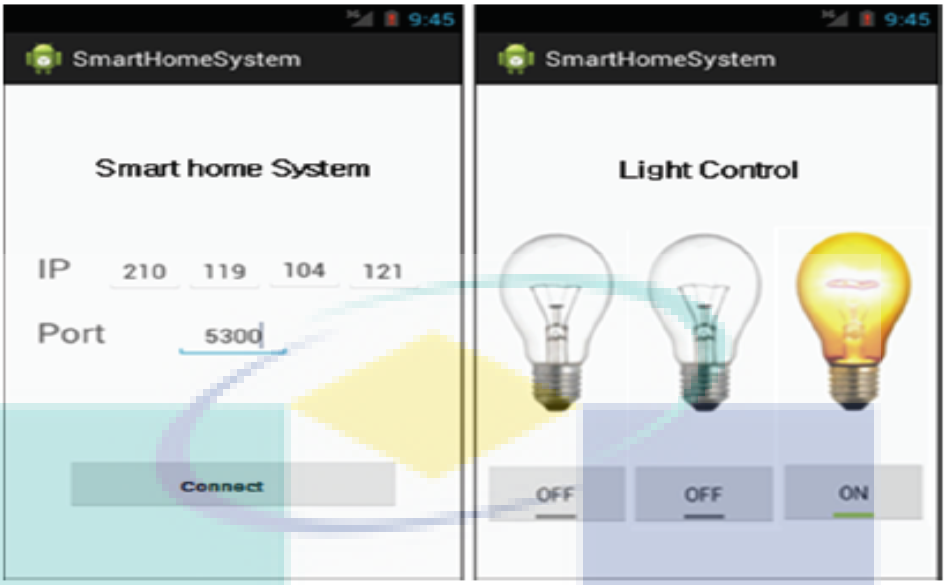


Figure 2.5 Screens of the smart power control application.

Source: Su-hong Shin (2013)

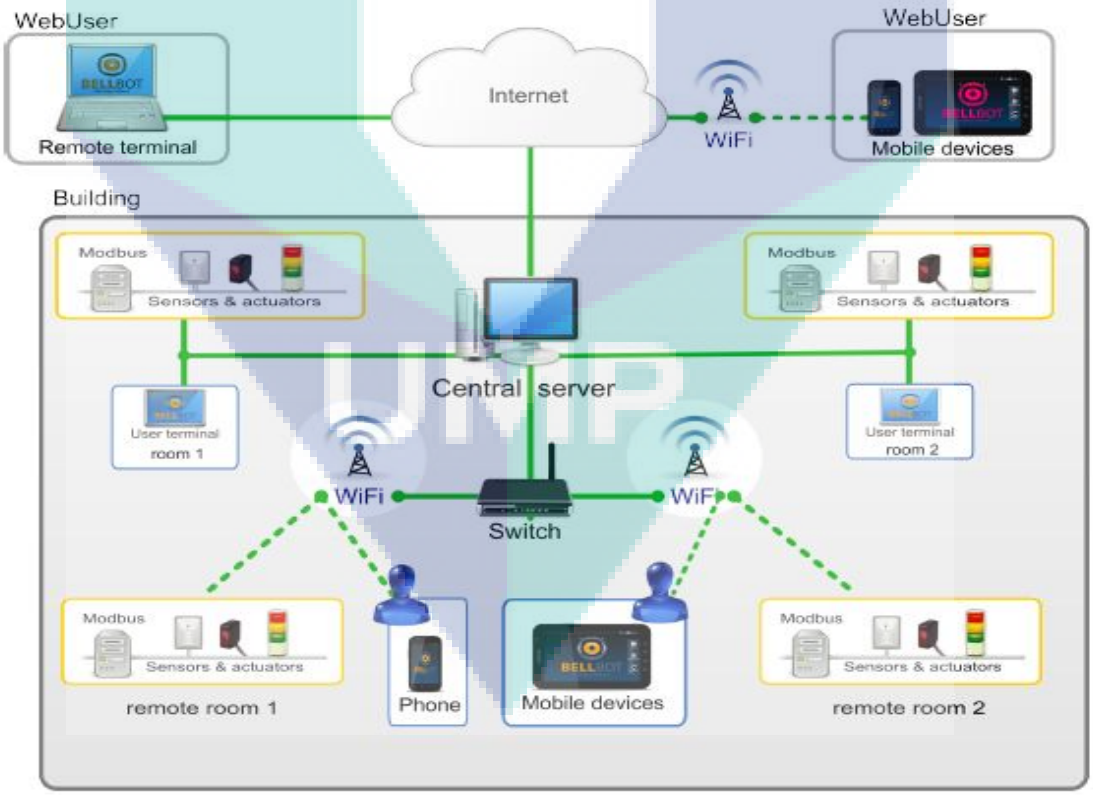


Figure 2.6 Overview of the home automation system.

Source: Joaquin Lopez Fernandez (2014)

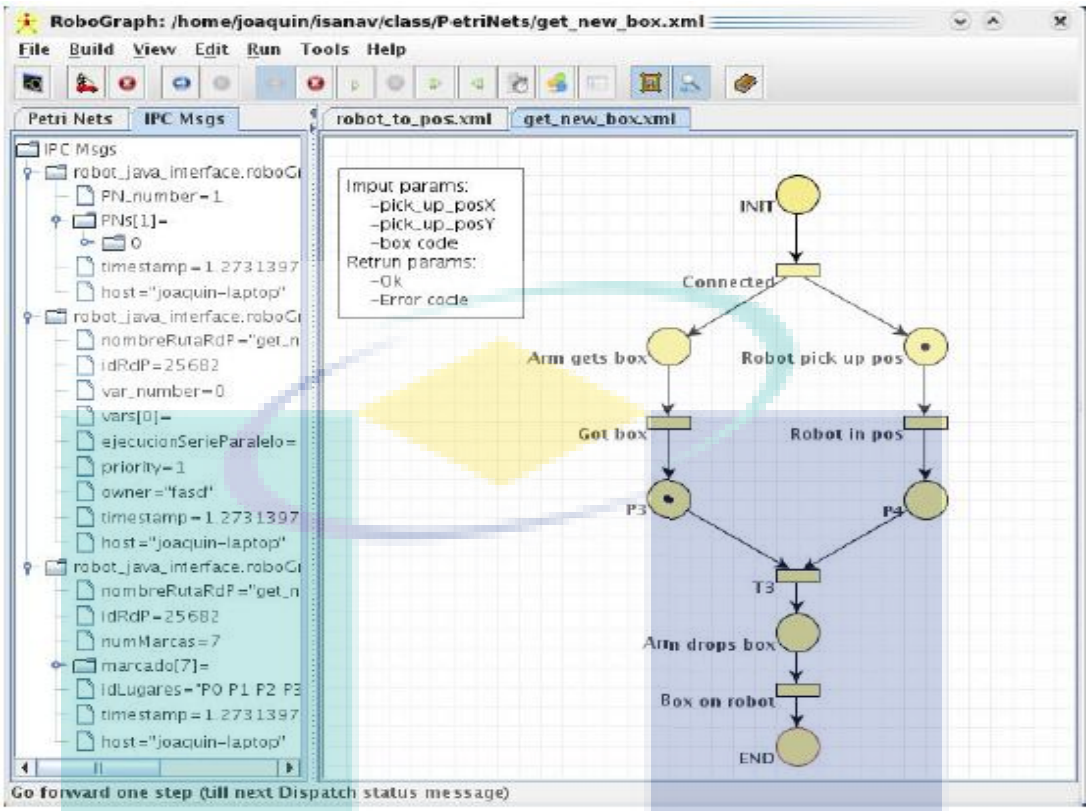


Figure 2.7 Petri net debugger main window.

Source: Fernandez et al. (2008)

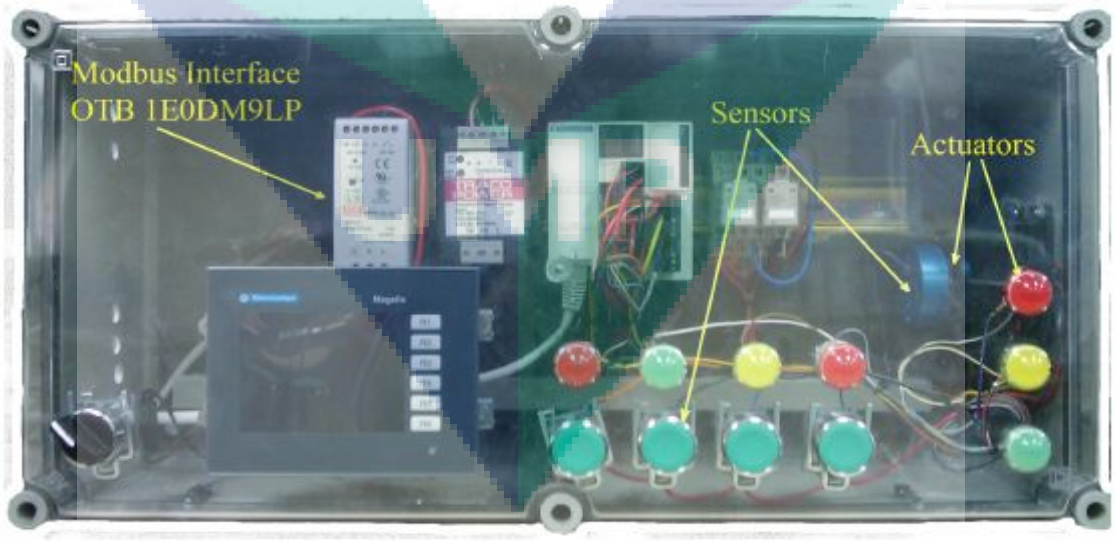


Figure 2.8 Modbus module used to test the transactions between building devices and the central control system.

Source: Fernandez et al. (2008)

From another view on Smart Home Technology in other specifications than energy saving, (Shruthi Suresh, 2015) proposed that the main objective is to clarify the main applications of various home automation technologies example for the use of elderly and the disabled persons are able to self-care anytime. Another feature of Smart Home is to provide future enhancements needed but not only minimize energy conservation in household. The world smart living concept is used instead of smart home to hit the main goal which is to provide an overall idea in the advancement of technological in the construction fields, and also proposed an area need more attention from the scholars and technicians. In view of all that has been mentioned so far, in the medical sector the primary goals of this study is to facilitate standard living, minimize energy conservation, and make self-sufficient for elderly or disabled persons with the concept of smart living. There are disadvantages of smart living appear due to some problems occur in implement electronic health records (EHR). Another obstacle which is it may become a great burden to affect people lifestyle, financial status, emotional and psychological wellbeing of family members if E-health is applied. It will become a worry for the user due to raises unnecessary issues. From this result that has been discussed, it was concluded that the Smart Living or Smart Home technology can apply as to identify, to analyse and to implement a wide range of aspects in both technological and non-technological areas, to live a life up expectations and realize a large-scale commercialization.

In (Manuel Ramos Cabrer, 2006) indicates that cooperative environment between the Interactive Digital TV (IDTV) and the networked home with the aim to achieve smart home. It has selected Multimedia Home Platform (MHP) standard and Open Service Gateway Initiative (OSGi) as platform and using XbundLET as a bridge to set up Residential Gateways as shown as Figure 2.9. In this concept, any possible connections in between MHP and OSGi are explored, in the context of Residential Gateways. With the respect of the work in (Manuel Ramos Cabrer, 2006), OWL-OS has been defined which means to adapt the OWL-based ("OWL-S 1.1 Release ", 2004) Web Service ontology with the peculiarities of OSGi services. Figure 2.10 shows that the concept of OWL-OS ontology. According to this concept, it makes the services more easier based on operations-at-home and also allow a bundle to express the other services requirements. From it proposed that this automation would open the platform to

ambitious applications of controlling the services at home, like automatically composes a service which triggers the ringing alarm, unlocks the doors, calls the fire station, etc.

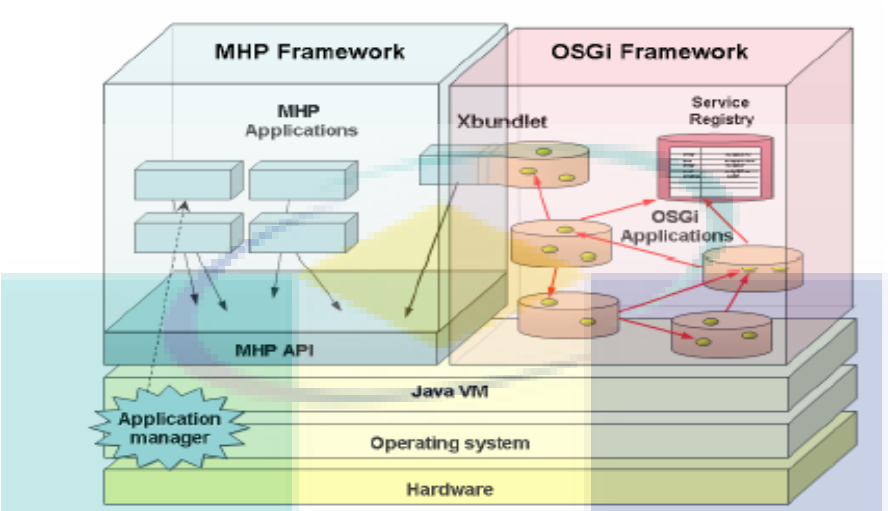


Figure 2.9 The XbundLET entity in between MHP framework and OSGi framework.
Source: Manuel Ramos Cabrer (2006)

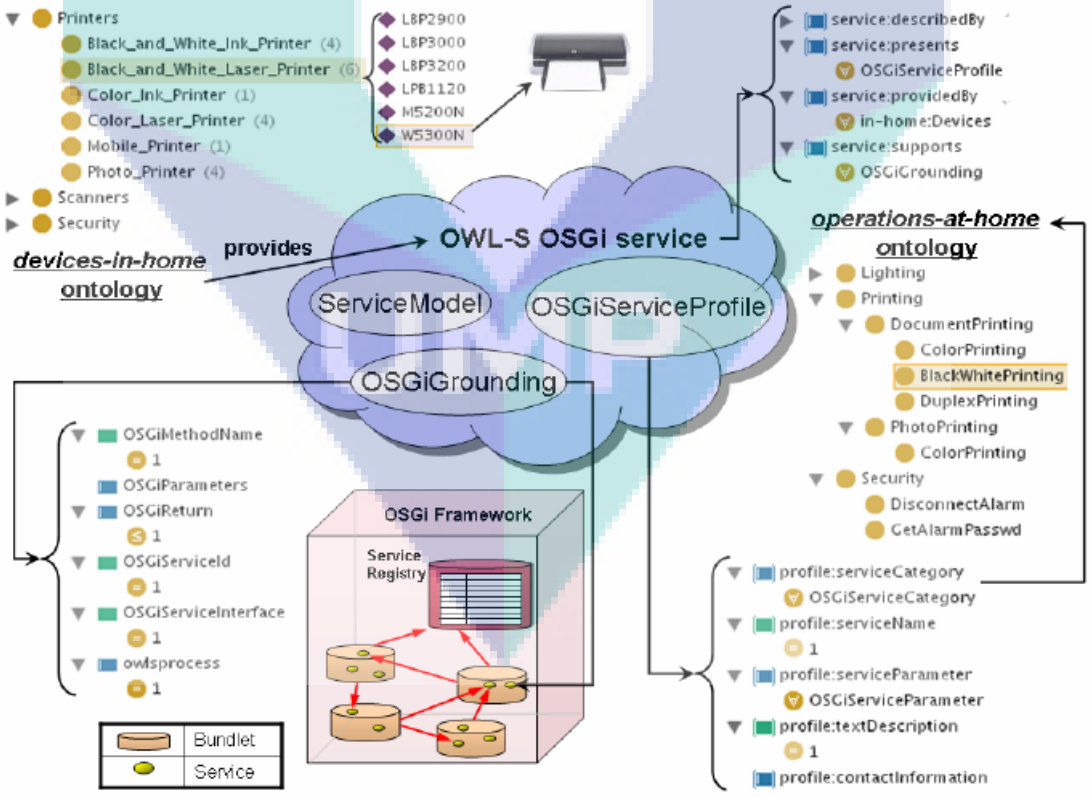


Figure 2.10 The OWL-OS ontology (OWL-OSGi Services ontology)
Source: Manuel Ramos Cabrer (2006)

Previous research has reported that designing smart health care technology is getting on demand. In the research (Bahón, C.A. Lara, & R.A.T., 2004), development of smart home architecture is focused on delivering intelligent health care. The co-evolution algorithm used with the version of Enforced Sub Populations algorithm (ESP) in three types of experiments which are ESP with a central controller, ESP with distributed controller, and specially devoted to analyse the intelligent hardware sensors. It can concludes that analysing data using collective intelligence technology will be vital from distributed sensors and also achieve the adaption of software modules in conventional computers and implementation of hardware into the system. The main feature is to develop a task without the particular each agent and reduce computing complexity associated to each intelligent hardware units (IHU). Figure 2.11 shows that the working methodology for certain IHU. On top of that, a robustness system has been demonstrated to be processing with the intelligent hardware sensors and scalability of this architecture to achieve more efficient control of the system.

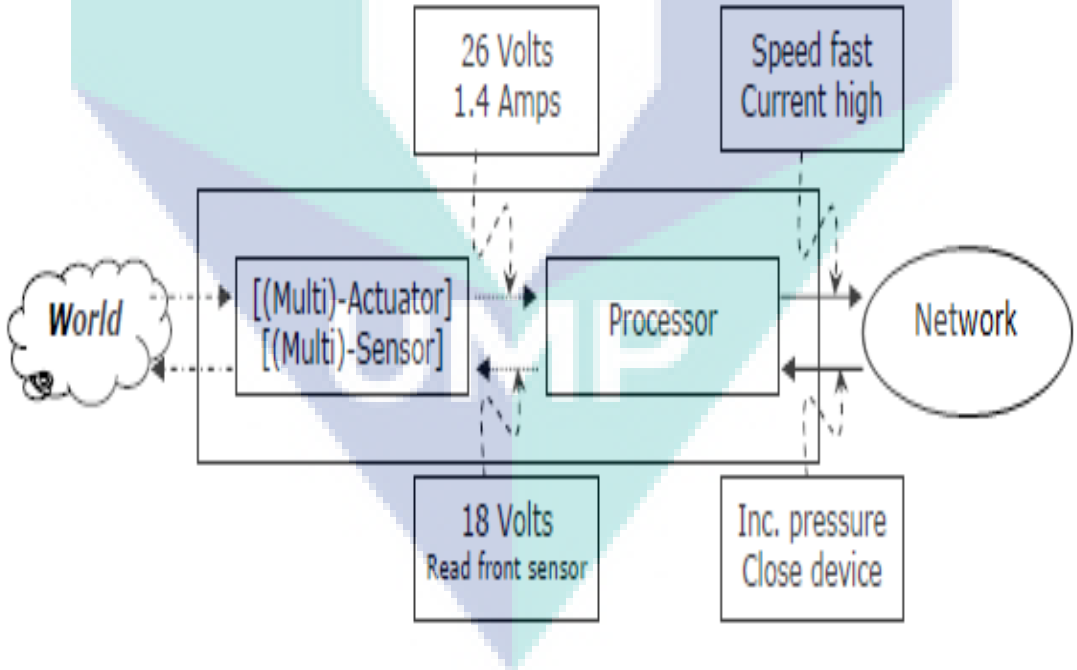


Figure 2.11 The working methodology for a certain intelligent hardware unit (IHU). Source: Bahón et al. (2004)

In research of (Husin S.H. , 2013) and in related references it was observed that the work of smart home is more emphasize in the latest technology to turn ordinary home into extraordinary. Programmable Logic Controller (PLC) as primary control unit, Global System for Mobile Communications (GSM), Short Messaging System (SMS) and others will be used to utilize advance and complex technologies, life is made easier and comfort for everyone under its roof. The aim is to develop a system by using GSM communication to notify user the current status of electrical appliances, ensure safety issues from any cases of accident that will caused by electrical appliances, and make improvement of the existing system in market. Figure 2.12 shows that the flowchart of running Smart Home Automation by using GSM. In conclusion, it shows enable user to control the home appliances and prevent problems that happened in home automation system. It will become commercial due to the advance technology is applied even the cost is high in the development.

Based on the research, (Govindraj, Sathiyanarayanan, & Abubakar, 2017) states that a design of smart home automation system with the aid of IoT to build a low cost, extensible, flexible wireless system to access and control the devices and appliances in housing area by using Android based Smart phone app. The proposed system would provide a framework that utilizes the combination of cloud networking and wireless communication to control the electrical appliances and also monitor constantly the home environment and store the data onto the cloud. All the working principles of the proposed system are based on the help of sensors, Wi-Fi and RF signals. One of the ability in this proposed system is to control the appliances by means of appropriate sensors to detect the room temperature, make motion detection, make gas leakage detection and detect touch sense. Besides that, two different modes are provided in the system which are Manual Mode or Automatic Mode based on the command selected by user. All the working principles are built in two different stations which are Base Station and Satellite Station in the system. Both of the stations are showed in Figure 2.13.

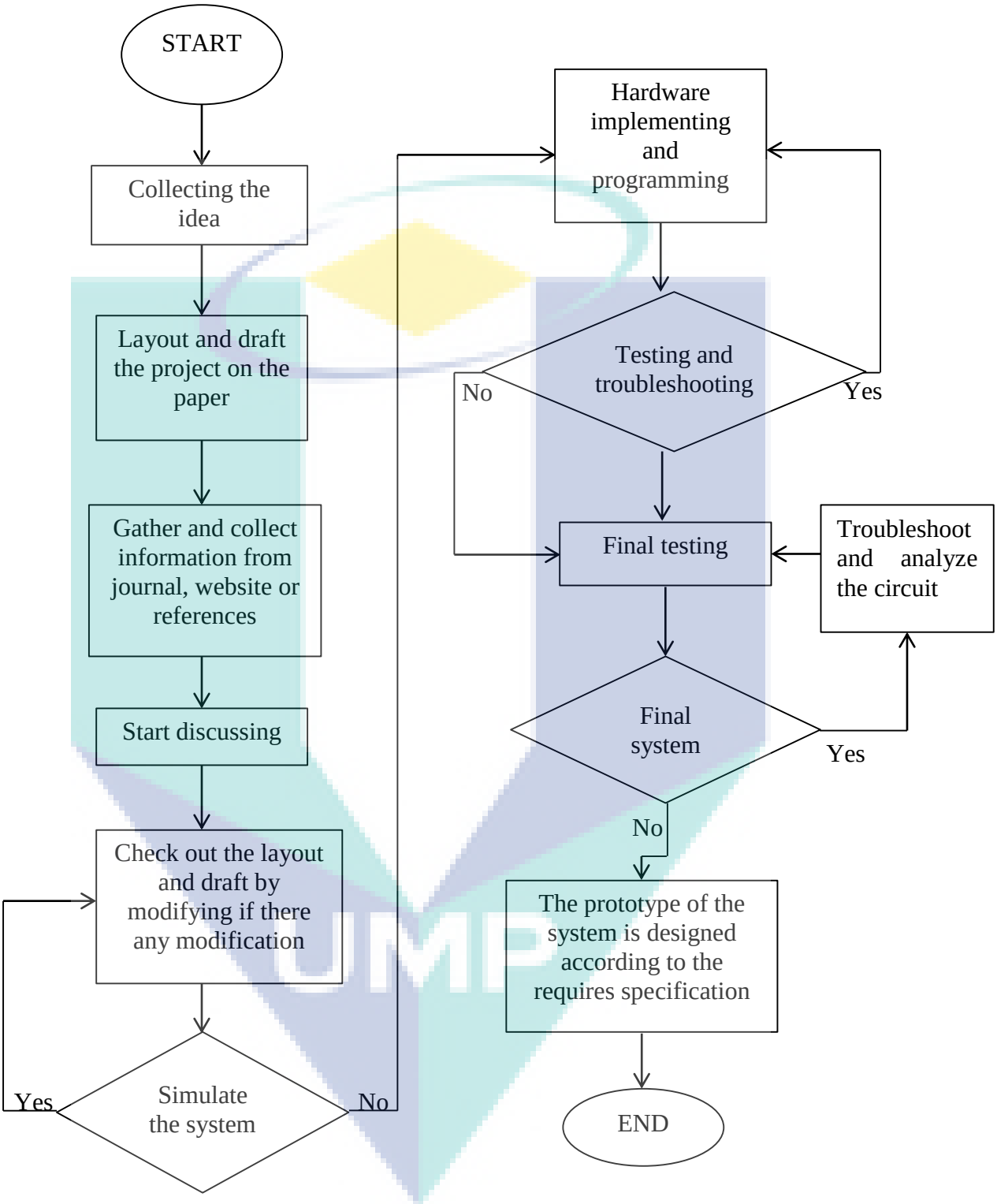


Figure 2.12 The flowchart of Smart Home Automation by Using GSM.

Source: Husin S.H. (2013)

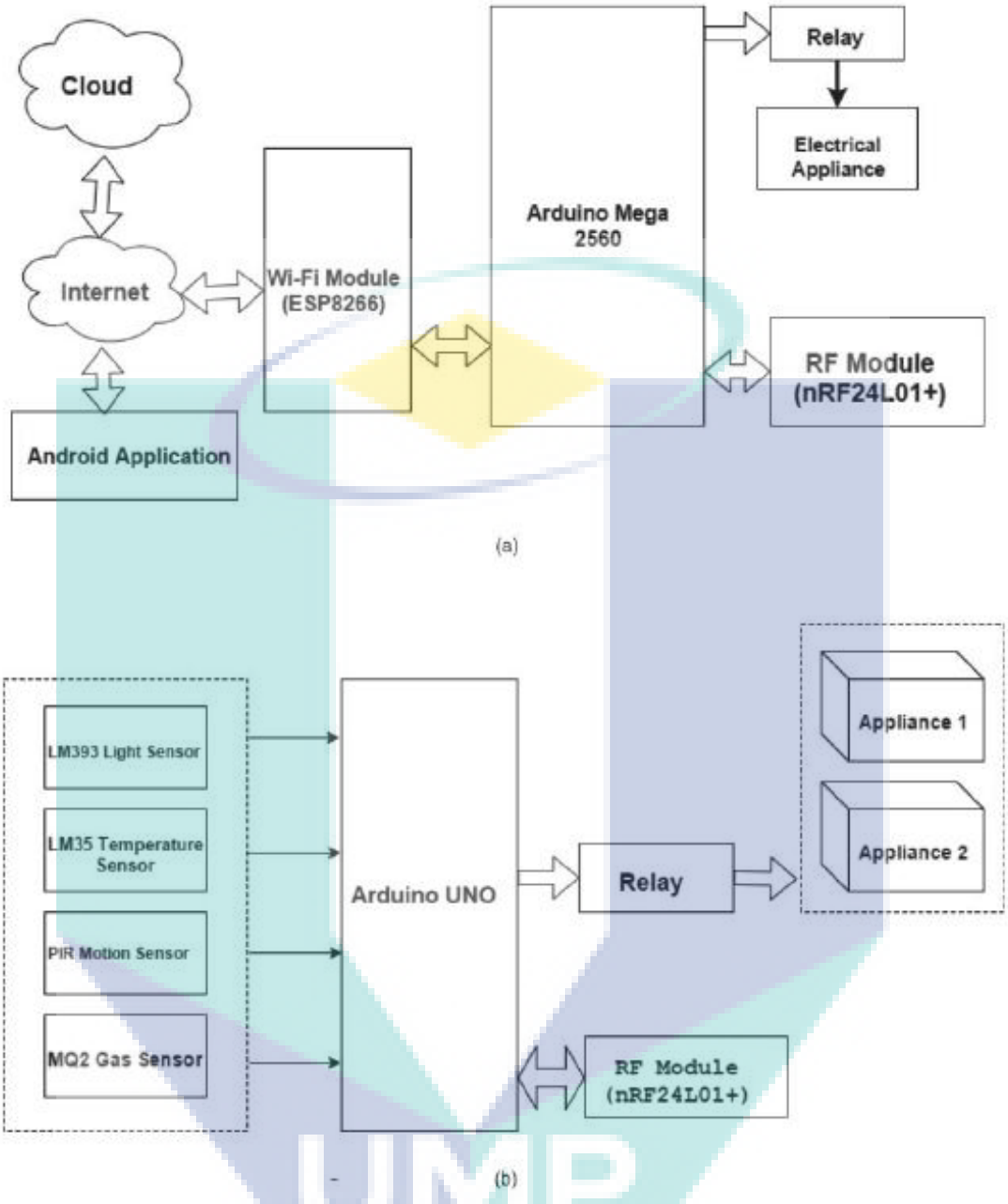


Figure 2.13 Basic block diagrams: the two blocks are (a) the Base Station and (b) the Satellite Station. Many Satellite Stations are controlled by the Base Station

Source: Govindraj et al. (2017)

2.5. Smart Energy Management Methods

From another research, (Alaa Alhamoud, 2014) developed a framework called SMARTENERGY.KOM based on wireless sensor networks and human activity detection to realize energy efficient smart home. In this idea includes a set of electrical appliances to detect current related activity and monitor its fine-grained appliances-level

energy consumption to avoid any wasting energy. The framework of EnergyAdvisor is applied to utilize the detection of activity based on its energy consumption, and recognized any appliances are wasting energy and informing the user about optimization potential. This SMARTENERGY.KOM framework include three main components as shown in Figure 2.14 which are data collection units with the aid of sensor using, data processing units with the aid of microcontroller and control server and data visualization and feedback unit with the aid of smartphone. The EnergyAdvisor framework is responsible to report all the activity detection and generate the energy saving recommendations to the user in the form of text messages. Based on the results, it can be concluded that the research introduced SMARTENERGY.KOM framework for conserving energy and also EnergyAdvisor framework has shown a significant potential for energy saving which was greater than 50% for certain activities in smart homes as showed as Table 2.7. In future work, the researcher will focus on utilize the system consider of multiple and overlapping activities since the system do not detect any in that moment.

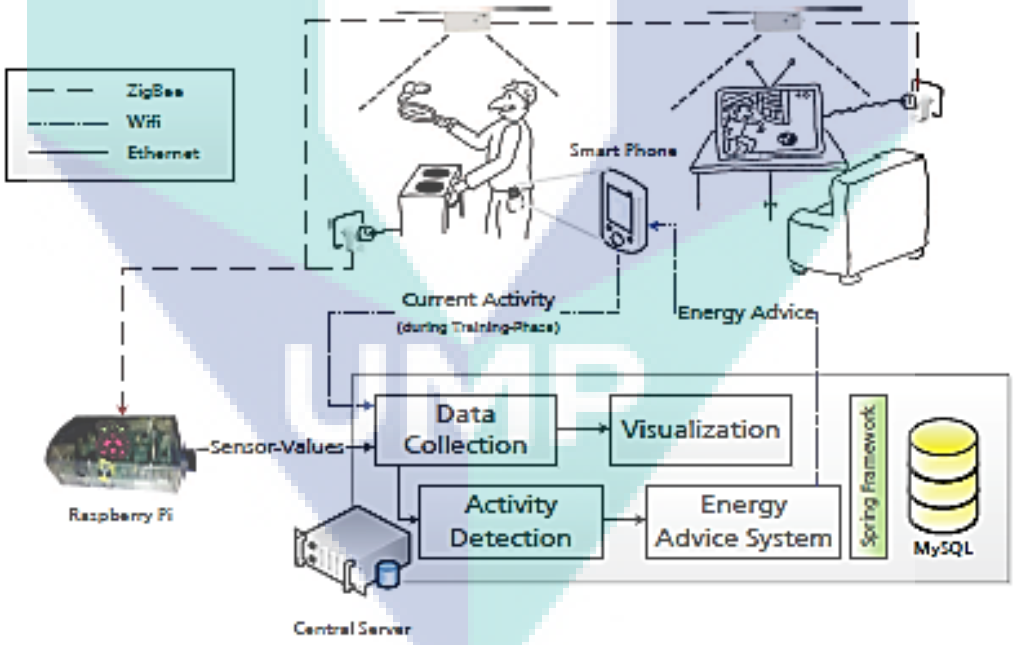


Figure 2.14 The system architecture and network topology.

Source: Alaa Alhamoud (2014)

Table 2.7 The record of Saved Energy at Home.

Activity	Consumed Energy	Potential Savings	Proportion
Eating	1818Wh	1231Wh	67.70%
Ironing	287Wh	4Wh	1.54%
Listening to Radio	218Wh	71Wh	32.72%
Making Tea	1118Wh	84Wh	7.47%
Not at Home	1258Wh	647Wh	51.47%
Reading	244Wh	114Wh	46.89%
Sleeping	3644Wh	1952Wh	53.56%
Cutting Bread	20Wh	13Wh	65.30%
Watching TV	18682Wh	176Wh	0.94%

Source: Alaa Alhamoud (2014)

In another research from (Rutuja D. Ekatpure, 2016) presented that Wireless Home Automation system (WHAS) using IoT to make automatic control and monitoring of household appliances and residential house features in order to save the electric power and human energy. Figure 2.15 shows that a detailed design for the proposed system. It involves three main components which are local hardware and local network devices to connect household appliances, web server to connect the system with the local hardware and mobile smart devices and also deal with the records stored in the database of the system, mobile smart device to run Android operating system to make customers contact with and manage the in home devices via the server and also provide a non-complex graphical interface for controlling easily the automated machines at home. With this research it involves different intelligent subsystems which are lighting system, electrical appliances control system, window curtain system, environment control system and safety assurance system. Software proposed is responsible to control all the subsystem. At last it will send the commands to the server and then it sends the commands to the microcontroller to enable or disable the connected relay which place in plug points. Figure 2.16 shows that a data flow diagrams in the system. It has clearly shown that IoT is able to work satisfy by connecting simple appliances and controlled remotely through internet. This designed system is able to monitor the sensor data, actuates a process according to requirement, and stores sensor parameters in the cloud (Gmail). This makes user easier and convenience to use all the time.

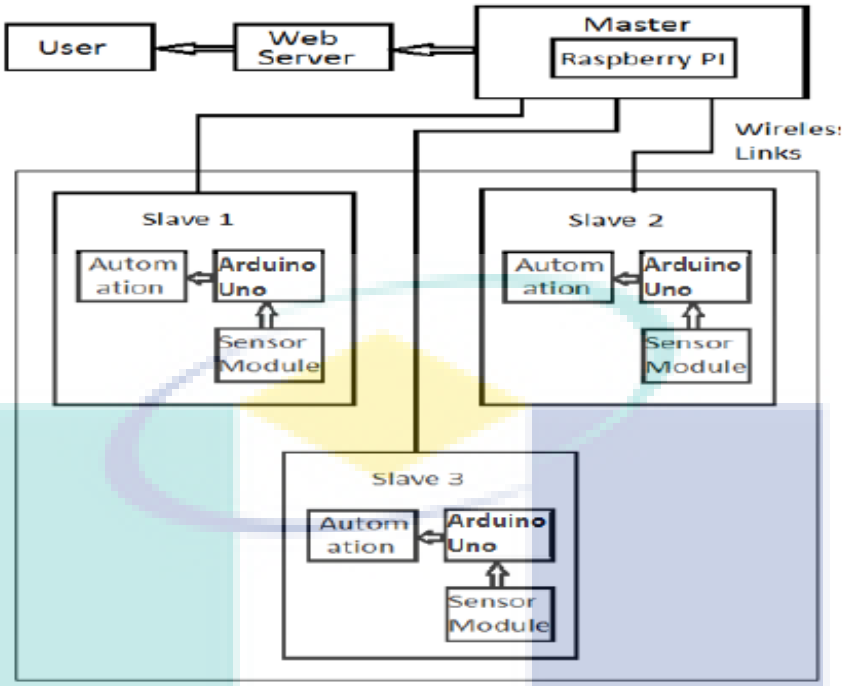


Figure 2.15 The Detailed Design.

Source: Rutuja D. Ekatpure (2016)

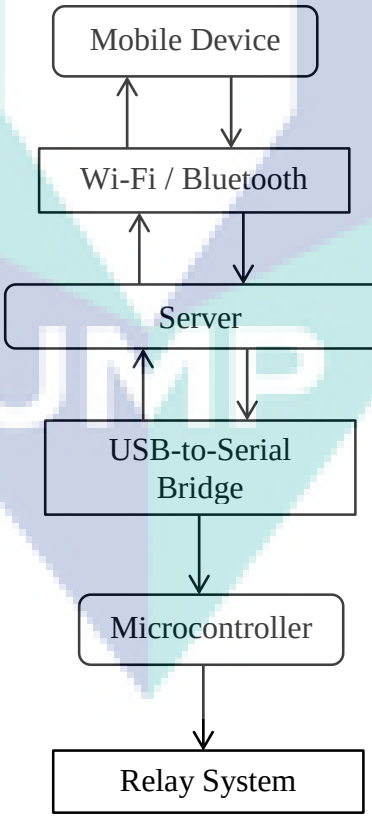


Figure 2.16 The Data Flow Diagram.

Source: Rutuja D. Ekatpure (2016)

This view was supported by (Abhishek Bhati, 2017) which writes that the smart technologies nowadays design in smart homes is fulfil consumers' behaviour and targeted to reduce energy consumption. It is focused on the perception of Singapore households on smart technology and aim to reduce energy consumption regarding on the areas of current research include energy consumption in Singapore households, public programs and policies in energy savings, use of technology in energy saving, and household perception of energy savings in smart homes. It has been made a research of three case studies that have implemented smart homes to save energy, together, these studies outlines that the residents are seem lack of general awareness about proper energy saving behaviour and proper guidance, less of understanding well to the appliance energy consumption such as smart meter. Nevertheless, a portion of residents showed their households' behaviour towards saving energy positively changed due to installation of smart home technologies. In Figure 2.17 shows that the motivation to adopt technology at home based on the opinions of participants in the current survey. In summary, households in Singapore have shown concerns on environmental issues and willing to invest in smart home technologies to address them once they get the information and importance of saving energy. On top of that, to apply smart home technologies in Singapore must integrate into public services and utility sectors but not only saving energy and also provide a service which giving notifications to turn on certain appliances through mobile gadgets or house consoles.

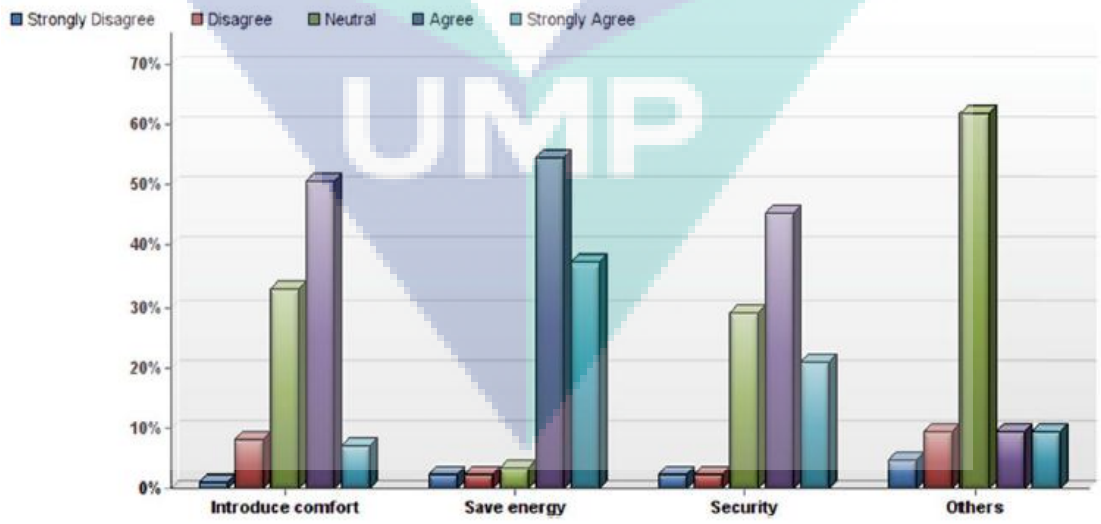


Figure 2.17 Motivations to adopt technology at home.

Source: Abhishek Bhati (2017)

Similarly, in (Ashour, 2011) analyse that a smart home technology would provide energy management technique for energy saving but not only care about security and comfort for people. It proposed that the effectiveness way based on a static correlation between the power consumption and saving. It concludes a set of sensors such as temperature sensor and occupancy sensor and certain specific software to manage intelligently to control the devices of home appliances to reduce the energy consumption. Table 2.8 shows that the result of comparison between the assumptions listed in terms of power consumption, percentage saving in power, and consequently electricity bill. From the data analyse in calculation by the specific software, it can concludes that the increase in power saving is accompanied by a great increase in cost saving from the assumption calculations and it showed as Figure 2.18. This showed that a home energy management is able to maximize the action of energy saving and hit the economical target but not individual need only.

Table 2.8 Comparison between the different assumptions.

3rd assumption	**2nd assumption**	**1st assumption**	
1549.08	1858.23	935.31	**Total KWH/month**
619.2	379.47	224.13	**Total saving KWH/month**
38.58 %	20.42 %	23.96 %	**% saving/month**
48.82%	27.44%	61.3%	**Saving in LE %**

Source: Ashour (2011)

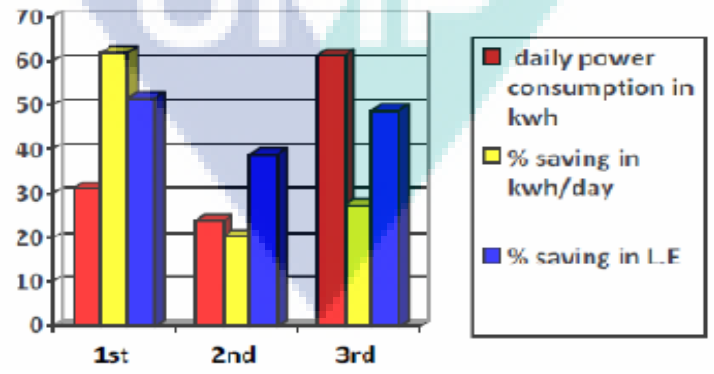


Figure 2.18 The daily consumption, percentage saving in power and in electric bill for the previous trials.

Source: Ashour (2011)

Much research on smart energy management method has been done. According to (Bilal Mubdir, 2016), to operate home appliances by developed Smart Home Energy Management System (SHEMS) in an optimum approach with the aim at reducing energy consumption when the system detect the resident's activity of three stages which are active, away, or sleep. With this concept it helps to solve the current world issue on save the energy by reduce the consumption and also decrease global warming. Wi-Fi technology is needed for data transmission inside home and GSM technology is needed for external communication in this proposed system. Figure 2.19 shows that overall SHEMS architecture. This system and its algorithm are seemed to be save energy successfully however it shows a complex combination of two technologies to perform the system.

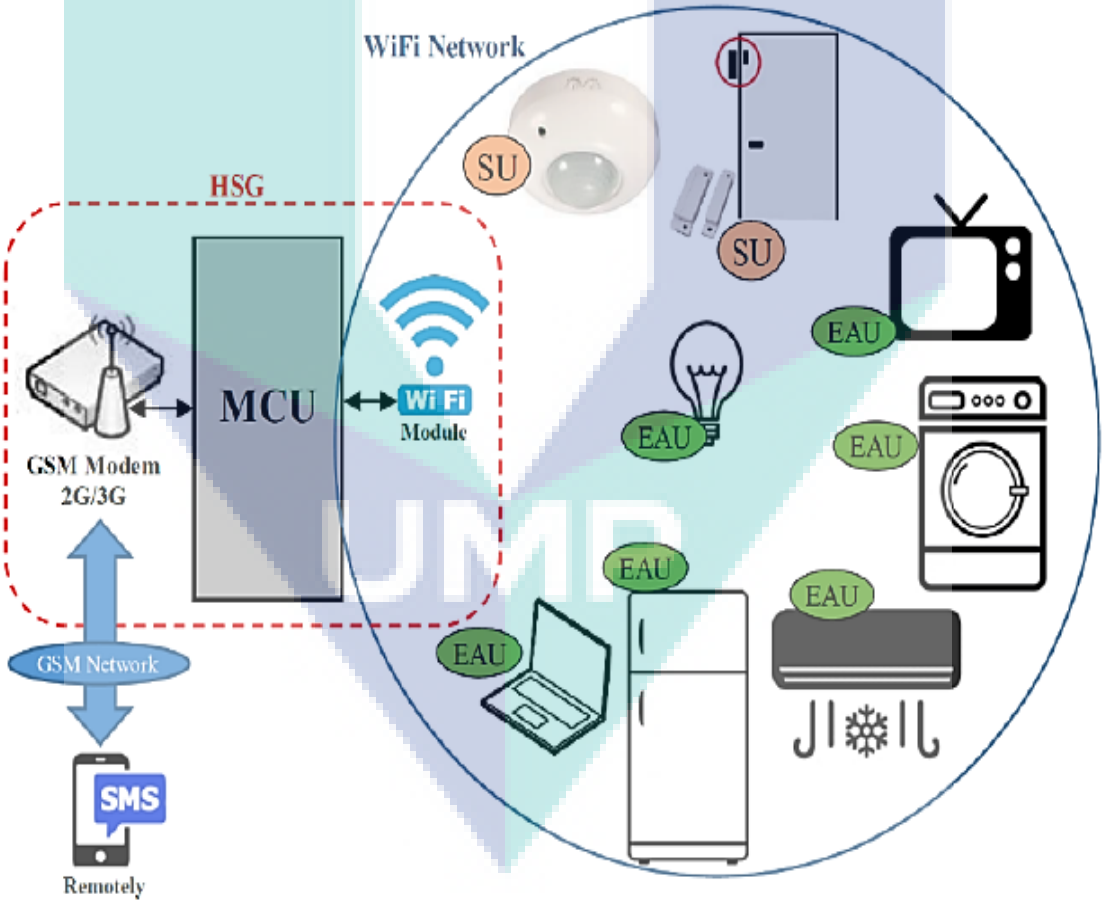


Figure 2.19 The proposed SHEMS architecture.

Source: Bilal Mubdir (2016)

2.6. Summary of Literature Review

Table 2.9 shows the summary of advantages and disadvantages in other's research review.

Table 2.9 Advantages and disadvantages of the research in literature review.

Method/ Technology used	Advantages	Disadvantages
Using green roof as building regulators (Castleton H.F., 2010)	• Extend energy saving with reduce heat and cooling loads	• High cost to build the well-insulated buildings • Slow to see the impact
Activity of recycling building materials to build life cycle energy assessment (Oyeshola F. Kofoworola, 2009)	• Reduce energy consumption • No-cost energy conservation behavior • Reduce using natural resources	• Not much recycling materials are suitable to use to build life cycle energy assessment • Does not consists of any practical for office buildings
Indoor set-point standard of air-conditioner spaces as a tool (N. Yamtraipat, 2006)	• Reduce energy consumption highly consume energy by different sectors such industrial , commercial, residential • Reduction of CO2 emissions and GHG emissions	• Does not apply in practice to people who had been acclimated to different climate • An accurate analysis of the energy saving is premature as detailed energy consumption data are not yet available.
Keep the thermal indoor environment close to nature (Rune Vinther Andersen, 2007)	• Build a lower energy consumption with control criteria • Reduce the solar heat gain and direct energy transmission relate with clothing insulation valves, metabolic rates and infiltration rate	• Need to highlight the behavior of occupants for consuming energy • Some of the equipment shows energy save due to a longer period is needed.
Automated Light Control (Adelakun, 2014)	• Reduce the usage of electrical energy • Control the light automatically	• Only available for lighting types • Only achieve 50% accuracy based on premise manual control switches.

Table 2.9 Continued

Method/ Technology used	Advantages	Disadvantages
Smart power control algorithm using RF communication in Smart Home Environment (Su-hong Shin, 2013)	• Wireless network environment to minimize the data losses in sensor network. • Implement a system to monitor and control a smart home at any time and place.	• It might not operate without a mobile communication • Support of technologies is needed helping to control or manage various digital devices.
Home Automation System using Robotics Integrated Development Environment (RIDE) (Joaquin Lopez Fernandez, 2014)	• Low-cost home automation system with flexible task scheduling concept • To check the behavior and properties of modeled system and monitoring in the system	• Limited to monitor the house device • Use more interact based on the connection; it cannot function well without internet.
Home Automation Technologies (Shruthi Suresh, 2015)	• For the use of elderly and disabled person are able to self-care anytime • Provide future enhancements needed but not only minimize energy conservation in household	• Do not consists of detailed existing publication related to the Smart Home • Require a huge investment to support EHR models.
Smart Home with cooperative environment between the Interactive Digital TV (IDTV) and the networked home (Manuel Ramos Cabrer, 2006)	• Automation would open the platform to control the services at home • The platform applied is purposely for Residential Gateways	• Limited to maintain the present functionality of MHP platform as set of services • The relation with definition of a semantic OSGi framework still improving to support more sophisticated queries
Smart Health Care Technology (Bahón et al., 2004)	• Deliver intelligent health care • Demonstrate a robustness system and scalability to achieve more efficient control of system	• Limited function for the system which in the way of caring health care • Complex system to use due to the simulated robotic pet platform.

Table 2.9 Continued

Method/ Technology used	Advantages	Disadvantages
Smart Home Automation by using PLC, GSM, SMS and others (Husin S.H. , 2013)	• Notify user to ensure the safety issues from any accident which will caused by electrical appliances • Smart Home System is equipped with latest technology and given leisure for user	• High cost is needed in advance technology development • It used complex technologies by combining lots of sub-systems to form smart home system
Smart homes using Internet of Things(IoT) and mobile application (Govindraj et al., 2017)	• Provides features selection of Manual or Automatic Mode for controlling home appliances • Able to monitor the home environment	• The system only works when Wi-Fi is available • The system only works when internet is available to store data.
SMARTENERGY.KOM framework (Alaa Alhamoud, 2014)	• Recognize any appliances wasting energy and informing the user • Conserve energy by generate recommendation of energy saving to the user	• This framework mainly reliable use in home electrical appliances. • Only able focus on one activity rather than multi-tasking of overlapping a few activities at the same time
Wireless Automation System(WHAS) (Rutuja D. Ekatpure, 2016)	• Automatic control and monitoring of household appliances to save energy • Designed system is able to monitor the sensor data, actuates process, and stores sensor parameter	• The system might not able to function well without internet • Not reliable to use in every system while Android Based Home Automation System is applied
Smart Technologies design in Smart Homes (Abhishek Bhati, 2017)	• To reduce energy consumption in households, public programs and policies in energy saving, use of technology in energy saving	• Not every household afford and willing to invest smart home technologies • Not every residents show positive behavior towards saving energy positively changed due to installation of smart home technologies.

Table 2.9 Continued

Method/ Technology used	Advantages	Disadvantages
Smart Technologies design in Smart Homes (Abhishek Bhati, 2017)	• Implement general awareness about proper energy saving behavior, proper guidance and understand well to the appliances energy consumption	
Smart Home Technologies (Ashour, 2011)	• Effectiveness way between power consumption and saving • To save energy with hit the economical target but not individuals need only	• Not every user willing and to know well to use the system especially old age. • Not all equipment is able to accompany in power saving due to the occupant's behavior.
Smart Home Energy Management System(SHEMS) (Bilal Mubdir, 2016)	• Reducing the consumption energy and decreasing global warming • Display a clear interface to the user to show all the data recorded in detailed.	• There are lack of some situation in the predicted situation table • It is more reliable use in home area compare to industrial or work area.

In conclusion, based on the literature review the existing research consists of both advantages and disadvantages. However, some of the existing researches are less suitable to apply due to some of the reasons like higher costs involved, longer time is needed to see the impact, the energy saving is lesser compare to the smart energy saving and monitoring system. Besides that, certain systems are able to operate when internet is available, or the system need to control by using mobile communications, and these would become an obstacle to the user to apply the smart system.

On top of that, majority of the smart system are more suitable to be applied in the house but not in office. In order to set up the system there are some requirements need to be fulfilled. The requirements are the environment condition, the usage of the system in specific area, and the total working hour of different staff and others factors. Smart energy saving and monitoring system is more reliable to be applied in office environment compare to existing system, to collect the data for analysis purpose, to display the data of working hours of every staff in the each offices, to switch OFF and ON automatically when nobody or somebody in office with no movement more than 10

minutes, and the most important is to save the energy consumption from the heavy loads of electrical appliances. There are many new technologies are used in saving energy but Smart Energy Saving and Monitoring System is more specific in office area.

CHAPTER 3

METHODOLOGY

3.1. Principles of Smart Energy Saving and Monitoring System

Smart energy saving and monitoring system is to achieve the goal of energy saving at working office area in building. Normally, it is costly to modify an existing building compare to rebuild the building with a new technology. This is because to modify an existing building it involves additional wiring and devices. However, this system results with a lower cost compare to existing smart system due to the wireless network principle in the system. Moreover, this system also easier to apply in any existing building with the portable concept of the system and this will allow the user more convenience to use. The system not only works as reducing the energy consumption, but also to increase the quality of work performance and the improvement in efficiency at work area. The system works to control the switch of electrical appliances and also to monitor the condition of each office. The data of more than one office is collected in the system at the same time for data analysis purpose and also display on the monitoring sub-system.

This system applies the circuit designed instead of using complex and high cost equipment in terms of hardware and software to build the system. The equipment used in this system includes programmable controller, transceiver module, relay control switching, sensor for detection of movement, some of the electronics components, and with the aid of software to control the whole system. Sensor network is used to detect and collect data in a room condition. After the sensor network collects data, it would send to programmable controller to make an analysis and decision. Programmable controller also provides connectivity with the electric devices of the system and this allows higher suitability in any circuit and connection.

When the controller is analysed the data collected from sensors network, it would make decisions using the programming that setting earlier by producer. It controls the operation of all power switches depends on the conditions at the room. After the decision is made, the controller will send signals to the relay switches through the transmitter. In this system, the purpose of using transceiver is to emphasize a wireless network and communication when sending and receiving data. The receiver will receive the data from transmitter, and then it will pass the data to another controller to analyse and make the decision. The decision will control the relay switches to ON or OFF state. For instance, the light or air-conditioner will switch OFF when there is no one in the room by using the external relay switches that connect parallel to the normal switch of light and air-conditioner.

This system is mainly applied in work area with a timing set within 24 hours. The system will operate fully automated without any outsider to control it after it is being completely done by programmer and this is able to reduce man power and also save time compare to existing system in market. This will help to increase efficiency of smart home system compare to previous research with lower cost. On top of that, it reduce the concern of user to control the system all the time and also save money in placing the internet access to it since the system is able to run without any usage of internet access. It is convenient for any different area or user to use to achieve save time, save the needs of man power, save data usage and mainly to save energy use in daily working time. The operation and process of this concept will present as detail as following and includes the design and circuit connection.

3.2. Implementation of System Design

In this research, there are a few sub-systems involved and also the wireless data communication using RF to transmit related data. Besides that, the locations to place all the sub-systems at different places are considerable to play their roles to achieve their aim respectively. All the data in whole system that had been processed in every moment, will be saved and the data collected will use for data analysis. The progress of data analysis involves the calculation of how much power consumption has been saved using created software. The flow chart, block diagram and figures will show the detail of how is every sub-systems work in overall.

3.2.1. General Flow of the System

Smart Energy Saving and Monitoring System consist of three sub-systems to run the operation which are Detection System, Switches Control System, and Monitoring Control System. These three sub-systems are three separated equipment to play their own role when placing separately and different location respectively. Detection System will detect the movement of the staff in the office and send the related signal to the Switches Control System. After the signal reaches the Switches Control System, the system will start to make the decision of switching the electrical appliances in the office depends on the signal given by Detection System. The data of the decision made will then send to Monitoring Control System for the next operation. The data collected will keep in the Monitoring Control System and also easier to monitor the condition of the office through the desktop. Moreover, the data collected is used for the calculation of how much energy have been used and saved in the whole system. Figure 3.1 shows the general flow of whole system.

These three sub-systems will be placed separately at different location. For the Detection System will be placed at the suitable location to detect the movement of user, for example to place the system right in front of the user, to increase the accuracy of condition in the office whereas for the Switches Control System will be placed at the location which near to the main power supply of electrical appliances in the office so that it is able to control the operation of switches depend on the condition of office. On the other side, Monitoring Control System must be placed at a location which is able to connect to desktop for monitoring and data analysis purpose.

Detection System and Switches Control System will be equipped in the same room of work areas. All of the rooms will be equipped Detection System and Switches Control System. However, only one room will be installed the Monitoring Control System and will be placed in the work area, which is means that the location place will be far from the Detection System and Switches Control System. Detection System is to make detection whereas Switches Control System is to control the operation of switches in all of the offices. Besides that, only one room will be installed the Monitoring Control System which is to monitor the condition of every office and then to make data analysis. This is because one Monitoring Control System is able to receive more than one data from every office with application of Detection System and Switches Control

System, so that the person in charge is able to track the condition of every staff in office area.

There are some precaution of placing the sub-systems in the offices which are all the sub-systems must be placed in the office at same level in building and place the sub-systems at different level is avoided. Figure 3.2 shows that the map of placing all the sub-systems at work area in building. From the Figure 3.2 states that from room 2 to room 34 will place the Detection System and Switches Control System, and room MS will place the Monitoring Control System together with the desktop. When the room is still occupied by the staff like room 18, room 20, room 25, and room 30, the signal will send to the Monitoring Control System in room MS whereas the rest of the room will send the signal of absent condition to the system.

Furthermore, different conditions of the environment of work area are figured out before the systems apply so that to increase the accuracy of data collected. There are two state conditions depends on the staff in an office which are active (S1) and non-active (S2). In addition, the probability when one condition changes to another or remain the same is presented in 4 situations. Figure 3.3 shows every condition that probably occurs in the office area and the transition state when one condition changes to another.

Every probability of state condition is set with different timing to control the operations of switches in an office. The timing set for every probability of state condition is showed in Table 3.1. When one state conditions either active (S1) or non-active (S2) remains the same (a11 or a22), the time taken for checking is within 5 minutes in the system, the data collected for the movement is remain unchanged and the switches will remain in its current state. When the current state is active condition, the system will check the environment of office through the movement of the staff, and the system will turn into non-active state condition (a12) when no movement within 10 minutes is detected, the data collected for the movement is “2” and the switches will turn OFF. However, if the system detects any movement within 5 seconds in the office, the current state or non-active state condition will turn into active state (a21), the data collected for the movement is “1” and the switches will turn ON.

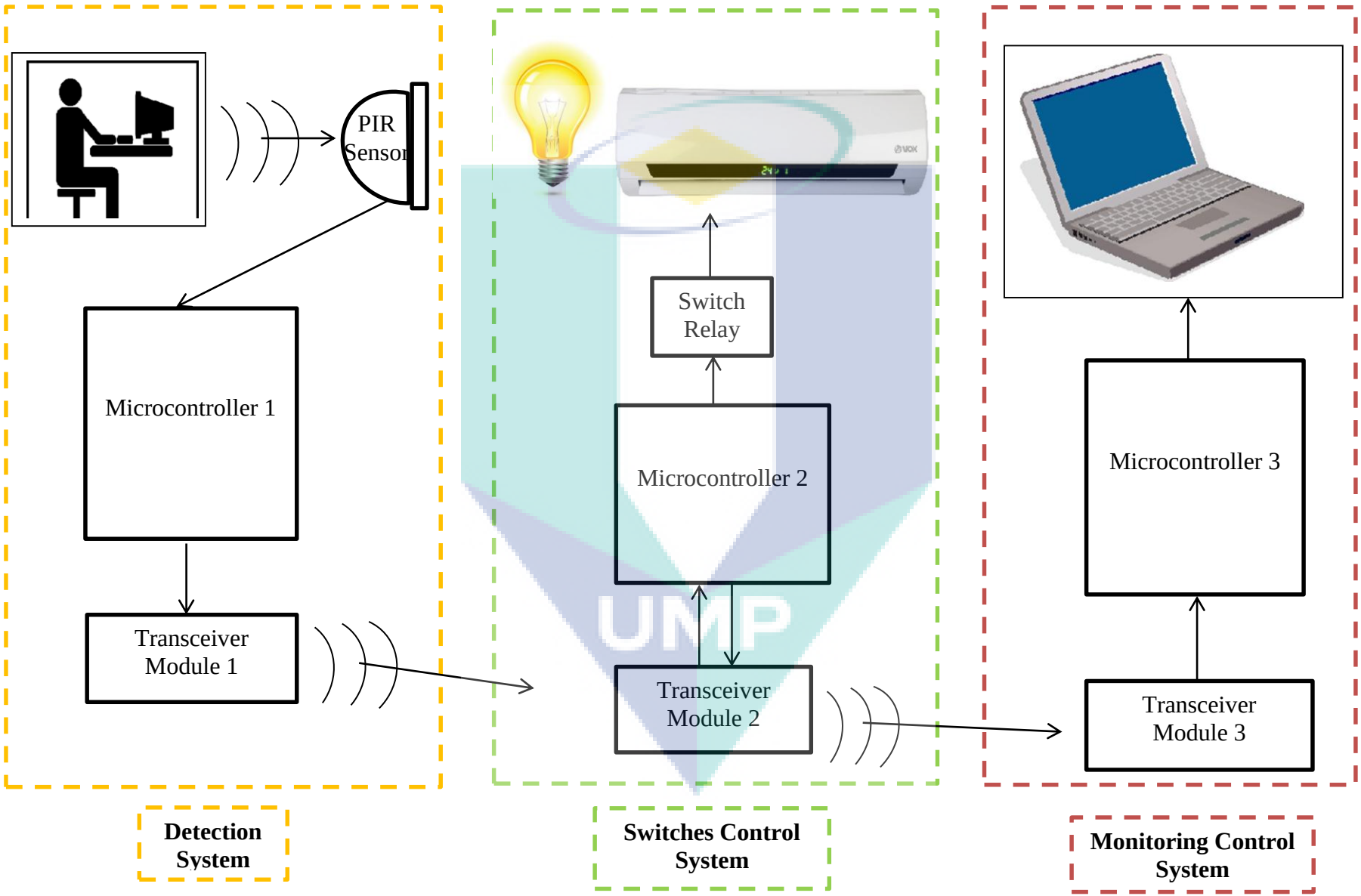


Figure 3.1 Block diagram of General Flow of Whole System

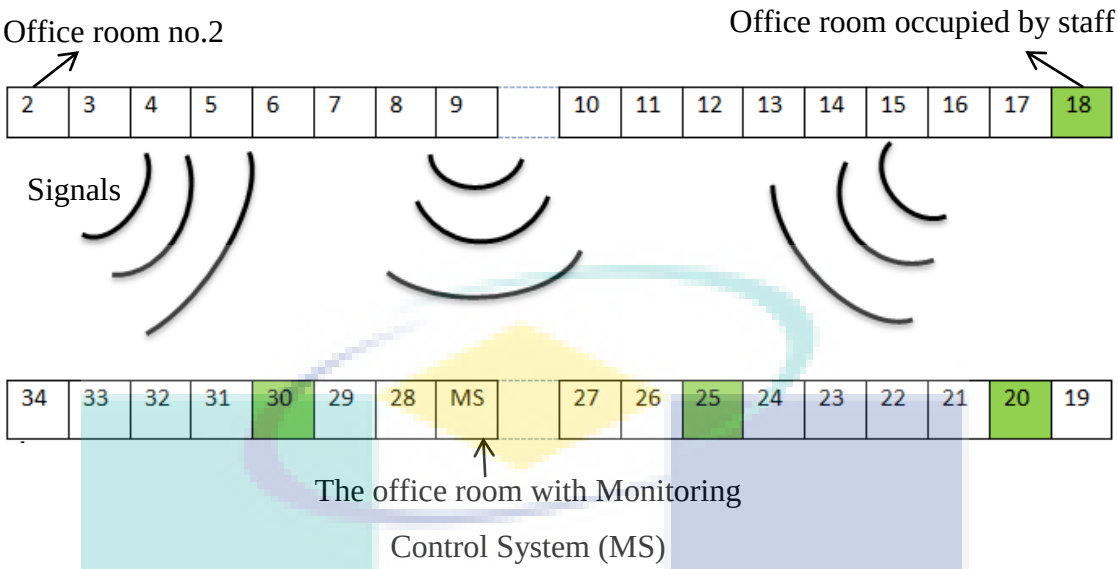


Figure 3.2 The map placing the system at offices (same level) in building.

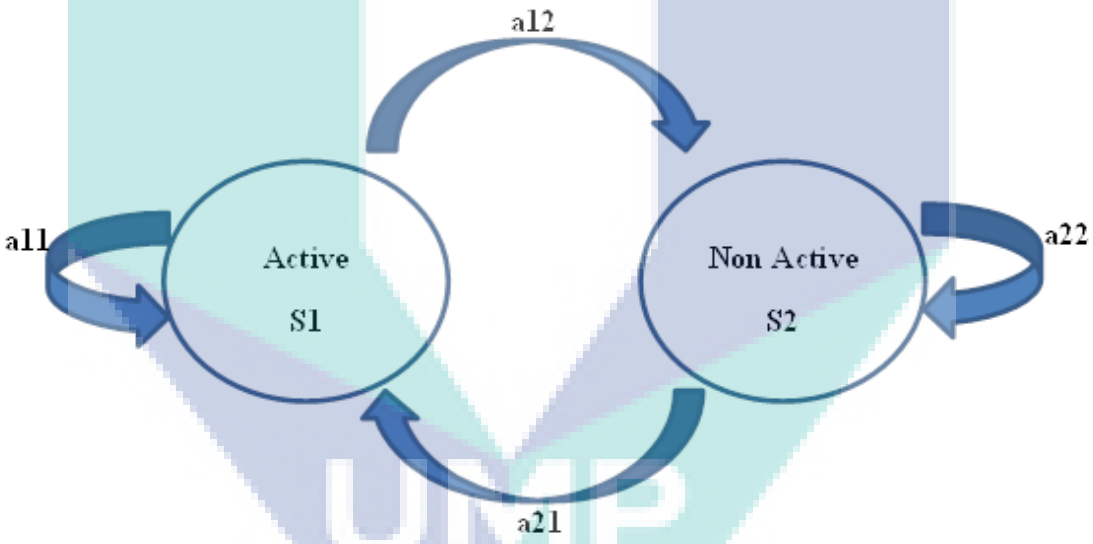


Figure 3.3 The transition state of every condition in office.

Table 3.1 The transition table of every condition in office.

	Time Taken (t)	**Movement (M) / Sensor(C)**	**Current State**	**Next Estimated State**	**Switch State**
a11	5 min	1	Active	Active	ON
a12	10 min	2	Active	Away	OFF
a21	5 sec	1	Away	Active	ON
a22	5 min	2	Away	Away	OFF

3.2.2. Working Principles of Detection System, Switches Control System, and Monitoring Control System

In this research, three sub-systems play their role to make the operation of saving energy at office in buildings. The first sub-system works to makes detection of the condition in office known as Detection System. Detection System works as detector in whole system and to detect the presence of staff in the office. Passive Infra-Red (PIR) sensor is used to sense motion, which means to detect whether the staff has moved in or out of the sensor range. After the sensor received the detection signal, the microcontroller I in Detection System will collect the signal and send to next sub-system through transceiver module I in Detection System. Figure 3.4 shows the flow of how Detection System works in office.

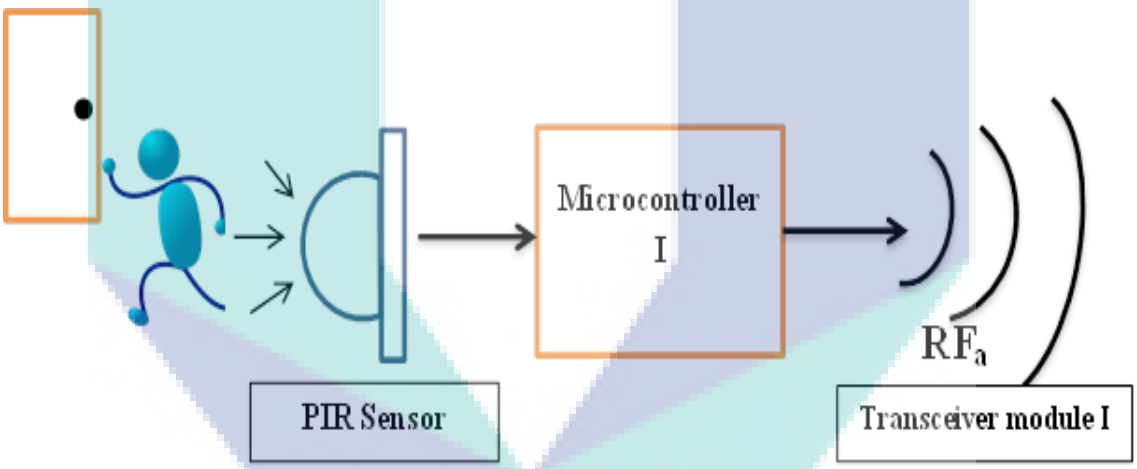


Figure 3.4 The flow of Detection System

The next sub-system to carry out the operation is known as Switches Control System. The components in this sub-system include a microcontroller, transceiver module, and relay module. The transceiver module II will then receive the signal from the Detection System and collect by microcontroller II in Switches Control System. After that, the microcontroller II start to make the decision of controlling the switches based on the signal collected in the office. After decision is made, the switches of electrical appliances are controlled follow by the application of relay module. Relay module is used as protection to avoid any destroys from high voltage flow into the microcontroller in system. The relay module will switch ON or OFF according to the

decision made by microcontroller II. Meanwhile, the data based on decision made is then sending to the next sub-system through the transceiver module II in Switches Control System. Figure 3.5 shows the flow of how Switches Control System works.

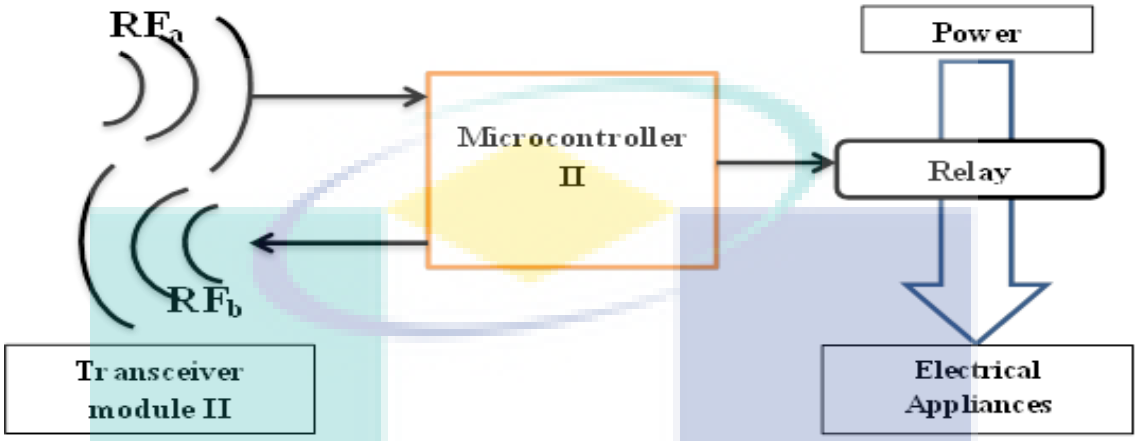


Figure 3.5 The flow of Switches Control System

The next sub-system after Switches Control System is known as Monitoring Control System. The data sent from the Switches Control System is then collecting by the microcontroller III through the transceiver module III in the Monitoring Control System. The data collect is used to make the analysis data of how much of energy has been saved within working hours. Moreover, the data collect will be displaying on the screen of desktop when the condition of every office monitor by the user in room MS in Figure 3.2. At last the data collect and the data analysis both will keep in the system as reference for future. Figure 3.6 shows the flow of how Monitoring Control System works in whole system.

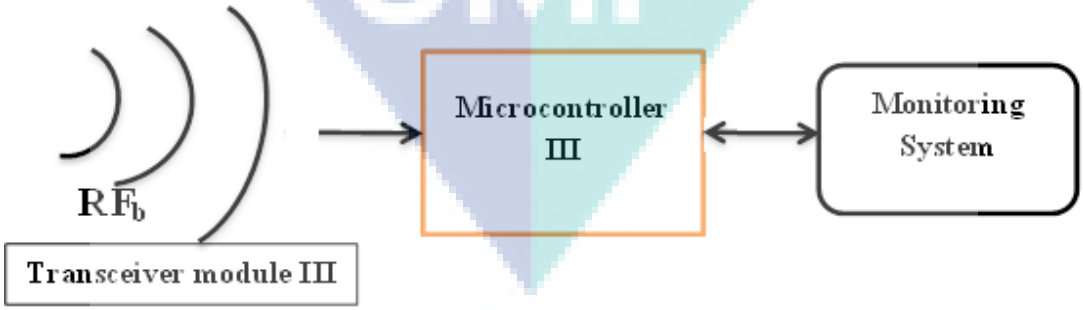


Figure 3.6 The flow of Monitoring Control System

The following flow chart in figure 3.7 shows the working principle of the system overall. The whole process divides into three parts in whole system, which represents the Detection System, Switches Control System, and Monitoring Control System respectively.

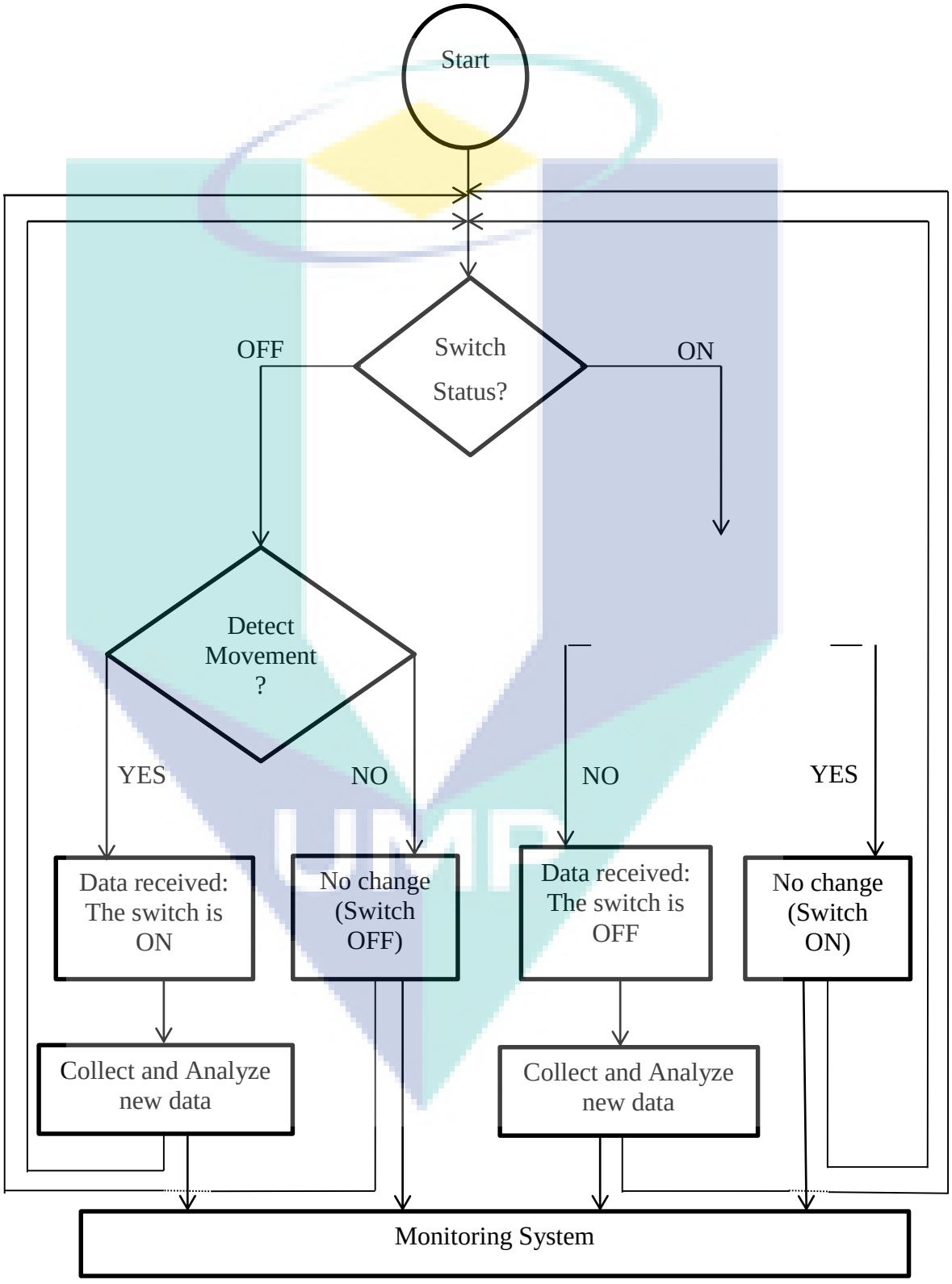


Figure 3.7 The flowchart of Smart Energy Saving and Monitoring System

3.2.3. Working Principles of Monitoring System and Data Analysis

After the operation of switching the electrical appliances is done, the work will be displayed on the screen in the desktop through the Monitoring System. The user is able to monitor instantly the condition of work place which is means the data would be collected time by time and would be displayed to the user. The software used to connect with the microcontroller to execute the command and display the data, known as GoBetwino.

The software GoBetwino is kind of a "generic proxy" for the Arduino. This program is running on a PC and to support Arduino work with some of the things that Arduino is not capable to do on its own. For an instance, the microcontroller and Arduino need to run the system and record the data in real time with the aid of GoBetwino. Besides that, GoBetwino will receive the command coming from Arduino and turn the command into actions, and the signal will possibly return back to Arduino at last. Besides that, GoBetwino is able to define a set of command in template and return back the command in actual form. In the other hand, GoBetwino is able to execute the command received from Arduino and return back to Arduino.

In Smart Energy Saving and Monitoring System, GoBetwino work as connector to support Arduino to execute the command and it function as receiving the input data and giving out the output data to the user. The user is able to monitor the condition of the work area all the time based on the actual command delivered out by GoBetwino which under controlled of Arduino, and the command return back. The data will keep for analysis data purpose after that. Figure 3.8 shows the interface of displaying the condition in office with the aid of laptop or desktop that connects to the Monitoring System. This interface will be going to use during the experiment.

According to Figure 3.8, the data shows switch 1 and switch 2 for the different electrical appliances in room 18 will turn ON or OFF based on the condition in the room. Number with "1" represent ON whereas number with "2" represent OFF for the electrical appliances in room 18. From that the data analysis, the staffs is not around at 10.56am. After 10 minutes, the system will OFF the operation of electrical appliances at 11.06am. When the staff came in at 2.37pm, the system would ON and activate again the operation immediately.

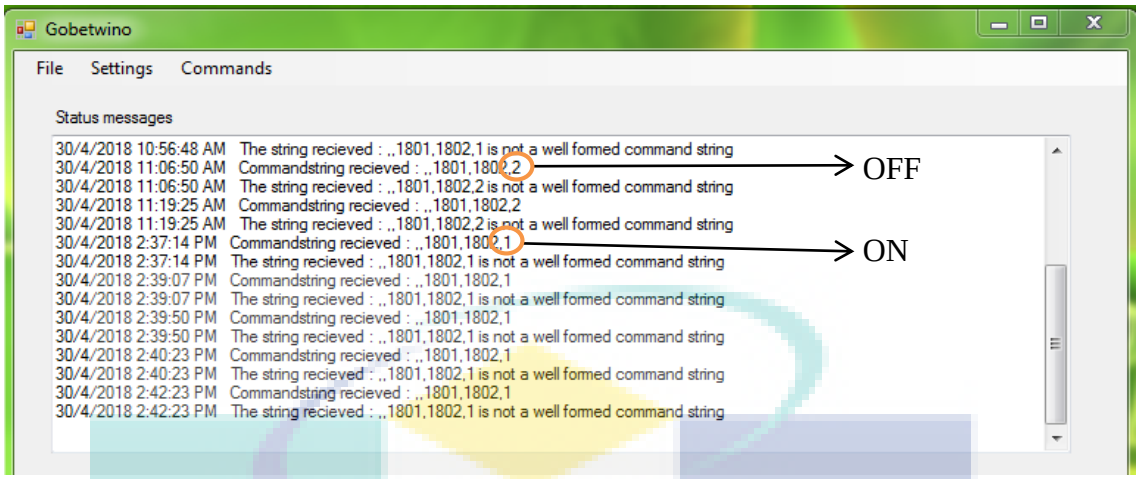


Figure 3.8 Monitoring System by using GoBetwino

In addition, the user is able to choose which room needs to display the condition of office in room which install the Monitoring Control System in Figure 3.2. Figure 3.9 shows that the interface of choosing which COM port to connect according to the Detection System and Switches Control System in any office. After the data showed in the Monitoring System, the data will keep in the system. The button "Automate Excel" will display out the previous data saved in Microsoft Excel.

The data will be generating out from a storage that is Notepad software. All the data collected would save and listed in Notepad automatically which show as Figure 3.10. After that, the data listed in Notepad would generated and display in Microsoft Excel. Figure 3.11 shows the data generated in Microsoft Excel according to data saved with date, time, and information of room number and status of switches listed in Notepad.

After the operation of monitoring the condition of room and saving the data collected, the system is able to start the part of analysing data. The system will figure out the total period of "OFF" status in a day according to the data generated in Microsoft Excel in every office at first. The result of that total period is then analysing with created software to calculate how much energy was saved according to different working hours and wattage in every office respectively. Figure 3.12 show the interface of created software to calculate how much energy was saved based on the data given. The data received from the results include the period of electrical appliances OFF in minutes, total wattage in work place and total working hours in a day. The software will

provide the information of how much energy had been saved and also the percentages. Total energy save is able to estimate in a month too.

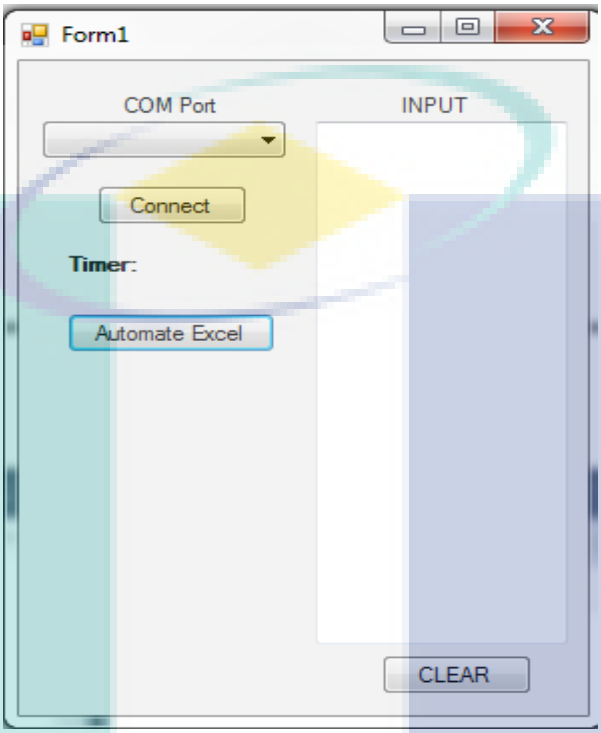


Figure 3.9 Interface of Monitoring System to choose which room to monitor and generate the data saved

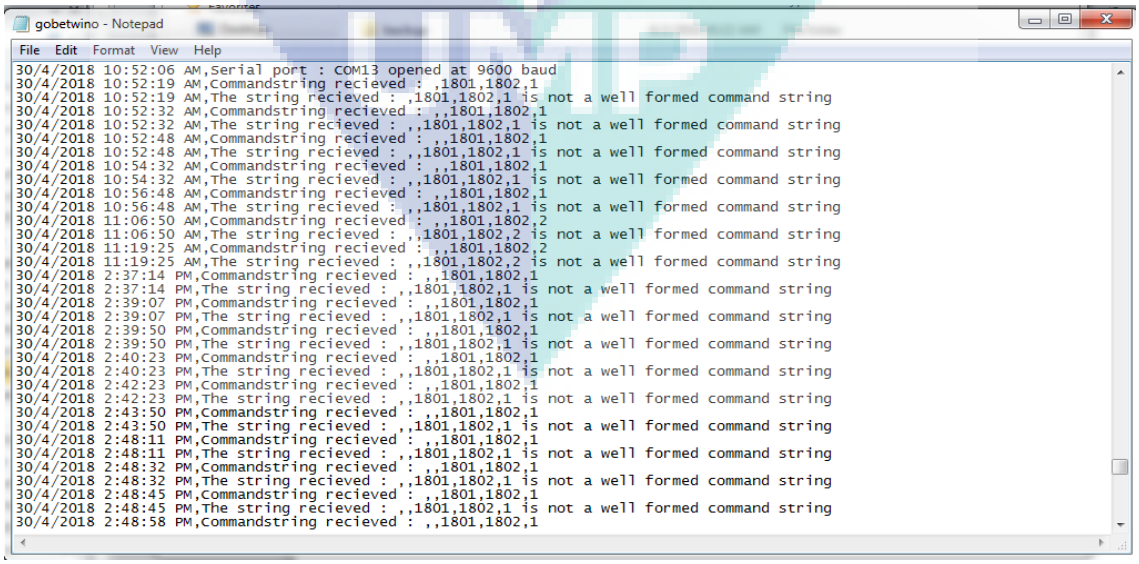


Figure 3.10 Data collected in Notepad software

	A	B	C	D	E	F
1	30/4/2018 10:52					
2	30/4/2018 10:52		1801	1802	1	
3	30/4/2018 10:52		1801	1802	1	
4	30/4/2018 10:52		1801	1802	1	
5	30/4/2018 10:54		1801	1802	1	
6	30/4/2018 10:56		1801	1802	1	
7	30/4/2018 11:06		1801	1802	2	
8	30/4/2018 11:19		1801	1802	2	
9	30/4/2018 14:37		1801	1802	1	
10	30/4/2018 14:39		1801	1802	1	
11	30/4/2018 14:39		1801	1802	1	
12	30/4/2018 14:40		1801	1802	1	
13	30/4/2018 14:42		1801	1802	1	
14	30/4/2018 14:43		1801	1802	1	
15	30/4/2018 14:48		1801	1802	1	
16	30/4/2018 14:48		1801	1802	1	

Figure 3.11 Data collected generate in Microsoft Excel

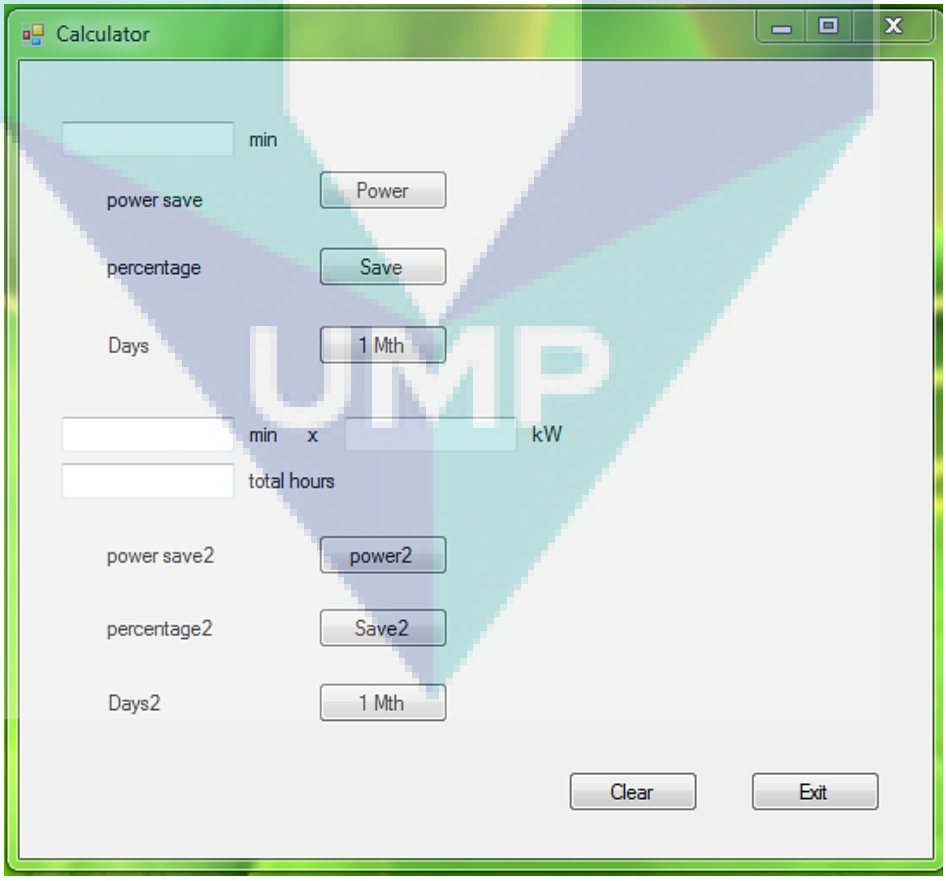


Figure 3.12 Interface of Created Software

One of the main objectives in Monitoring Control System is to analyse the data of how much energy save by using the information given include the wattage label on the electrical appliances and how much of time to use it. Furthermore, the method of analysing data is to apply the formula of estimating electricity usage by using information provided like the wattage of every appliances and the period used. This would finalise the total amount of energy usage by calculating the energy used of every appliance or electronic device easily.

For an example, Table 3.2 shows the power average usage for the appliances exist in the office area normally. Analysis data will calculate the energy used according to the information given in Table 3.2.

On top of that, Equation 3.1 is used to analyse data collected in the Monitoring System to calculate the results of kilowatt hour consumption or known as energy. The unit of kilowatt hour is equivalent to unit of energy, however the unit of energy is joule (J) but not kilowatt hour. This is because the according to International System of Units (SI), hour is unit of time but also non-SI units based on the metric system. Metric system is the system of measurement which developed by a committee of the French academy of Science from 1791 onwards.

According to the information of Table 3.2 and Equation 3.1, Table 3.3 shows the steps of estimating the energy usage consumed by appliances. For an example, the appliance with label of 1100watts is used for 3 hours in a day. Then the consumption is calculated in how many days per month to get the average usage. From the result shows in Table 3.3, the average usage for the appliance with 1100watts is 90kWh in a month.

After apply the Smart Energy Saving and Monitoring System, the research will make the comparison for the energy used before and after the system is applied. The results of energy usage after the system is applied are calculated by the created software in Figure 3.12 according to total time of all appliances is used. As the time for an appliance to consume the power is less, the power consumption will become less too. For an example showed in Table 3.4, the same appliance with 1100watts is used for 2 hours in a day after the system is applied. The average usage for the appliance will become 66kWh per month using the same calculation as Table 3.3. After the equation 3.2 is applied, the energy save is up to 26% for the appliance in total power

consumption. Based on this concept, the power consumption will reduce after the system is applied and the results have been analysed.

Table 3.2 The daily energy values listed for the most efficient units in their class.

Appliance	**Power(Watts)**
Room air-conditioner	1100-5200
Laptop computer	40-120
Desktop computer	80-120
Fluorescent light tube	36

Source: Website of Consume Guide to Home and General Electric

$$\frac{watt(W) * hours\_used\_per\_day(h) * days\_used\_per\_year}{1000} = kiloWatt - hour(kWh) consumption / joules(J) \quad (3.1)$$

Table 3.3 The steps of how to analyse the energy usage for appliance

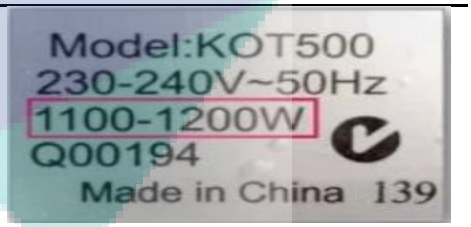
The Flow of Steps	**Steps of Working**
1. Check the wattage of the appliance used by looking for wattage label or manual	
2. Multiply the unit's wattage by the number of hours user use it to find the number of watt-hours consumed each day	1100 watts * 3 hours = 3300 watt-hours per day
3. Convert the unit to kilowatt since kilowatt is the unit used in electricity bill. Use watt-hours divide by 1000	3300 watt-hours per day / 1000 = 3.3kWh per day
4. Calculate the average usage over a month period	3.3kWh per day * 30 days = 90kWh per month (average)

Table 3.4 The data analyse of energy usage for appliances after apply the system

The Flow of Steps	**Steps of Working**		
1. After the system is applied, the time of power taken become lesser	1st hour √	2nd hour X	3rd hour √
2. Multiply the unit's wattage by the number of hours user use it to find the number of watt-hours consumed each day	1100 watts * 2 hours = 2200 watt-hours per day		
3. Convert the unit to kilowatt since kilowatt is the unit used in electricity bill. Use watt-hours divide by 1000	2200 watt-hours per day / 1000 = 2.2kWh per day		
4. Calculate the average usage over a month period	2.2kWh per day * 30 days = 66kWh per month (average)		

$$\frac{A - B}{A} * 100\% = energy\_saved(\%) \qquad 3.2$$

A = energy consumed before system applied (kWh)

B = energy consumed after system applied (kWh)

3.2.4. Implementation of Hardware and Software

A system is produced through the implementation of both hardware and software. The hardware consists of electronic components and the physical outer casing whereas the software consists of collection of code is made and installed in Smart Energy Saving and Monitoring System.

3.2.4.1. Circuit Diagram

Figure 3.13 shows the circuit diagram of (a) Detection System; (b) Switches Control System; (c) Monitoring Control System. According to Figure 3.13, the three different circuit connections are allocated at different sub-systems respectively. The

Detection System and Switches Control System will place at the same office whereas the Monitoring Control System will place at different office.

Three Arduino platforms are used because all needs to drive the microcontroller in all three sub-systems respectively. For the Detection System, Arduino platform work with microcontroller to control the detection by using the PIR sensor, after that send the related signal through the transceiver module. For the Switches Control System, Arduino platform work with microcontroller to control the relay to switch the electrical appliances and also receive and transmit the signals through transceiver module. On the other hand, Arduino platform work with microcontroller to receive the signal through transceiver module and display the data using desktop or PC in Monitoring Control System. Arduino platform use as connector in between the transceiver module and desktop or PC due to the desktop or PC does not provide Serial Peripheral Interface (Fabi, Spigliantini, & Corgnati) which allows sending the data. Besides that, Arduino platform is needed to display the data with aid of GoBetwino which work with Arduino. The use of desktop or PC is to monitor the condition of office easily and also use for analysing the data with the aid of created software showed in Figure 3.12.

Three transceiver modules are needed to work as media to transmit and receive signals within very long distance in between three sub-systems. Furthermore, the ability of transceiver module consists of transmitting and receiving more than one signal at the same time without internet. Transceiver module is very useful especially in Monitoring Control System because it is able to receive more than one data from every office at the same time in same level of the building.

The circuit works after the code is applied in the microcontroller respectively to play their role in the whole system. Certainly all the codes are different in three sub-systems since the function of every sub-system is not the same as each other. Both of circuit and coding applied would support each other to make the system works smoothly.

3.2.4.2. Code in Detection System

At first, the code will set the range of transmitting the signals to the receiver controller and which channel is need to connect (APPENDIX A). The follow by the code of detection system operate in the room. The PIR sensor will connect to the controller in Detection System when the sensor detects movement, the signal of presence of the staff will be recorded. In other words, when the sensor detects no

movement, the signal of absence of the staff will be recorded. The channel of transceiver module will turn on again to send the signal to the Switches Control System at last.

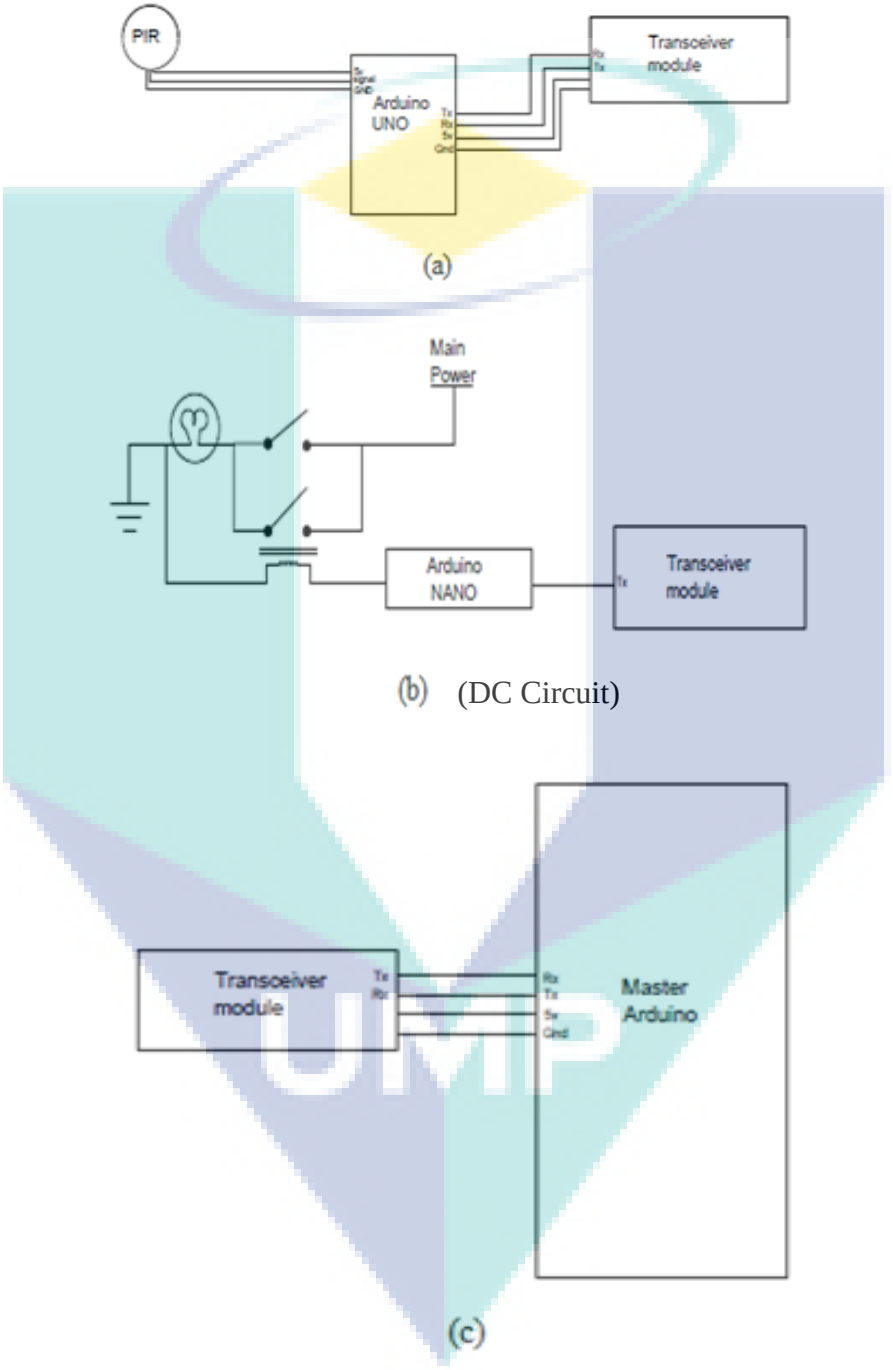


Figure 3.13 Circuit diagram of (a) Detection System; (b) Switches Control System; (c) Monitoring Control System

3.2.4.3. Code in Switches Control System

For the code in the controller of Switches Control System (APPENDIX A), the range of receiving and transmitting the signal is set and which channel need to connect is set at first. After the signal is received, then follow by the code of making decision. If the detected signal is HIGH, the assigned outputs which are the electrical appliances will be turned ON. If the detected signal is LOW more than 10 minutes, the electrical appliances will be turned OFF. This code will keep looping after every status is changed. Every decision made will be sent to the Monitoring Control System at last.

3.2.4.4. Code in Monitoring Control System

For the code in Monitoring Control System (APPENDIX A), the range of receiving signal is set and which channel is needed to connect is set at first. After receive the signal from Switches Control System, and then follow by the code of displaying the results. The monitoring system will display the condition of the room according to which of the room number the signal is send. If the room is occupied by the staff, the monitoring system will display "1". If the room is not occupied by anyone after 10 minutes, then the monitoring system will display "2". At last the signal will keep as history data for data analysis purpose.

3.3. Technical and Functional Specification

3.3.1. Microcontroller

The master in the concept to control the whole operation of the system is the microcontroller. In this research, a common and user friendly tool is used in the system which using Arduino board to function the microcontroller ATmega328 (APPENDIX B). Arduino is chosen to be used due to some advantages compare to other platform:

1. Lower-cost
2. Cross-platform
3. Simple, clear programming environment
4. Open source and extensible software and hardware

3.3.2. Transceiver Module

nRF24L01+ module is chosen to be used due to some advantages compare to other platform (APPENDIX C) as the following:

1. Low power mode and bring low power consumption.
2. Multiples channels to transmit and receive the signal more than one at the same time with different frequency.
3. Operation in the world-wide ISM frequency band at 2.400-2.4835GHz
4. The range able up to 150m.
5. Highly integrated and low-cost hardware for reliable telemetry and consumer applications.

3.3.3. Motion Sensor

PIR sensor is suitable to be used in this research (APPENDIX D) due to several advantages:

1. Easily to detect when a person has left or entered the area
2. Low power
3. Low cost
4. Pretty rugged
5. Presents of wide lens range
6. Easily to interface with any controller

3.3.4. Relay Module

The main operation of a relay is chosen to be used to control a circuit with only a low-power signal. Relay is used to switch on and off a larger current which controlled by smaller current after having an amplifying effect of a small voltage applied to the relays coil. This situation will make the protective relay prevent equipment from damages like overcurrent, undercurrent, overloads and reverse current.

The application of relay are used to realize logic functions in providing safety critical logic and to provide time delay functions for delay the time of open and close of contacts. On top of that, relays are widely used to starting coils, heating elements, pilot

lights and others. In this system, the main function of relay module is to control the power supply to the electrical appliances and also protect the system from the destroying of blowing in high voltage.

3.4. Setup for the experiment

3.4.1. Location of office to place the system

Although Smart Energy Saving and Monitoring System mainly apply at indoor office area, but not all types of offices are suitable to place the system. The system is preferable to apply in the area of office with less people due to fewer disturbances. More Detection System needed when more people occupied in the office area to increase the sensitivity and accuracy of data.

In this research, the locations of the office area have to be well selected while carrying out the experimental work especially in personal office or certain section in office area. The consideration of different types of offices was included lecturer's personal office, thesis room in library, office administration, service counter in faculty and others. Different results were collected from every work area and the results were analysed through the comparison made. The locations of different work area were showed in Figure 3.14, Figure 3.15, Figure 3.16 and Figure 3.17. The electrical appliances in work included the light, air-conditional, desktop, and others equipment in the office.

3.4.2. The way of placing Detection System, Switches Control System and Monitoring Control System

All of the three sub-systems will be placed separately at different location. Some of the precautions are considered when apply the sub-system. For example, the distance in between all of the sub-systems to be considered and the way of placing the sub-systems should be avoided from obstacle detected like the wall and doors. The distance between all of the sub-systems is up to 50 meters without obstacle and up to 40 meters with obstacle. The obstacles will reduce the detection of transceiver module and influence the signal transmitted. Therefore, the obstacles in between the sub-systems should be the less the better.

= Location of Detection System

Figure 3.14 Lecturer's personal office

Figure 3.15 Thesis room in library

Figure 3.16 Office administrative

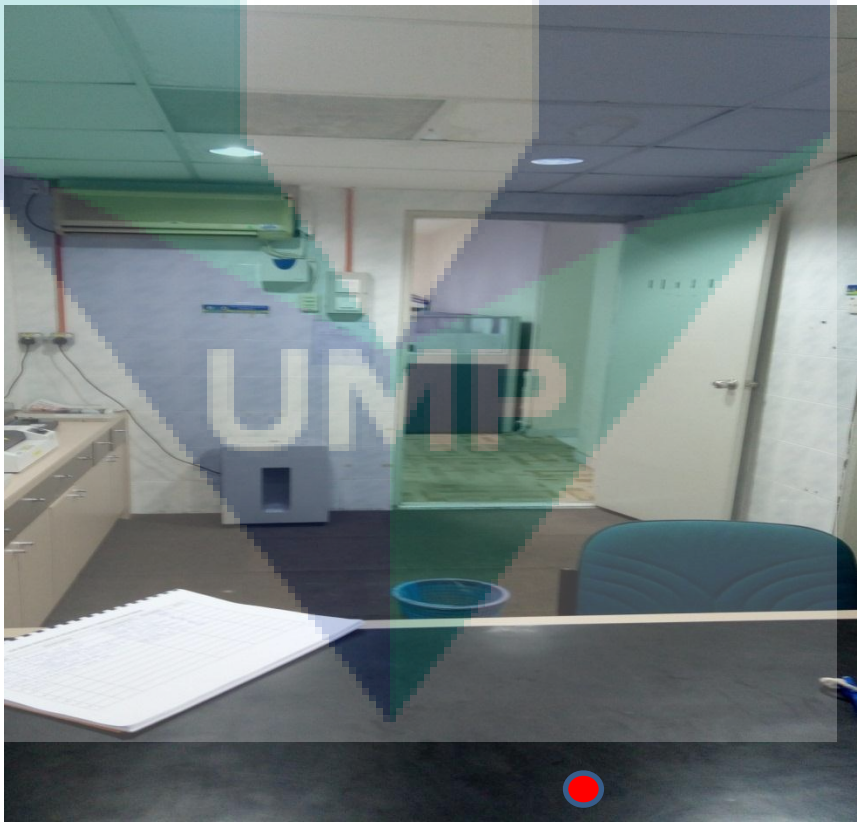


Figure 3.17 Service counter in faculty office

Detection System should be placed right in front of the staff or allocate at a corner which is able to detect the movement of people easily when anyone come in or out from the office area. Figure 3.14, 3.15, 3.16 and 3.17 have showed the examples of placing the system. Detection System should be placed at a higher position to make sure that PIR sensor has wider view allow making detection. Besides that, the sensor must be placed at somewhere which avoided from hot surface objects like desktop computer or lights to prevent any mistaken data collect in the system. The best position to place the Detection System is to hang on the wall right in front of the staff in the office.

On the other hand, Switches Control System should be allocated parallel to all main switches in the office such as the light and air-conditioner, or parallel to the main circuit breaker to control the operations of all switches of electrical appliances according to the condition in the office.

Furthermore, Monitoring Control System would be allocated in different room with Detection System and Switches Control System, and place at office with the mid-range of every office to ensure the data transmitting is easier. A desktop or laptop is needed to monitor the condition of office area. The data would be collected from time to time and display to the user based on the specific office. Another important thing was to make sure that Monitoring Control System would be placed in same level to the offices with the application of Detection System and Switches Control System to allow the data transmit smoothly and with condition of fewer obstacles. The lesser the obstacles in between all the sub-systems, the error could be minimized for the whole system.

Besides that, all of the sub-systems are available to change the setup according to different environment of work area due to the system is portable to use in everywhere. Modification of the existing office area to apply the system is easy and lower cost to apply the technology in the building. Figure 3.18, 3.19 and 3.20 shows the Detection System, Switches Control System, and Monitoring Control System respectively.

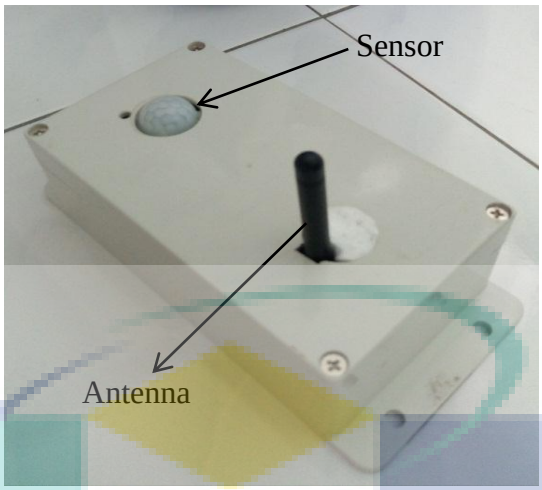


Figure 3.18 Detection System

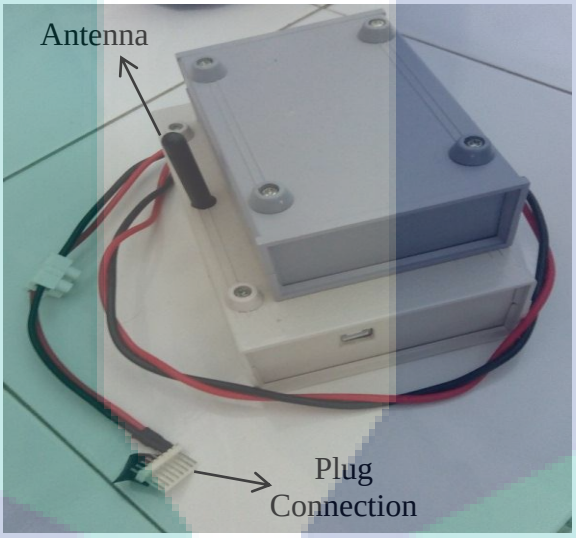


Figure 3.19 Switches Control System

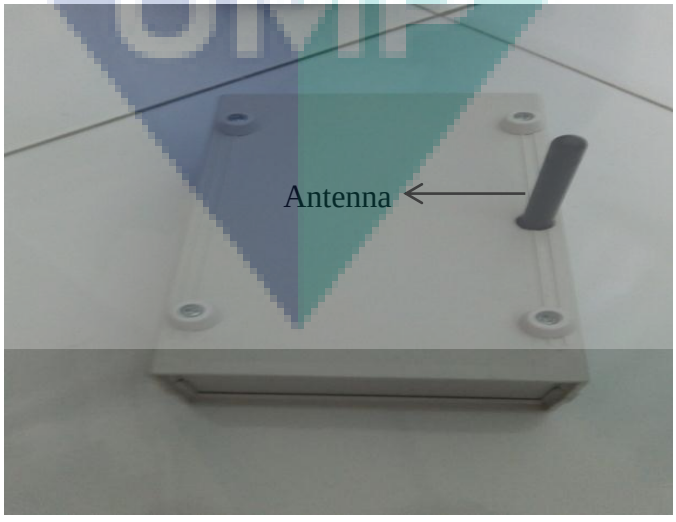


Figure 3.20 Monitoring Control System

3.5. Summary

Smart Energy Saving and Monitoring System works as a system to reduce the energy consumption with lower cost needed to install. The system also increases the quality of work performance and the improvement in efficiency at work area with the aid of monitoring system. The system consists of three sub-systems which are Detection System, Switches Control System and Monitoring Control System. The whole system would help to save the energy through several operations. Detection System would detect the presence of staff in the office. Switches Control System would switch ON and OFF for the electrical appliances in the office. Monitoring Control System would collect the data and analyse the data. The system would give a results of the overall energy saving. The system was able to be installed with lower cost and this is because the system was developed by its own design in both hardware and software. On top of that, some of the electronic devices were low cost and easily to get to build the system. However, some of the precautions were needed to consider before install the system in office area. For example, all the sub-systems must be allocated at suitable location to run the operation. In conclusion, the system was able to save the energy in better way.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1. Introduction

The research was carried out with the implementation of design and the prototype created. The experiment was carried out based on different aspect include identity of user, location to place Detection System and Switch Control System in work area, and location to place the Monitoring Control System according to the suitable distance and position. All locations found were almost similarly to the real office work area to collect high accuracy data. The data collected within working hour in working day which relies on the real condition in work area. Besides that, the timing to operate the switch was estimated in experiment when one transition state changes to another. All consideration was taken care to get a more accurate and precise results.

Data analysis of energy save was analysed based on the results collected from the experiment. Total of energy saved was calculated according to the Equation 3.1 and 3.2 with the parameters provides in results include the total time of electrical appliances in OFF state and the wattage of all electrical appliances in the offices. Lastly, a comparison was made according to the total energy use before and after the SESMS was applied and also the percentages of energy saved was showed in the final data analysis.

4.2. Initial Experiment

Before the experiment is carried out, there are some requirements involved. The consideration of locations taking for experiment include lecturer's personal office, thesis room in library, office administrative, service counter in faculty and others. All locations consists of similarity like personal office or less disturbance of a lot of people

come in and out of the room, specific working place for a staff, and electrical appliances in the office. The locations of the system placed are showed from Figure 3.14 to Figure 3.17. During the experiment is carried out, their movements in daily activity have been detected by the system and the data is recorded. The data of switching the relay is recorded according to the data in Detection System although the Switches Control System did not connect to the electrical appliances in the office.

The system was checked at first before carrying out the experimental in student's room. The system functions well and bring out the desired results of saving energy. After that, the experiment is allowed by some of the staffs and students, to place the Detection System and Switches Control System at their work place. A laptop is ready to connect to Monitoring Controller System and the location is well selected before the experiment is carried out.

All of the sub-systems are brought out the experiments with different distance in between the sub-systems. The number of obstacles that the transceiver module is able to afford is discovered out and the exact locations to place the sub-systems in the office are well selected before the experiment. This will increase the accuracy and precision of the data collected.

4.3. Results of Experimental Work

After the system was applied in the work area, the results of total energy used after the Smart Energy Saving and Monitoring System was applied and the results of total energy saves were recorded and showed in Table 4.1 and 4.2. Total energy saved has been analysed out by the calculation of how much time of the electrical appliances consume the power in working hour, and make the comparison with total working hour, then the results were analysed through the created software in Figure 3.12.

According to Table 4.1, total energy used before the system was applied had been recorded based on the electrical appliances in the office related and total working hours of the staff related. The data of total energy used after the system was applied had been analysed based on the total time of consuming the power supply in the office related. After that, total energy saved were analysed based on different identity of user and locations.

According to Table 4.2, total time in OFF state for the electrical appliances in the offices was analysed based on the data collected through the Monitoring Control System. Data of total energy saves and the percentages were analysed through the created software in Figure 3.12.

Table 4.1 Data analysis of total energy saved by making comparison of before and after the system was applied

Staff/Student/Location	Total Energy used before the system is applied (kWh)	Total Energy used after the system is applied (kWh)	Total energy save (kWh)
Lecturer	42.4952	32.7213	9.7739
Post-doc	44.8598	32.7297	12.1301
Lab assistant	33.5095	23.2120	10.2975
Admin	42.4989	32.2014	10.2975
Student in laboratory	33.5641	33.3023	0.2618
Student in workstation	44.0547	39.9532	4.1015
Intern student	44.5280	41.0370	3.4910
Fellowship student	45.2884	40.7505	4.5379
Lecturer hall	52.3600	34.2958	18.0642
Counter	47.1212	38.2200	8.9012
Thesis room	47.1220	22.2510	24.8710

Table 4.2 Data analysis of total energy saved by different user and different locations

Staff/Student/Location	Working hours (h)	Total time in OFF state (min)	Energy save (kWh)	Energy saves in percentages (%)
Lecturer	8	112	9.7739	23.99%
Post-doc	8	139	12.1301	27.04%
Lab assistant	6	118	10.2975	30.73%
Admin	8	118	10.2975	24.23%
Student in laboratory	6	3	0.2618	0.78%

Table 4.2 Continued

Staff/Student/Location	Working hours (h)	Total time in OFF state (min)	Energy save (kWh)	Energy saves in percentages (%)
Student in workstation	8	47	4.1015	9.31%
Intern student	8	40	3.4910	7.84%
Fellowship student	8	52	4.5379	10.02%
Lecture Hall	10	207	18.0642	34.50%
Counter	9	102	8.9012	18.89%
Thesis room	9	285	24.8710	52.78%

According to the Figure 4.1 and Figure 4.2, the application of Smart Energy Saving and Monitoring System is reasonable and reliable in work area based on different location and also different identity of user. The identities of user include lecturer, post-doc staff, lab assistant, admin staff, and student whereas the location of work area include personal office, laboratory, workstation, lecture hall, counter faculty, and library. The system was applied to all users in the work area with different standard of working hour. Based on the result in Table 4.1 and 4.2, total of energy saves was calculated through the total time of consuming the power for electrical appliances in working hours and the results were recorded in the experiment. Percentages of total energy save was calculated according to different standard working hours respectively.

For the lecturer in office area the total energy saves was 9.7739kWh whereas for the post-doc staff in computer room the total energy save was 12.1301kWh which showed the most among others. Total energy saves for lab assistant and admin staff was same as 10.2975kWh with different working hour. For the students in lab and workstation, the total energy saves were 0.2618kWh and 4.1015kWh respectively. Based on the specific location spotted in experiment, total energy saves were 18.0642kWh, 8.9012kWh and 24.8710kWh for the work area lecture hall, counter faculty and thesis room in library respectively. Total energy saves for the student show the least among all the users. Further explanation of data collected was analysed based on different aspect.

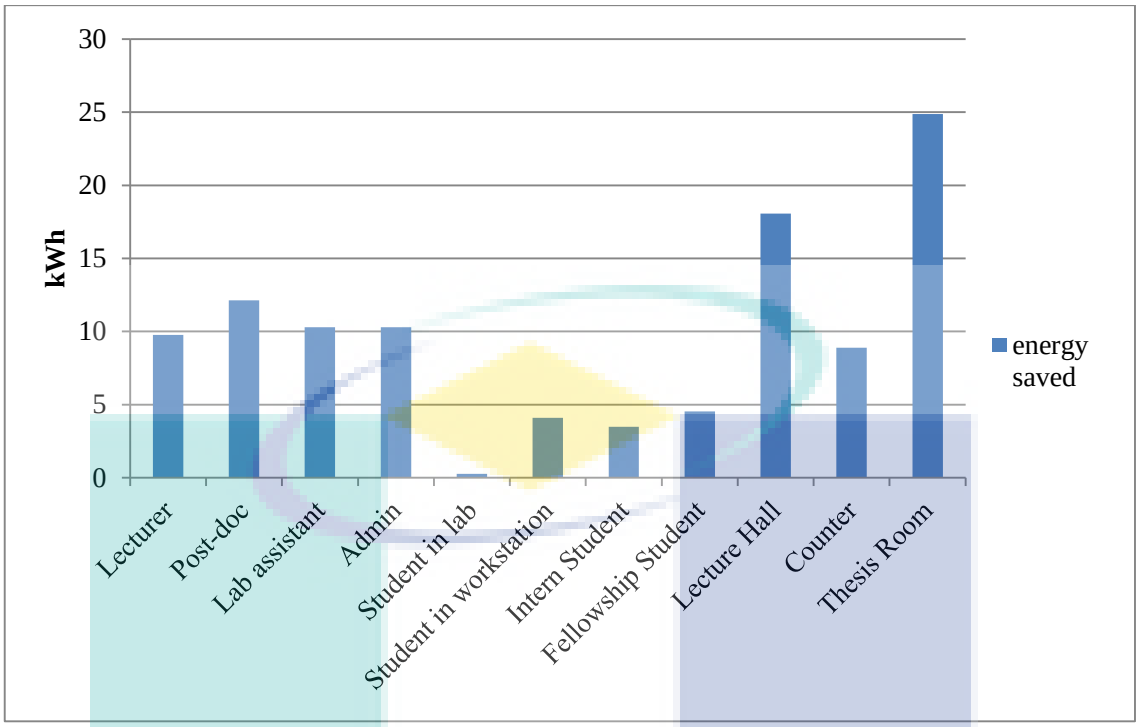


Figure 4.1 The total energy saved by different identity of user in work area

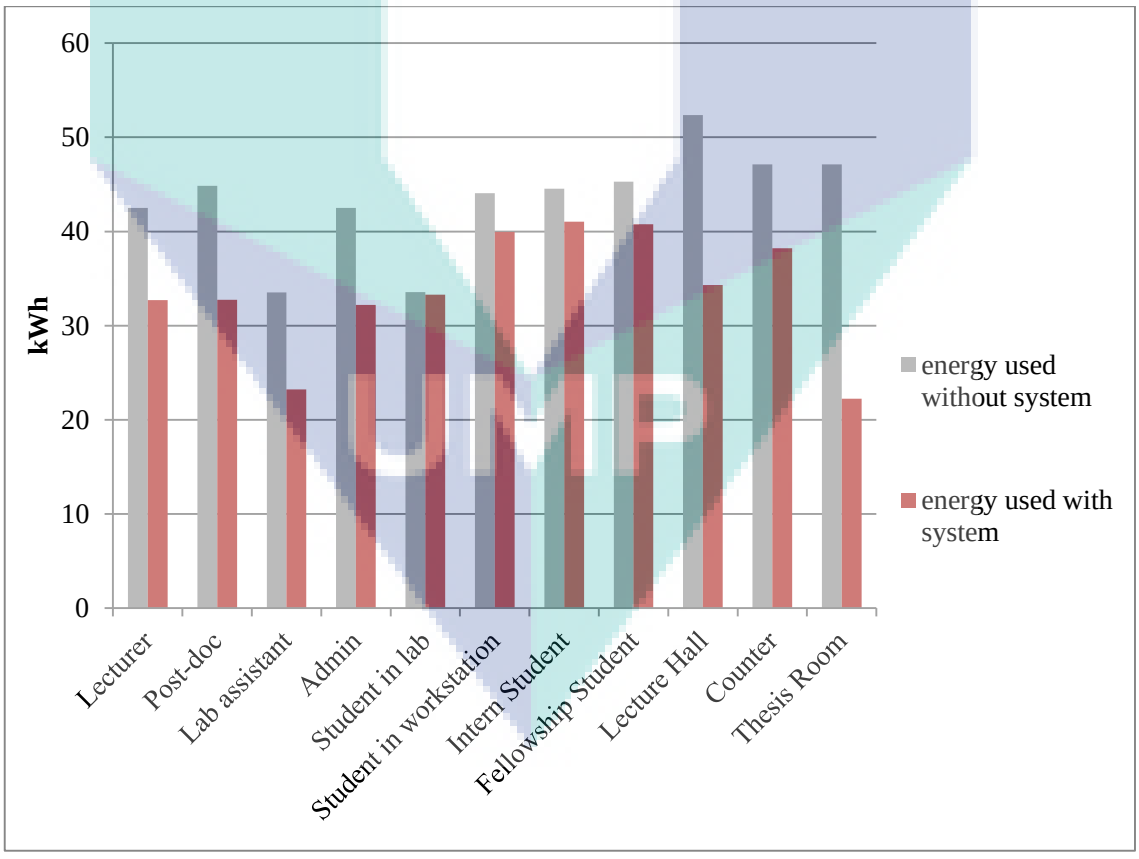


Figure 4.2 Data of energy used before and after the system was applied in work area

4.3.1. Location

The location of placing the Smart Energy Saving and Monitoring System is very important especially in work area. Not all kind of work areas is suitable to apply the system. The system is more reliable to place at personal office compare to a crowded work area. The system would probably receive wrong signal in a work place with more than one staff. For an instance, the result of total energy saves showed the least when the system applied in laboratory in Figure 4.1. The system is more reliable use in other work areas such lecturer's office room, office admin, or workstation with less activity normally. Laboratory is less suitable to place the system as the work place would be occupied frequently, and also some of the instrument in laboratory would probably operate 24 hours and the electricity is not able to shut down once nobody in laboratory. The system should place more sensors to make detection in crowded work place in case. On top of that, the lecture hall is needed to place more sensors to avoid any inaccurate data although the result showed much energy was saved. For the counter of faculty, the results showed that system was inappropriate to place due to the reason of a lot of people which will pass by the counter without putting any affair. Some specific work area like the thesis room in library is suitable to place the system with the aid of saving power. Thesis room was rarely fill with crowded and librarian only available when anyone request for the thesis reference. Hence, certain specific work area like thesis room, meeting room or student's activity room is suitable to place the system.

4.3.2. Identity of user

There are different types of user applied the system in work area which are staff and students in university showed in Figure 4.1. From the figure, the result showed that students category will save less power compare to staff category based on different standard working hours. Students are stay in their work place frequently normally compare to the staff with full of outside activity like meeting, giving lecture, doing research in lab and other. The system will be able to OFF the electrical appliances to save power when there is nobody in certain work area most of the time. The results collected conclude that the system is more suitable to user as staff in work area.

4.3.3. The timing set

The time set to OFF the electrical appliances was 10 minutes when no one in the work place. This setting was the optimum timing for the system to control the operational of electrical appliances in work place. If the electrical appliances turn OFF and back on with too fast and too often it would bring some negative effects. When turn ON immediately right after turn OFF the electrical appliances, it would cause power dissipation and also produce higher rate of inrush-current in the appliances. According to article ("Cool-down Time for Inrush Current Limiters," 2013), a maximum instantaneous input current drawn by electrical equipment during the initial power up would result high inrush current. Besides, when the equipment draws more energy until it heats up, possibly the components which build in resistance only as the local operating temperature increases and this would leave the equipment at risk with inrush peak current upon initial start-up (Heath, 2017). If the current drawn is too large it will bring the permanent damage to the equipment. The equipment requires a cool-down time to increase the resistance of inrush current after power is removed. Figure 4.3 shows that a sampling of convective cooling period for Amertherm NTC Thermistor Inrush Current Limiter. Some of the devices need more than 500 seconds to cool down totally. In conclude that the electrical appliances need some time to recover back to steady state.

Moreover, the time set less than 10 minutes in the experiment before, the system showed not ideal result. This is because the system is too fast to turn OFF the appliances. Some of the staff always busy with their work, they would just go out in a short while from the work place and come back after 5 minutes. This would make the system to turn ON the switches again, and it would damage the electrical appliances. The energy saved for the duration with 5 minutes was not much compare to 10 minutes. It was a high possibility of a person completely leaves from the office after the interval of 10 minutes. In conclusion, if the duration taken was too long, it was not energy practical anymore; if the duration taken was too short, the negative effect would harm the electrical appliances.

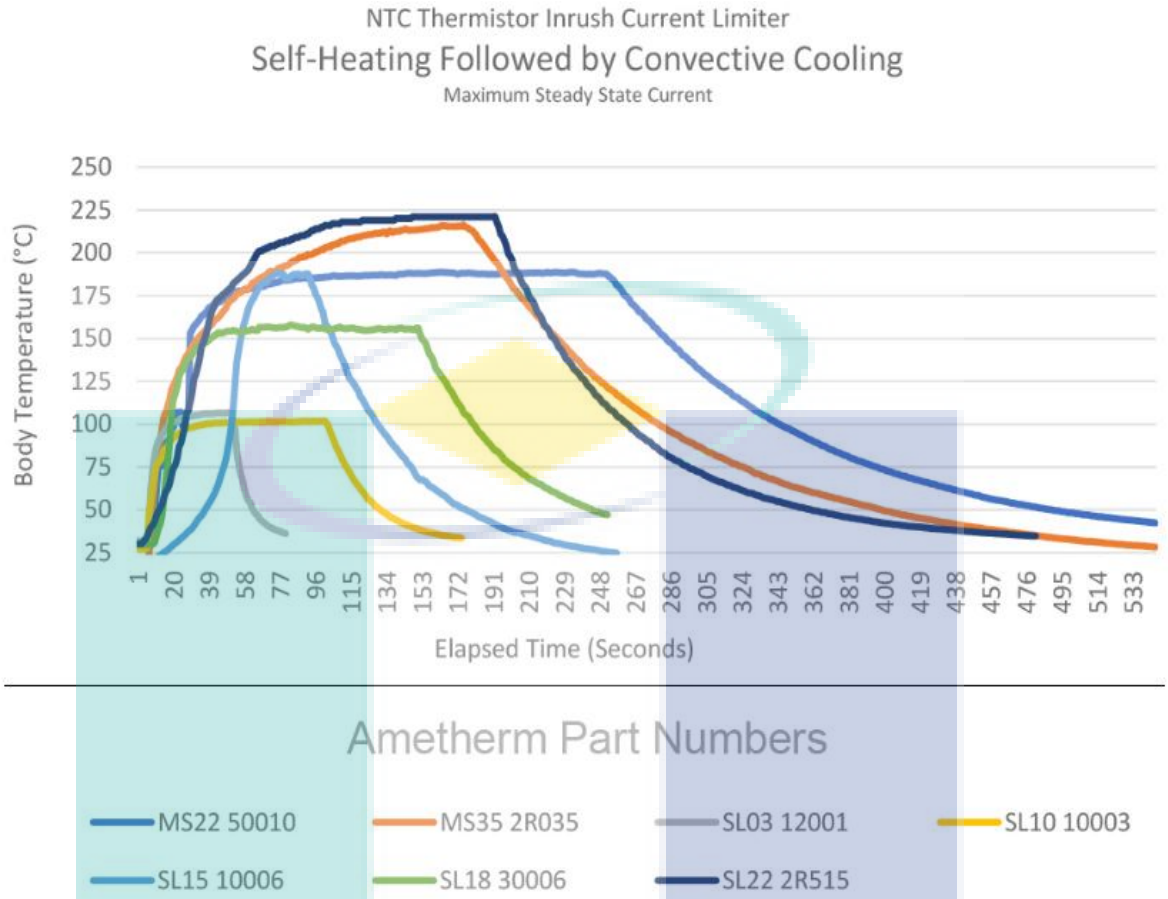


Figure 4.3 Self-Heating Followed by Convective Cooling for Thermistor

4.3.4. Distance between the sub-systems

There was three sub-systems in Smart Energy Saving and Monitoring System that known as Detection System, Switches Control System, and Monitoring Control System. Detection System and Switch Control System would place inside the same work place whereas the Monitoring System would place in other room with desktop. The distance between Detection System and Switches Control System has less worrying since these two sub-systems are placed in same work area. The distance between 2 sub-systems in the same work place and the Monitoring Control System in other office room could up to 40meters. This proved that the transceiver module is suitable to use in the system since the signal is able to transmit and receive in very long distance and with obstacle like doors, wall and stairs. The distance could be longer and probably up to 100meters to place the system if there is without any obstacle.

4.4. Results of Data Analysis

From the results collected, the total energy saved was been analysed in percentages and the data was showed in Figure 4.4. The system was able to save the power up to 30.73% in the work place of lab assistant. On top of that, the system also functions well in the work place of lecturer, post-doc staff and admin which showed 23%, 27.04% and 24.23% power saves respectively. From the data it showed that the system was applicable and reliable to the user in work place. However, the system showed lower percentage of energy saved in the work place of students. From the results showed that only 0.78%, 9.31%, 7.84% and 10.02% of total energy saved by students which stayed in laboratory and workstation. The data showed concluded that both of these work places were less suitable to apply the system. One of the reasons was because the system more reliable for the user as staff compare to students, and also the crowded work place like laboratory and workstation were less suitable to place compare to personal office area. To place the system in crowded work place unless more sensors build in the system. Besides that, the results showed that the total energy saved were 34.50%, 18.89% and 52.78% according to the locations of lecture hall, counter of faculty and thesis room in library respectively. From the results conclude that the thesis room showed the most suitable to apply the system compare to other work area due to less activity occur in that place.

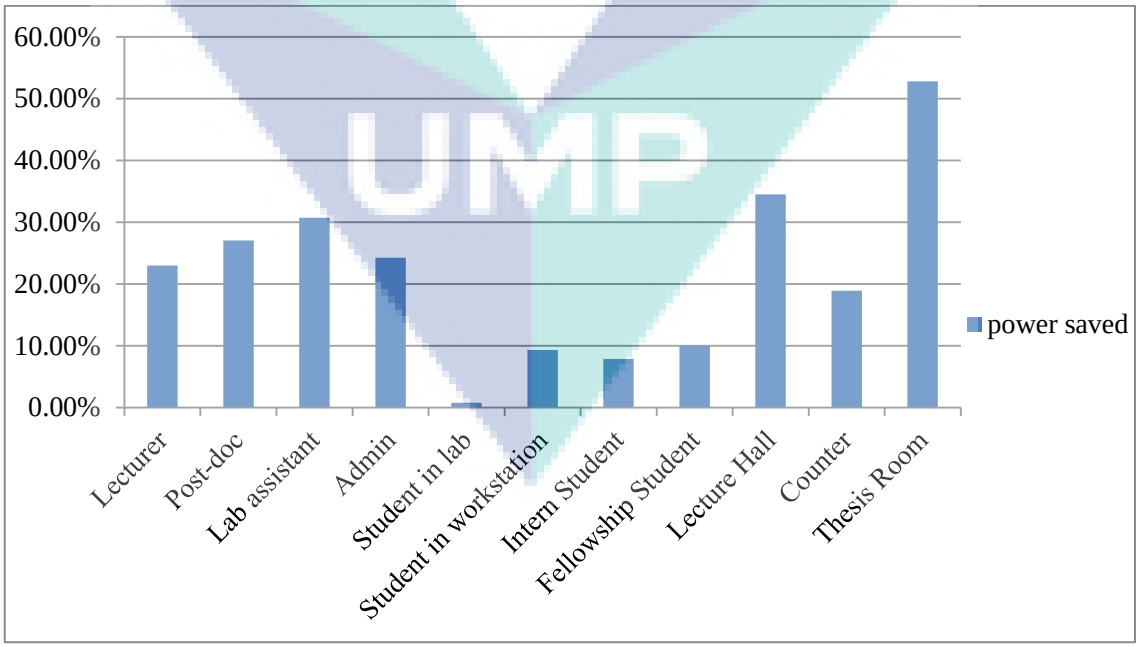


Figure 4.4 Percentages of total power saved

4.5. Discussion of features of the system

For every each feature in the proposed system, all attributes collected were reviewed. According to the existing system, one of the research (Adelakun, 2014) state that a 15% saving in the energy consumption with the application of simple building blocks by using PIR sensor, microcontroller PIC16F84 and relay transistor. A random selected test was brought out in the active working hours in lighting type used such as incandescent lamp and Flourescent lamp based on the premise that the manual control switches were operated with 50% accuracy. The energy saved showed by the existing system is less than the energy saved in the Smart Energy Saving and Monitoring System which showed at least 20% saving in energy consumption. On top of that, the system is more reliable to use compare to the existing system at indoor. From both of the experiments, the system is able to detect all the condition accurately compare to there was some mistake might occur which sowed in the data collected in the existing system. Based on the existing system only applied in lighting appliances to save the energy consumption compare to the proposed system is able to apply in lighting and air-conditional with high power consume in a room. In terms of monitoring system, the proposed system would display the condition to the user every moment while the existing system is only able to collect data through marking manually. Accuracy of data collected would affect the data analysis. Based on the comparison the proposed system is more reliable to use in a room especially in office area.

Based on other research (Govindraj et al., 2017), a flexible, adaptable and minimal effort remote-based home controlling and monitoring system is built. The concept of the existing system include of developing an Android application which allow selecting either Manual or Automatic Mode to control and monitor the home environment with the help of sensors. Technology of Wi-Fi and RF are used to provide a secure connection between Application and Arduino with different devices and also provide function of remote access to the appliances. The data collected through the sensors applied in the system would send onto the cloud. However, this existing system is only flexible to use in housing area if compare to the Smart Energy Saving and Monitoring System. In this existing system only works when internet and Wi-Fi is available whereas the system in this research is able to work no matter the internet is available or not. Data collected in existing system is only able to display in the cloud

whereas the data collected in the system of this research is able to display on the spot and also easily to generate by using Microsoft Excel.

4.6. Summary

The analysis data conclude that the system application needs to consider well in different aspects including the location to place the system, the identity of user who use the system and the timing set for the system. Therefore, the development of a reliable smart indoor power consumption system to minimize the energy losses is achieved and operated well which showed in the results collected. Total energy losses are decreased obviously after the application of the system. Furthermore, the data collected shows the system is able to monitor the condition of the work place and also to analyse how much energy was saved. Thus, the system built to monitor and analyse the power consumption in each of office in work building is achieved.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Introduction

In this highly developing era, the issue of highly demand of power consumption is no longer an unusual scene in this society. Most of people show their dependence in the usage of electricity provided to stay in a luxurious and comfortable life. The issues of power dissipated have been increased recently and the energy has almost been drained out due to highly power consumption. The system is achieved in the research to save the energy by reducing the power dissipated. The system shows to play an important role to save energy in a practical way compare to the way of teaching the user to use the energy wisely. The system also shows a proper way to save the power permanently in the work place as long as it works all the time. The system in research is able to save the energy by controlling the operational of all electrical appliances in the specific work place. On top of that, the system is able to monitor the condition of work place well and clearly to the user, and also analyse the data by calculating how much power has been saved in a day, a week, a month, even a year. This is more advantages and usable to the user in a company compare to the smart system in market or modification with higher cost smart concepts nowadays. All the operational of the system function automatically and this will save the effort to control the system manually by the user. All the advantages bring out by Smart Energy Saving and Monitoring System probably will become the first choice to choose among the others smart system in the market in terms of the functionality, the structure, or even the reasonable price to apply at office area in building.

5.2. Conclusion of Study

Based on the data collected in the results showed, the system in research is able to function well to save the energy by decreasing the power dissipated in unnecessary usage. For an example in the results, the work place that less to occupy by staff power saved around 10kWh. Besides that, the system is able to monitor clearly every condition in each of the sections in work building and also analyse the data to conclude that how much of energy have been saved. For an example in the results, the monitor display the electrical appliances were switched OFF during lunch hour most of the time. The Monitoring Control System was able to use the OFF time taken to analyse how much of energy had been saved. Both of the results are achieved the objectives in the research.

A wireless and function automatically Smart Energy Saving and Monitoring System was built in this research. Both of Detection System and Switches Control System are functions well respectively, the system is able to detect the movement of staff in a certain distance from the sensor, and also the electrical appliances is being controlled well by the system to ON and OFF according to presence of staff in work place. On top of that, the system is able to receive the signal well in different work place in a long distance through the radio frequency operate in the system, as explained in Chapter 3.2. The results collected through this prototype are coinciding almost with the estimation data before and after the experimental work. For example, the results showed in Table 4.2 most of the personal office areas were showed the energy saved from 24% to 30%. For the indoor public space like lecturer hall and thesis room, the energy saved from 35% to 50%. The target of power save is completed and the results are showed in the Figure 4.4. The design of a wireless and reliable indoor smart power saving system and develop the hardware to minimize the energy losses at work station areas is achieved in the research.

From the Monitoring Control System, the user is able to monitor clearly the condition of work building every moment to check how much time of the staff spend during working in their office in a day. For example in the results, the Monitoring Control System showed that the electrical appliances in personal office were switched OFF more than 100 minutes in the period of working hour. Not only has that, the system is able to receive more than one signal at the same time and this new technology allows the user to check the available of any staff in anytime. Furthermore, the data

collected have been analysed and calculated of how much energy saved after the system is applied. These results managed to make comparison before and after the application of the system in the research. For example in the data analysis showed in Table 4.1, the energy saved from 9kWh to 12kWh for personal office. Besides, for the indoor public space like lecturer hall and thesis room the energy saved from 18kWh to 24kWh. According to all results in experimental work, the aim to analyse the power consumption specifically at each office of the work building is achieved in the research.

5.3. Recommendations for Future Work

From this experimental work in the research, the Monitoring Control System is only able to monitor one of the offices occupy by the user but is not able to monitor more than one office in once. Although the Monitoring Control System is able to receive signals more than one office, but there is a difficulty to monitor all the office at the same time. The Monitoring Control System can be improved with the way of improving the design and programming of the system, to allow the user monitor more than one office in a work building in real time.

The system is only able to save the data collected without listed consequently and clearly. There are some improvements needed to generate the data automatically in the analysing system. Besides that, the system is only able to analyse the data in calculate how much energy was saved and energy save in percentages by adding the data involved manually. Created software is used to make the calculation according to the data given. The system can be improved to build in the function of analyse data fully automated.

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APPENDIX A

CODE IN DETECTION SYSTEM, SWITCHES CONTROL SYSTEM, AND MONITORING CONTROL SYSTEM

The text below shows the code applied to the microcontroller in Detection System. The coding allows the microcontroller to control the PIR sensor to make detection in the office, send the signal to the next sub-system with the aid of transceiver modules.

```
[code]
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

RF24 radio(9,10);

const byte address[6] = "00001";
boolean pirState = 0;
 int pirPin = 3;    //the digital pin connected to the PIR sensor's output
 ////////////////////////////
//SETUP
void setup(){
  Serial.begin(9600);
  pinMode(pirPin, INPUT);

  radio.begin();
  radio.openWritingPipe(address);
  radio.setPALevel(RF24_PA_MAX);
  radio.setDataRate( RF24_2MBPS);
  radio.stopListening();
//  radio.setRetries(15,15);
  }

////////////////////////////
//LOOP
int y1 = 0;
void loop(){

  while (digitalRead(pirPin) == HIGH){
    Serial.print("Relay is ON  ");
    Serial.println(y1++);
//    y1 =0;
//    delay(1000);
    sendSignal();
  }
  int x=0;
```

```
 for (int y=1; y<21; y++){
  if ( digitalRead(pirPin) == LOW){
    x = x+1;
    //      delay(1000);
  }
}

 if (x>=20){
  Serial.println("Relay is OFF");
    y1++;
    sendSignal();
    }
 }
void sendSignal(){
 if (radio.available())
 Serial.print("Radio on.\n");
 else Serial.print("Radio NOT available.\n");

 pirState= digitalRead(pirPin);
 radio.write(&pirState,sizeof(pirState));
 Serial.println("send");
}
        [/code]
```

The text below shows the code applied to microcontroller in Switches Control System. The coding allow the microcontroller to receive the signals with aid of transceiver module, and make the decision follow by to switch ON or OFF the electrical appliances according to the signals received with the aid of relay. After that, the code allows the microcontroller to transmit the data to the next sub-system through transceiver module.

```
[code]
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

RF24 radio(9,10);

const byte address[][6] = {"00001","00002"};
boolean pirState = 0;
boolean ledState = 0;
int ledPin = 6;

void setup() {
  Serial.begin(9600);
```

```
radio.begin();
radio.openWritingPipe(address[1]); //00002
radio.openReadingPipe(0,address); //00001
radio.setPALevel(RF24_PA_MAX);
radio.setDataRate( RF24_2MBPS);
 radio.startListening();
radio.setRetries(15,15);
pinMode(ledPin,OUTPUT);
digitalWrite(ledPin, HIGH);
}

int y1 = 0;
int x = 0;
void loop() {

 if (radio.available()){
   radio.read(&pirState,sizeof(pirState));

   if (pirState == HIGH)//if detect people
   {
   x = 0;
   digitalWrite(ledPin,LOW); //led on, active low
   delay(1000);
   Serial.println("Detect Movement!!");
   Serial.println(y1++);
   ledState = HIGH;
   radio.write(&ledState,sizeof(ledState));
   radio.startListening();
      }
      else{
    if (pirState == LOW){
      x=x+1;
      delay(1000);
   }

   if (x>=600){
     digitalWrite(ledPin,HIGH);//led is off, active low
     Serial.println("-------");
     Serial.println("No Movement");
     ledState = LOW;
     radio.write(&ledState,sizeof(ledState));
     radio.startListening();
   }
   }
   }
   }
[/code]
```

The text below shows the code applied to microcontroller in Monitoring Control System. The coding allows the microcontroller to receive the signal from other sub-systems, easier for user to monitor the condition of office in real time, and execute the data to GoBetwino software which showed in Figure 3.8.

```
[code]
#include <SPI.h>
#include <nRF24L01.h>
#include <RF24.h>

RF24 radio(9,10);

const byte address[][6] = {"00001","00002"};
boolean ledState ;
int SW1801;
int SW1802;
int sensor ;

void setup() {
  Serial.begin(9600);
  radio.begin();
  radio.openReadingPipe(1,address[1]); //00002
  radio.startListening();
  radio.setPALevel(RF24_PA_MAX);
  radio.setDataRate(RF24_2MBPS);
  radio.setRetries(15,15);
  }

void loop() {
  if (radio.available()){
    radio.read(&ledState,sizeof(ledState));
    SW1801 = 1801;
    SW1802 = 1802;

    if (ledState == HIGH){
      sensor = 1;
      Serial.print(",");
      Serial.print(SW1801); Serial.print(",");
      Serial.print(SW1802); Serial.print(",");
      Serial.println(sensor); Serial.print(",");
    }
      else if(ledState == LOW){
      sensor = 2;
      Serial.print(",");
      Serial.print(SW1801); Serial.print(",");
      Serial.print(SW1802); Serial.print(",");
      Serial.println(sensor); Serial.print(",");
```

```
    }
  }
        delay(1000) ;
}
[/code]
```

APPENDIX B

ARDUINO

A microcontroller is an independent system which consists of peripherals, memory and a processor that can be used as an embedded system. A programmable microcontroller can be used in technology unlike microprocessor to operate a system that able to configure out the output connect to the receiver part in a connection. A suitable microcontroller is important in a system to run it smoothly and efficiently to achieve the aim of this research.

Arduino is an electronic platform which includes built-in and easy-to-use hardware and software. Arduino board include inputs to receive the signals detect by the tools connected to it and turn into desired signal to be transmit out as output to the tools connected to it. It will function as brain of the system to make decision after a set of instructions are program and sending to the microcontroller in the board. Arduino board consists of several basic parts might interact with in the course of normal use in operation which are power and ground pins, digital pins include the specific pins for Serial In/Out, analog pins, reset button, external power supply in, Toggles External Power and USB Power, and USB. Every part plays their roles to make connection of electronic hardware to the microcontroller in a system.

Arduino Integrated Development Environment or Arduino Software (IDE) contains several functions and make connection to the hardware board to upload program and communicate with them. The codes used in Arduino are two common programming languages C or C++. Arduino libraries have provide basic functions and it able to combine with the code after the compiler turns the human readable code into machine readable instructions.

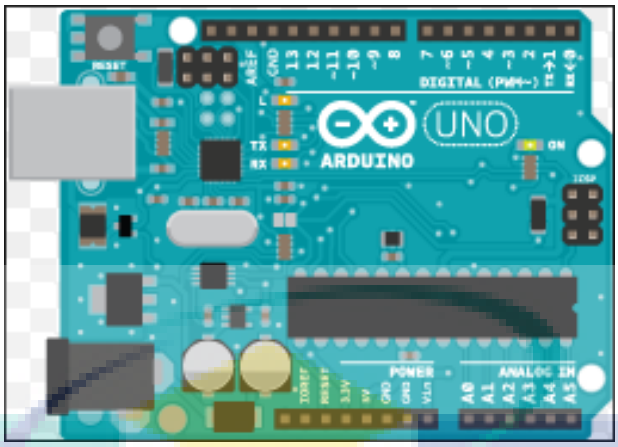


Figure B- 1 Arduino Board

Microcontroller of ATmega328 consists of 14 digital I/O pins include PWM output provider, 6 analog input pins, DC current in every I/O pin is 40mA, 32KB of flash memory, 2KB SRAM and 1 KB EEPROM. Every part plays their specific functions in different roles and it can be used for general purpose via the commands given. Not only that, it consists of features such high performance, low power AVR 8-bit microcontroller, it has advanced RISC architecture, high endurance non-volatile memory segments, speed grade with 20MHz at 4.5 – 5.5v and others. In this research, ATmega328 is chosen among the others due to bigger memory size, bigger boot loader support, and bigger interrupt vector sizes. It is also used on most recent Arduino boards.

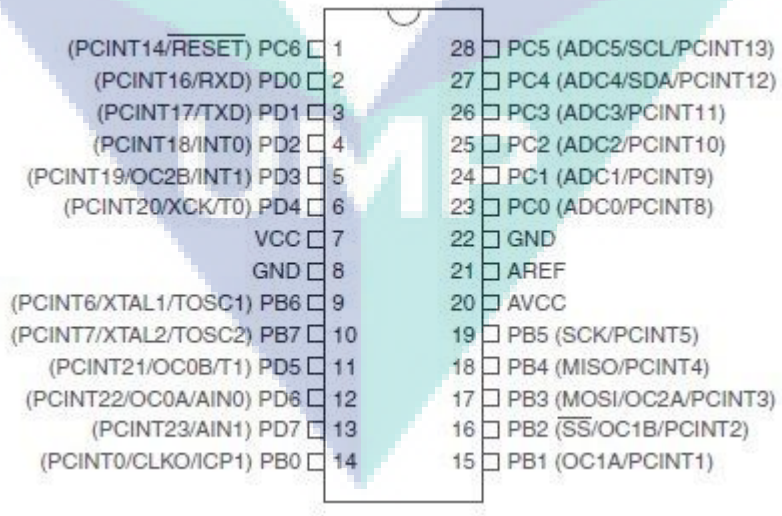


Figure B- 2 Configuration of ATmega328

APPENDIX C

TRANSCEIVER MODULE

A transceiver is a device which comprised both transmitter and receiver in a single package. Transceiver applies with wireless communications through high speed data transmission using radio frequency in a circuitry. It acts as a two-way radio exchanging information in half-duplex and full-duplex mode. Half-duplex is known as the process of transmitting and receiving connect to the same antenna and both are done on the same frequency. Whereas, full-duplex mode is required when the transmitter (Tx) and receiver (Rx) operate on substantially at different frequencies so that transmitted signal does not interfere with reception (Rouse, 2005; Stone, 1902). The transceiver-to-satellite or transmitted signal is known as uplink and the satellite-to-transceiver or received signal is known as downlink.

In this research, the Nordic nRF24L01+ transceiver module has been chosen to be used in research. nRF24L01+ module integrates a complete 2.4GHz RF transceiver, RF synthesizer, a power management with integrated voltage regulator and baseband logic supporting a high-speed SPI interface for the application controller. The application of this module in different types of devices such wireless PC peripherals, mouse and keyboard, game controller, ultra-low power sensor networks and others. The block diagram and pin assignment for every part in the module has clearly state out as figures and tables following.

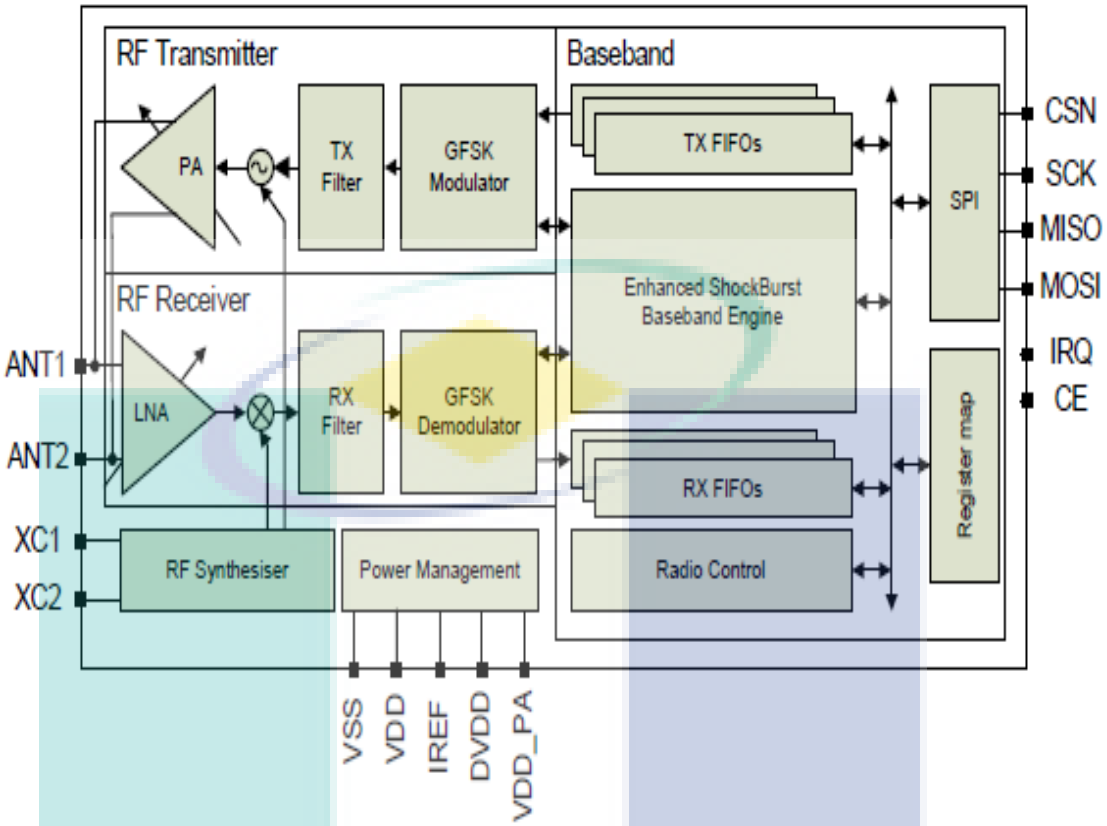


Figure C- 1 Block diagram of nRF24L01+

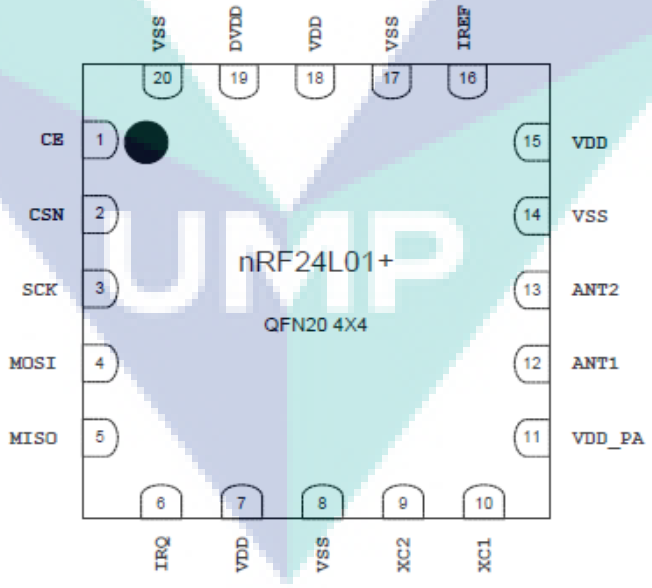


Figure C- 2 Pin Assignment for QFN20 4x4 package

Table C- 1 Functions of every pin in nRF24L01+

Pin	Name	Pin function	Description
1	CE	Digital Input	Chip Enable Activates RX or TX mode
2	CSN	Digital Input	SPI Chip Select
3	SCK	Digital Input	SPI Clock
4	MOSI	Digital Input	SPI Slave Data Input
5	MISO	Digital Output	SPI Slave Data Output, with tri-state option
6	IRQ	Digital Output	Maskable interrupt pin. Active low
7	VDD	Power	Power Supply (+1.9V - +3.6V DC)
8	VSS	Power	Ground (0V)
9	XC2	Analog Output	Crystal Pin 2
10	XC1	Analog Input	Crystal Pin 1
11	VDD_PA	Power Output	Power Supply Output (+1.8V) for the internal nRF24L01+ Power Amplifier. Must be connected to ANT1 and ANT2
12	ANT1	RF	Antenna interface 1
13	ANT2	RF	Antenna interface 2
14	VSS	Power	Ground (0V)
15	VDD	Power	Power Supply (+1.9V - +3.6V DC)
16	IREF	Analog Input	Reference current. Connect a 22kΩ resistor to ground.
17	VSS	Power	Ground (0V)
18	VDD	Power	Power Supply (+1.9V - +3.6V DC)
19	DVDD	Power Output	Internal digital supply output for de-coupling purposes.
20	VSS	Power	Ground (0V)

Table C- 2 Operating conditions

Symbol	Parameter (condition)	Notes	Min.	Typ.	Max.	Units
VDD	Supply voltage		1.9	3.0	3.6	V
VDD	Supply voltage if input signals >3.6V		2.7	3.0	3.3	V
TEMP	Operating Temperature		-40	+27	+85	°C

APPENDIX D

MOTION SENSOR

Motion sensor is a device to detect moving objects or particular people in a specific area to preserve the security system. It uses one or multiple technologies to detect movement in an area. Motion sensors have been discovered and used around since long time ago. At first, a developer name Samuel Bagno using radar to develop an electrical components by doing research on ultrasonic alarm. After that, a new generation of infrared technology is applied to fulfil the demand of non-military applications. Today, radar and infrared motion sensing both are widely used in everywhere.

There are different types of motion sensor available based on technology to detect occupancy. The most common types of sensors are ultrasonic based sensor which sends out pulses of ultrasonic waves and measures the reflection off a moving object, microwave based sensor and CW Radar based sensor which almost the same as ultrasonic sensor but it emits electromagnetic with lower frequency, vibration based sensor, image processing sensor which applied in the area to be sensed is highly segmented, and infrared motion sensor which detect heat and movement in the surrounding areas create a protective "grid". The main purpose of all types of motion sensors is to sense an intruder for safety purpose or alert controlling system for other functions.

In this research, Passive Infrared Sensor (PIR) has been chosen to use in the system to enhance the controlling of energy usage in work area indirectly. It is used detect movement of human body or automobile motion and control the switch of electrical devices which connected to it. PIR sensor contains components of pyro-electric element which enable to detect levels of infrared radiation, noise cancellation and enhanced detection. A higher level of radiation when higher temperature object compare to room temperature is detected by the sensor and all the responds are represented a signal to trigger the fluctuation in the pyro-element. With this fluctuation it will produce signal conditioned in the signal conditioning circuit. However, PIR sensor does not emit energy actively in order to detect motion and it will prolong idle operations when there is no movement to be detected. This is due to some reason of the

electronic package within the sensor fairly rapid change in amount of infrared energy if any motion is easily detected. In summary, PIR sensor detects a sharp increase of infrared energy emitted by body heat and to trigger the electronics devices which connected to it. PIR sensor provides a wide view of detection due to the Fresnel lenses covering the sensor. The Fresnel lens condenses light and provides a large range of infrared to the sensor.

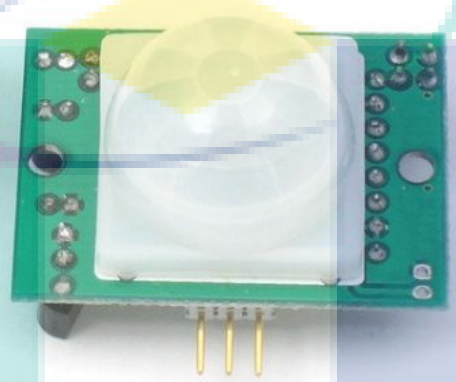


Figure D- 1 PIR Sensor

Figure D- 2 Sensor detect heat and movement in surrounding area

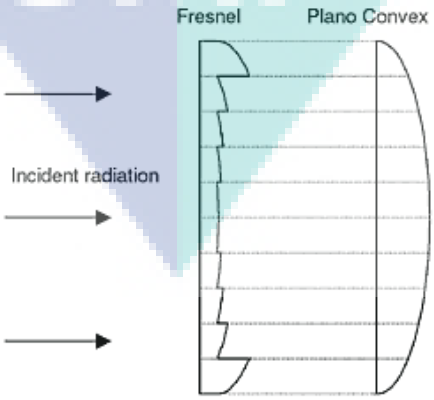


Figure D- 3 Radiation emit to the PIR sensor

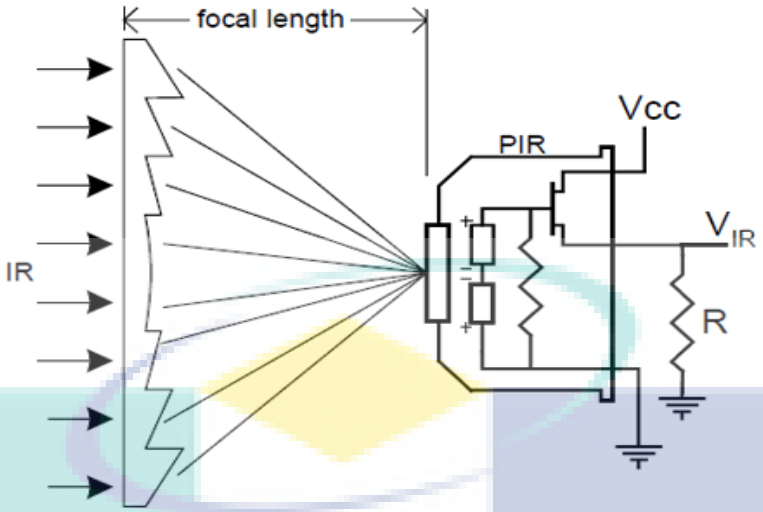


Figure D- 4 The convex shape will condenses the infrared energy and concentrate at the module

Key features of PIR sensor consists of several parts in the module:

Table D- 1 Function of pin and description of jumper setting in module

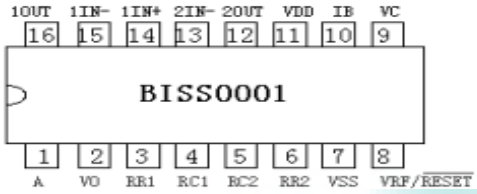
Pin Definitions and Ratings

Pin	Name	Function
-	GND	Connects to Ground or Vss
+	V+	Connects to Vdd (3.3V to 5V) @ ~100uA
OUT	Output	Connects to an I/O pin set to INPUT mode (or transistor/MOSFET)

Jumper Setting

Position	Mode	Description
H	Retrigger	Output remains HIGH when sensor is retriggered repeatedly. Output is LOW when idle (not triggered).
L	Normal	Output goes HIGH then LOW when triggered. Continuous motion results in repeated HIGH/LOW pulses. Output is LOW when idle.

Table D- 2 Description of BISS0001 PIR chip



Pin description

Pin Number	Symbol	Description
1	A	Retriggerable & non-retriggerable mode select (A=1 : re-triggerable)
2	VO	Detector output pin (active high)
3	RR1	Output pulse width control (Tx) * See definition below
4	RC1	Output pulse width control (Tx) *
5	RC2	Trigger inhibit control (Ti) *
6	RR2	Trigger inhibit control (Ti) *
7	Vss	Ground
8	VRF	RESET & voltage reference input (Normally high. Low=reset)
9	VC	Trigger disable input (VC >0.2Vdd=enable; Vc<0.2Vdd =disabled)
10	IB	Op-amp input bias current setting
11	Vdd	Supply voltage
12	2OUT	2nd stage Op-amp output
13	2IN-	2nd stage Op-amp inverting input
14	1IN+	1 st stage Op-amp non-inverting input
15	1IN-	1 st stage Op-amp inverting input
16	1OUT	1 st stage Op-amp output

Calibration of Delay Time Adjust is giving 'warm-up' time to involved in 'learning' its environment to settle down in order to function properly. The adjustment of sensitivity is to respond by making high output of the sensor according to slowly changing conditions and the environmental conditions change.

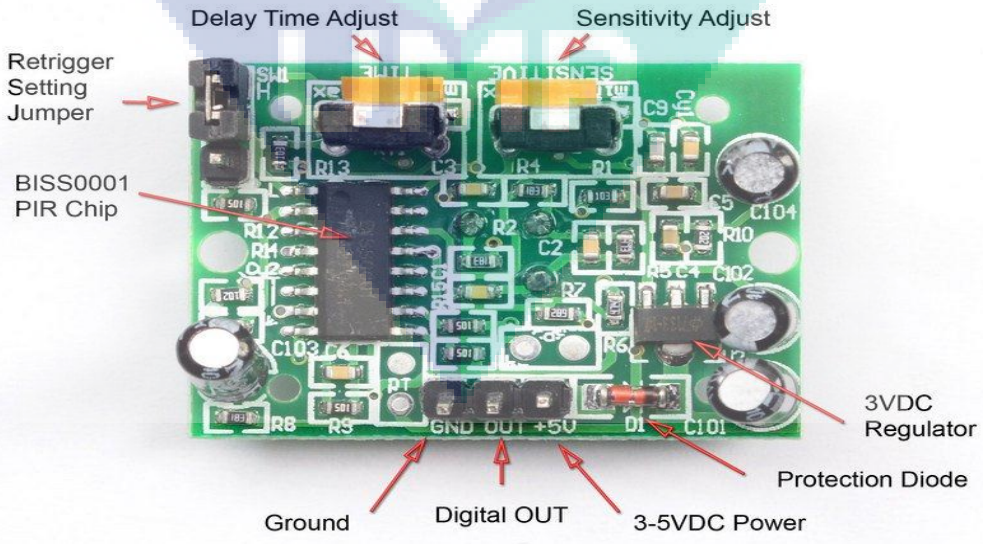


Figure D- 5 Overview of module in PIR sensor