IOT BASED CONTROL SYSTEM FOR ENERGY SAVING IN WORKPLACES

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ABSTRAK

"Dunia yang saling berkaitan", yang ditakrifkan oleh pelaksanaan teknologi pintar yang komprehensif, telah muncul sebagai hasil dari pertumbuhan pesat teknologi maklumat dan komunikasi dan ini termasuk penerapan sistem Internet of Things (IoT). Internet of Things adalah rangkaian yang komprehensif yang terdiri daripada banyak komponen yang saling berhubung antara satu sama lain. Sistem ini, yang terdiri daripada beberapa modul, sensor, dan komputer, secara langsung menghantar data dan melakukan operasi yang telah ditetapkan. Pandemik COVID-19 menyebabkan kekacauan dalam organisasi dengan cara yang tidak pernah dirasai sebelum ini. Walaubagaimanapun banyak individu di seluruh ekonomi global terus bekerja dari jarak jauh, kehidupan bekerja akan kelihatan berbeza ketika kita beralih ke sistem bekerja di rumah. Sebilangan besar organisasi mencari teknologi yang membolehkan Internet of Things memperbaiki persekitaran dengan lebih selamat dan mengurangkan kos perbelanjaan ketika syarikat berusaha mengumpulkan dan memperbaiki pendapatan yang telah rugi angkara wabak tersebut. Sistem pejabat pintar telah disatukan dalam visi kami untuk meningkatkan kecekapan bangunan atau tempat kerja di samping mengurangkan penggunaan tenaga elektrik. Oleh itu, di sini kami telah mencipta sistem kawalan yang lebih baik di pejabat yang dapat dilakukan dengan menggunakan sistem komputer kecil (ESP32) bertindak sebagai pengawal dan pengatur input data daripada sensor. Sebahagian daripada metodologi kami adalah menghasilkan prototaip sistem pejabat yang dapat mengawal dan memantau segala alatan elektrik terutamanya sistem pencahayaan untuk menghasilkan persekitaran kerja yang baik dan kondusif. Keputusan ini akan ditentukan oleh pilihan individu dan maklumat sensor yang telah dikonfigurasi secara manual oleh pengeluar sistem.

ABSTRACT

"An interconnected world", defined by the implementation of comprehensive smart technologies. Because of the rapid advancements in information and communication technology, including the use of Internet of Things (IoT) systems, a new term has emerged. The Internet of Things is a comprehensive network made up of many components that are interconnected with each other. The system, which consists of several modules, sensors, and computers, directly transmits data and performs predefined operations. The COVID-19 pandemic caused chaos in the organization in ways never felt before. Although many individuals across the global economy continue to work remotely, working life will look different as we move to a work -at -home system. A large number of organizations are looking for technologies that allow the Internet of Things to improve the environment more securely and reduce spending costs as companies strive to collect and improve revenue that has been lost by the epidemic. Smart office systems have been integrated in our vision to increase the efficiency of a building or workplace while reducing electricity consumption. So here we have created a better control system in the office that can be done by using microcontroller (ESP32) acting as a controller and regulator of data input from the sensors. Part of our methodology is to produce prototypes of office systems that can control and monitor all electrical appliances especially lighting systems to produce a good and conducive working environment. These results will be determined by individual preferences and sensor information that has been manually configured by the system manufacturer.

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LIST OF SYMBOLS

CO^2	Carbon Dioxide
W	Watt
Kw/H	Kilo Watt Hour
MHz	Mega Hertz
GHz	Giga Hertz
’’	Inches
V	Volt
ºC	Degree Celsius
mm^2	Millimetre square
mm	Millimetre
%	Percent
PPM	Parts Per Million

LIST OF ABBREVIATIONS

IoT	Internet of Things
Wi-Fi	Wireless Fidelity
GUI	Graphic User Interface
WSN	Wireless Sensor Networks
HVAC	Heating, Ventilation, Air Conditioning
BAS	Building Automation System
IC	Integrated Circuit
AC	Alternating Current
IDE	Integrated Development Environment
BLE	Bluetooth Low Energy
RFID	Radio Frequency Identification
LoRa	Long Range
CFL	Compact Fluorescent Lamp
MCU	Micro Controller Unit
IP	Internet Protocol
GPIO	General Purpose Input/Output
SDP	Senior Design Project
PIR	Passive Infrared
PVC	Polyvinyl Chloride
I/O	Input/Output
SPI	Serial Peripheral Interface
I2C	Inter IC
UART	Universal Asynchronous Receiver Transmitter
PDR	Packet Delivery Rate
RTT	Round Trip Time
SLP	Simple LoRa Protocol
GSM	Global System for Mobile Communication
GPS	Global Positioning System
TVOC	Total Volatile Organic

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CHAPTER 1

INTRODUCTION

1.1 Project Background

In this modernized world, technology is rapidly growing and it has already become a part of our life. Moving to a smart office will bring positive impacts to the workplace in multiple ways. Based on figure 1.1 below shows a Smart modern office technology. The word smart office refers to the control appliance by remote and monitor. Energy consumption is a major problem these days as well as controlling the on/off switch of a device with a button that looks difficult and old school. According to the Ministry of Energy, the peak demand for electricity in Peninsular Malaysia reached 15476 Megawatts in 2011 and it maybe can reach 25 Gigawatts by 2030 (Sulaima et al., 2019).

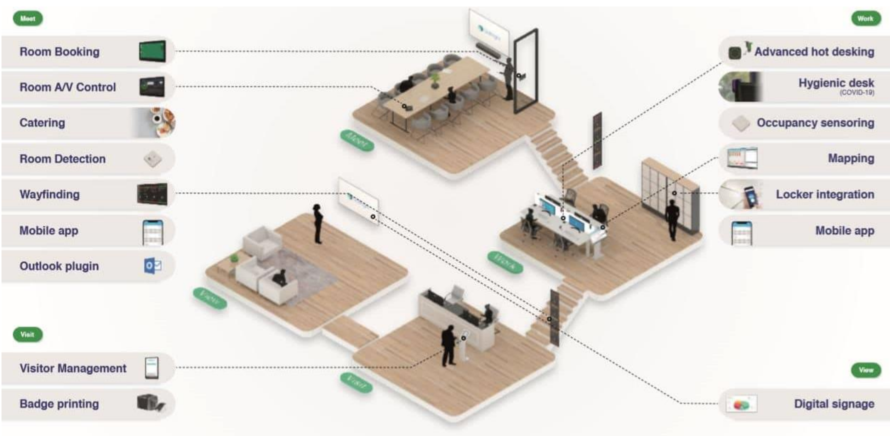

Figure 1.1 Smart Modern Office Technology
(Sakaci et al., 2018)

To overcome the problem, we have decided to develop a control system for the smart office by using technology on trend which is the Internet of Things (IoT) with a wireless communication technology (Wi-Fi) (Zou et al., 2018). Hence, users will be able to monitor and remote the real time information received from the office to determine the condition through the developed system. In this system, various sensors are used to collect the information and transmit the data to the IoT platform application for users to monitor remotely.

The process of transforming an office into a smart workplace can be divided into three stages: planning, implementation, and evaluation. The internet, laptop computers, and mobile phones, all of which were introduced during this period, helped to increase productivity from 1996 to 2006. During phase 2, which lasted from 2006 to 2016, the rate of technological advancement was also extremely rapid. Finally, we have reached the third and final phase, during which the vast majority of employees have accepted and are actively utilising the concept of a smart office. According to a report published by Allied Market Research, the global market for smart buildings will grow by 29 percent over the next few years, according to the report (Voisin-Grall et al., 2019).

1.2 Problem Statement

Climate warming is presently among the highest complex environmental concern in many countries. Excessive electricity consumption associated with conventional lifestyles is one of the primary causes of global warming. Reduced greenhouse gas emissions have become a global concern, necessitating a collective economic and technological commitment, as well as consumer participation. To enable accomplish this goal, consumers should be encouraged to adopt a pro-environmental attitude especially in workplaces.

Nowadays, the rapid developments in technologies have brought the concept of smart home application to be implemented in smart office technology and smart buildings (Barker, 2020). All these smart technologies are the fundamental concept for smart cities and have been focused on many projects in order to increase the energy efficiency and improve the security system.

The electrical or the electronic devices are normally controlled by turning on and off the switch or using a remote control in the office. However, based on research, most of the existing system has the limitation where it is only used for the purpose of monitoring the appliances. There is a need in the developed system to monitor and to remote appliances in the smart office easily with the application. The IoT technologies and emerging of communication could be mitigated by composing multiple sensors with one microcontroller as a node to perform monitoring and control of several events and send data to users in real time over the Internet using Wi-Fi technology.

Other than that, the application of smart offices using IoT will bring a green impact to the environment as it will reduce the energy consumption used (Mishra & Chakraborty, 2020). However, there will be unnecessary wastage of the energy consumption. This because some staff leave their office or move to other place while keeping their utilities at office switching ON without real need. In addition, this will contribute to the increase in electrical bills also the lifespan of an electrical appliances such as air-conditioners and light will decrease.

1.3 Objective

This project's main objective is to create an IoT-based control system for a smart office that can monitor and remotely (manage) the workplace's electrical appliances while reducing energy consumption. To achieve the purpose, several objectives are accomplished.

- To design an IoT-based control system for energy saving in workplaces via facilitating the monitoring of office conditions and controlling the office appliances remotely over the Internet.
- To develop a smart and hybrid system that composes multiple sensors (motion, temperature and humidity, smoke, actuators, and ESP32 as a micro controller to perform monitoring and control of multiple events simultaneously over the IoT platform.
- To implement a user-friendly GUI (IoT@Office) based on Blynk application for enabling the functionalities of monitoring and controlling in real time over a Web-based and Mobile App dashboards and system performance evaluation.

1.4 Scope of Dissertations

The scope of this project focuses on the implementation of the Control System in a Smart Office which reduces the energy consumption by design sensing from multiple sensors for instance motion sensor HC-SR501, temperature and humidity sensor DHT22, and smoke sensor MQ2. The occupancy in a smart office can be determined by the data obtained from the motion sensors along with the condition have been programmed. Next, building a control system that can monitor and remote the appliances in the office through web application using Wi-Fi as a communication tool.

1.5 Significant of Research

Smart offices or workplaces were created as a result of the usage of data and technology in office buildings. Air conditioning, fire prevention, lighting, and other functions can be controlled by a smart building or smart workplace system. Furthermore, smart offices will boost occupant satisfaction and productivity by enhancing mobility and applying customization through the use of sensor data. Smart buildings system may also lead to employee satisfaction and attract new talent also improves the performance and well-being of the people who work there, while also being more environmentally friendly than traditional offices. To provide comfort for their occupants, the built environment, which includes commercial real estate and houses, requires over 40 percent of total of the world's energy (Andrić et al., 2019). Energy efficient buildings and facilities are gaining greater attention in the development of global concerns about energy use and the rising requirement for sustainable constructions. Smart choices are crucial aspects for making buildings more energy efficient. For example, when a conference room is vacant, the system will automatically be switching off or dimming the lights, lowering the air temperature when the temperature outside increases will help to save energy and enhance the productivity of electricity usage costs. Last but not the least, in this research, we also implement the IoT system that will make our workplace more pleasant and safer for our employees, as well as improve everyday duties and increased employee performance.

1.6 Organization of Research

This study is organized into 5 chapters. Chapter 1 describes the goals and scope of the general study with software and electronics design, as well as discussing and explaining the smart technology that can contribute to save energy consumption at workplaces, a brief explanation about smart offices and also the trend of using the IoT system. The project background, problem statements, objectives, scope dissertations, significance of research, and proposal organisations have all been covered in this chapter.

The second chapter discusses the study's purpose, provides a background on the topic, and includes a literature review to establish the need for this research. The overview of the internet of things (IoT), concept of the smart office and the technology that has been used is discussed in this chapter.

Chapter 3 includes the methodology of the smart office system, flow chart of the project, hardware and software components that will be used and some electrical diagram and architecture of the system has been written in this chapter.

Finally, in chapter 4 discusses the result for our project and sees whether this project meets our objectives and also suitable to implement at the actual situation and the findings of the experiments that were discussed and accomplished are described in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, we will discuss developing an Internet of Things that is based on the Workplace to reduce current consumption, good wireless communication systems and sensors that will be used. A literature review was conducted to analyse the use of IoT technology in the workplace and to resolve these study research issues.

2.2 Overview of Internet of Things

The number of connected devices that are connected to the web has been continuously growing. Today, it is experts estimate that hundreds of millions of equipment are linked. The Internet of Things (IoT) is allowing for the expansion of Wireless Sensor Networks (WSNs) (Tran et al., 2018), that have really gained considerable attention in recent years due to its superior benefits such as low-powered sensing, wireless connectivity, and, most notably, high scalability in remote areas where wire connections seem to be impractical to draw (Behera et al., 2019). Rapid advancement of the Internet in recent years, every aspect of our lives has become closely linked with its use. This assists individuals in improving their work proficiency and the essence of life. The internet of things, which is built on the internet, has emerged with the aim of meeting the rising business sector demand and continuously achieving the outgrowth of social development, conducive and intelligent (Sakaci et al., 2018). Internet of things (IoT) relates to the trillions of the hardware equipment hooked up to the internet and gathering information and exchanging world-wide distribution of information beyond the limit. Since ultra-low-cost computer processors and wireless networks are widely available, it is now possible to connect everything from a pill to an aircraft with an Internet of Things connection, making it possible to cover everything from a pill to an aircraft (Katare et al., 2018).

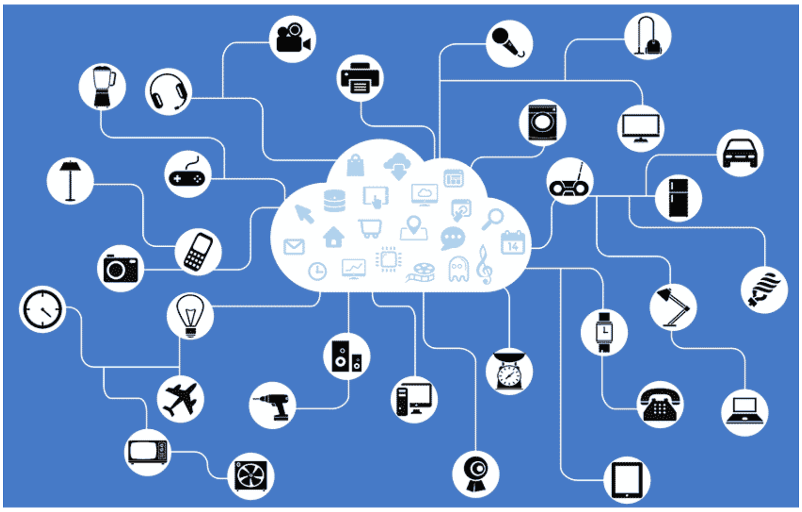

Figure 2.1 Internet of Things Inter-connected System
(Bennett et al., 2020)

The evolution and advancement of Internet of Things applications such as mobile application, and the web are accelerating day by day. Internet of Things (IoT) devices are now becoming increasingly common (IoT) (Adeogun et al., 2019), as in figure 2.1 describe the next generation includes the Internet of Things, which enables a multitude of things to be related, as well as big data, which enables everything in our environment to be decoded and displayed. Internet of Things system are made up of several wireless sensing devices and a gateway access point, where they allow widespread of sensing and data selection at a fine resolution even over a broad area. Consequently, it is well suited for monitoring areas (environment, agriculture) or objects as a result of these capabilities (human healthcare, smart buildings). Besides, the contribution of the internet of things cloud computing servers, all data will be collected and analysed to become valuable information or data to address specific needs when it is uploaded to a server. Smart office technologies are being adopted for a variety of purposes. It will improve workplace efficiency, simplify usual tasks, and create safer and much more relaxed working environments for workers by implementing the Internet of Things in office buildings (Adeogun et al., 2019).

2.3 Concept of The Smart Office System

A smart office concept is a place or working space where new technology allows workers to work faster, proficiently.

Figure 2.2 Smart Office Concept

Figure 2.2 is the system probably would be one that ensures that IT resources and physical facilities are used effectively and efficiently. In other words, today is information technology generation, mostly offices and industry infrastructure are fully automated. A transparent technologically advanced environment is required. Thus, office automation enables systems to become more transparent, allowing for more open information sharing, providing an opportunity to have a significant impact on the functioning of the industrial sector and the functioning of business (Cascio & Montealegre, 2016). The application of various technological devices in the system, and even some effective advanced automation, has a big impact on a company's or any organization's global expansion throughout time (Sunyaev, 2020).

2.3.1 Smart Office VS Conventional Office System

The word "smart" has become increasingly popular over the years to classify the technologies that have become progressively incorporated into our everyday lives. Smartphones and smartwatches are ubiquitous these days, smart cars are now on the road, and smart homes seem to be the norm (Sunyaev, 2020). The trend of “smart” as shown in figure 2.3 is becoming a part of our workplaces as well. Smart technology is not just making the transition from our personal lives to our workplace, but also reshaping the modern office thus changing the physical environment for work (Firouzi et al., 2020).

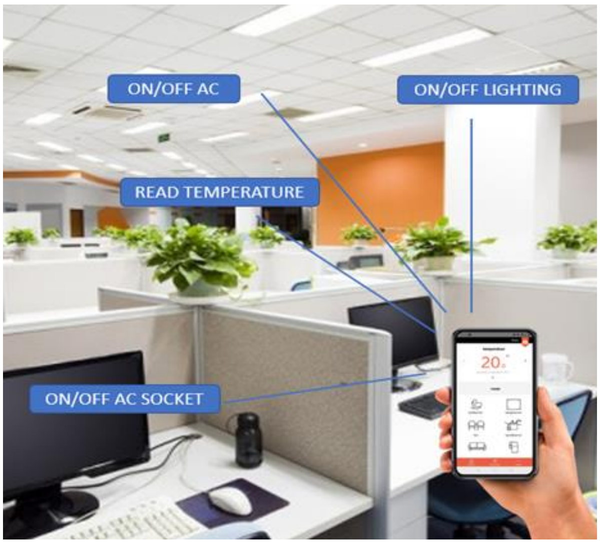

Figure 2.3 Smart Office System

Working smarter, better, and faster in the new system like smart office technology can be accomplished by eliminating obstacles in the employees' path, such as menial work and unnecessary obstacles, and the most essential part is energy efficiency (Sisavath & Yu, 2021). Employees may choose to use beacons, sensors, and mobile applications to help themselves perform their tasks more efficiently. Sensors are used to detect whether anyone seems to be in the building, where they are at any specified period, and also specific meeting room is fully booked.

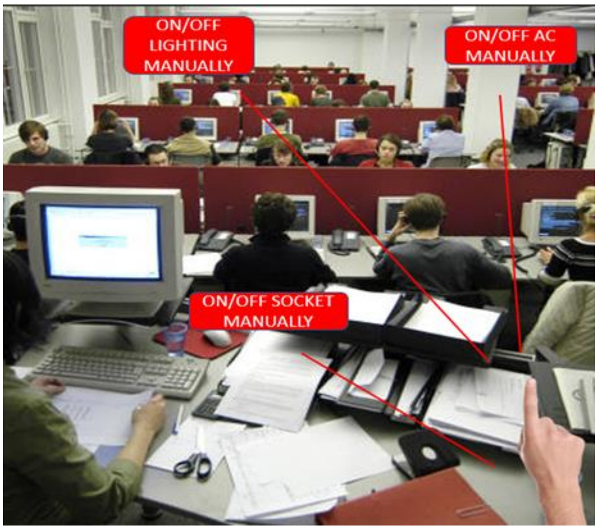

Figure 2.4 Conventional Office System

In contrast with the traditional office system on figure 2.4, employees in the conventional workplace lacked secure and cohesive communication structure. The worker only can control and monitor office condition manually. Electrical appliances such as lighting system need to be control manually and thus will contribute to the increasing in energy consumption.

2.3.2 Smart Office Top Benefits

When compared to a conventional workplace, the smart office is a total paradigm shift. For a wide range of people in the workplace, the transition to a more interconnected, digitally enhanced workplace makes life simpler. Now, smart homes are designed with cutting-edge technology which could be used to monitor and perform a wide variety of tasks. Wi-Fi or the Internet is used to turn the devices on and off on a regular basis (Zourmand et al., 2019). The same server could be used globally to perform this control function. This is employed to enhance both convenience and safety (Rashid et al., 2019).

One of the most visible benefits of smart office solutions is that the energy savings are achieved by automation that appeals to modern office staff. "The users also feel isolated from the management of systems such as temperature and lighting, and therefore are less prepared to commit to the energy saving concept," said John Tan, Key Account Manager at ABB (Lin et al., 2022). "A comprehensive automation system can overcome this disinterest."

Typically, the automation of HVAC and lights relies on sensors to “sense” the present conditions in the office. A difference variety of smart sensor technology is available, ranging from presence detectors with built-in lux sensors to outdoor weather sensors, which allows the office space to be self-managed automatically and obtained high energy efficiency while maintaining comfort (Yang et al., 2020). Those sensors will allow the workplace to adjust its configurations, such as lighting, HVAC, automated blinds, and windows, automatically in response to changes in the climate.

This type of automation will significantly improve the profitability. Although investing in these solutions may be more costly at first, the savings in energy will make the investment worthwhile. Even though initial investment will tend to be higher than that of a traditional system, the monthly savings may be substantial. A smart office system has been shown in case studies to result in a nearly 50% reduction in energy consumption, which is another reason for businesses and employees to switch to smart offices.

Table 1 Smart technology in the existing system with rate of energy saving

Types of System	**SMART Concept Technology**	**Percentage Of Energy Saving**
Heating, Ventilation, Air-Conditioning (HVAC)	Drive with Variable Frequency	15-50% of pump or motor energy
Heating, Ventilation, Air-Conditioning (HVAC)	Smart Thermostat	5-10%
Lighting	Smart Lighting Controls	45%
Plug Load	Advanced Power Strip	25-50%
Window Blind	Smart Blinds	21-38%
Building Automation System	BAS	10-25% of the whole building

sources : DOE 2004; DOE 2016b ; Lutron 2014 ; GSA 2012, Boss 2016; Hydraulic Institute, Europump, InviShade 2016, Gilliland 2016, Ravenwindow 2016 and SageGlass 2016

Table 1 explain about the consumption based on system in the building. Smart buildings conserve energy by automating controls and improving facility design and construction. While upgrading a single component or independent device can result in a 5–15 percent reduction in energy consumption, a smart building with integrated systems can result in a 30–50 percent reduction in energy consumption in buildings that would otherwise be redundant (Pešić et al., 2019).

2.4 Technology in Smart Office

The definition of Smart Office, as in an Internet of Things (IoT) design system, usually includes capabilities that allow intelligent work environment behaviour patterns, including office spaces. Temperature, humidity, light intensity, movements, noise level, and other in-room environment parameters are controlled using a network of dedicated actuators, sensors, and several specialized devices in conjunction with user preferences (Torres Padín, 2020). According to IoT concepts as in figure 2.5 below, interconnected sensors and devices function as self-contained, adaptable devices that exchange generated and consumed data through Internet-like protocols, provide information embedded directly in the devices, modify their internal status, and events that occur as a result of changes in the external environment are produced.

Figure 2.5 Smart Office System with controlling and monitoring features

2.4.1 Hardware Components in Smart Office System

A series of advancements in the use of machine intelligence and deep learning to enhance these structures and make them more accessible to the general public have been made in recent years, with the goal of making them more accessible to the general public. In order to develop smart office system, there is several components need to be used and apply to make the system more beneficial and suitable in a workspace or office area.

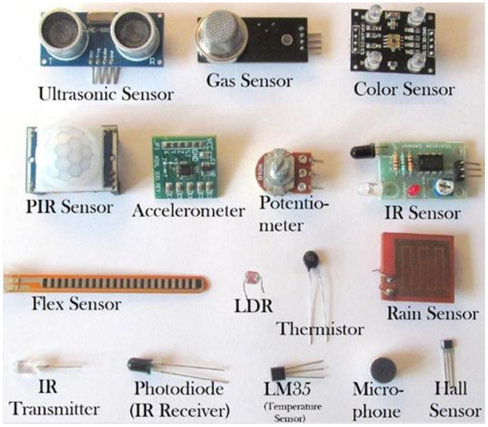

Figure 2.6 Multiple types of sensor

Electronic sensors detect and measure a physical phenomenon such as motion, pressure and temperature. Sensors also can define as input devices that provide output with specific input. The words “input device” can define the sensor is a part of a bigger system that serves input to the main microcontroller (control system). In IoT, sensor was a great role in creating solutions and all sensors need different requirements for IoT applications. Furthermore, after signal translation and processing, the sensors are connected direct or indirect to an IoT network. Sensor data is becoming more accessible and impactful in the energy area as the Internet of Things (IoT) age approaches (Wu et al., 2019). Data on power consumption has become an important aspect in resolving a wide range of energy issues. The sensor that is used in the system needs to choose wisely to help energy saving. The sensor will transmit the information to the microcontroller unit that is connected to the Wi-Fi in the office to send data to the IoT platform to process and store.

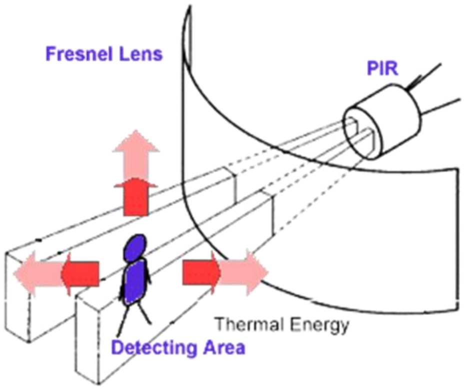

Figure 2.7 PIR sensor range of motion

A motion sensor is designed to detect and measure movement. It is also a part of security systems. Based on figure 2.7, it is the most useful device to detect workers in the workplace that can help to switch off the system automatically when people are not around. This sensor detects the movement and signal will be sent to the security control that is connected with the controller (Amrullah et al., 2021).

Figure 2.8 HC-SR501 PIR sensor

Among the many different types of motion sensors available, the most common are active motion sensors and passive motion sensors. For active sensors, it is equipped with a transmitter and a receiver. As a method of detecting motion, the receiver measures changes in the sound or radiation reflected into it. PIR is an abbreviation for passive infrared, as illustrated in figure 2.8. These are the devices and components that do not generate energy but can store or dissipate it. They are referred to as passive devices or passive components. Infrared radiation is defined as having wavelengths that are longer than those of visible light. Despite the fact that radiation is emitted by everything, even at extremely low levels, when something is hotter, it emits more radiation than when it is colder. PIR sensors make use of pyroelectric elements in order to detect infrared levels from nearby objects. Materials that are both piezoelectric and pyroelectric in nature are similar in their properties, but piezoelectric materials generate a voltage when movement is caused by them. Pyroelectric materials, on the other hand, react when the temperature is raised or lowered. A voltage cannot be generated by pyroelectric materials when they are kept at room temperature. When a material cools or heats up, a voltage is generated as a result (Verma et al., 2021).

The role of a temperature and humidity sensor is to detect, measure, and report moisture as well as ambient temperature and send data to the controller. The relative humidity of the air is calculated as the ratio of the amount of moisture in the air to the maximum amount of moisture at a given temperature of the surrounding air (Soni et al., 2020).

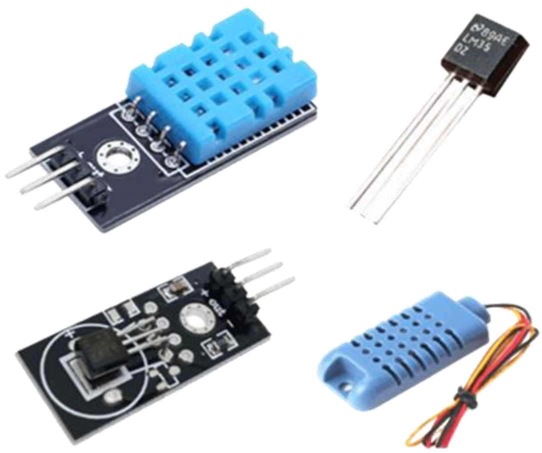

Figure 2.9 Type of temperature and humidity sensor

As illustrated in figure 2.9 above, that sensor is designed for indoor use to reduce wasted energy. This sensor works by catching changes that alter electrical current or temperature in the air. In addition, normally this sensor can connect with a control system (Shin et al., 2020). There are three fundamental types of humidity sensors which are capacitive, resistive, and thermal, and they all measure changes in the environment to determine the humidity level in the air.

Figure 2.10 DHT22 temperature and humidity sensor module

Figure 2.10 shows DHT22 sensor module. The DHT means D stand for digital, H for humidity and T for the temperature (Koestoer et al., 2019). By this name, it can easily understand this sensor use to measure humidity as well as temperature in the form of digital format. This sensor is widespread used since it is inexpensive while still providing excellent performance.

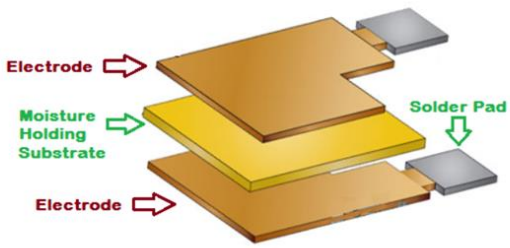

Figure 2.11 DHT22 sensing component

Humidity sensing components are found inside the DHT sensor as depicted in figure 2.11. These components, in order to function as a dielectric, should have 2 layers of electrodes separated by a substrate that retains moisture. Capacitance is affected by humidity, which results in a change in its value. Apart from that, the integrated circuit components will convert the resistance value into a digital representation. Aside from that, this sensor measures temperature with a thermistor with a Negative Temp coefficient, which causes its resistance value to decrease significantly as the temperature increases. This sensor is typically constructed of semiconductor ceramics or polymers in order to achieve a higher resistance value even when subjected to minor temperature variations (Islam et al., 2018).

A gas sensor, as the name implies, is a device that measures the concentrations of gases in the atmosphere. The resistance of the substance contained within the sensor varies according to the concentration of the substance contained within the sensor. The output voltage value gives the types of gas and also the concentration level of gas (Pham et al., 2019).

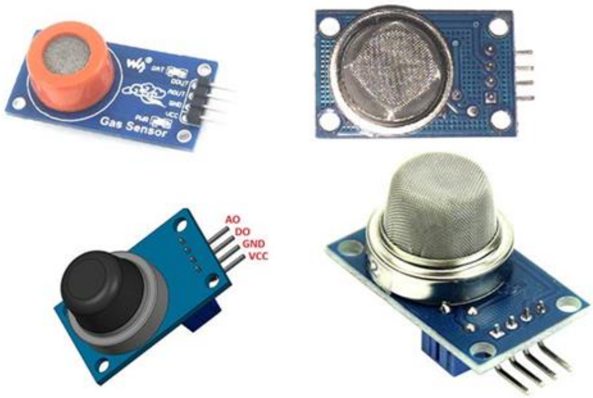

Figure 2.12 Multiple type of gas sensor module

Figure 2.12 shows a gas sensor that can be classified as either a gas sensor or a pressure gauge, depending on the type of sensing element that is present in the sensor. In the workplace, fire or smoke needs to be sensed and detected quickly so the workers can escape safely. It is more difficult to evacuate and escape safely if the warning is discovered early, but the amount of time available for safe evacuation and escape will increase if the warning is discovered early. Ionization and photoelectric smoke detectors are two of the most widely used types of smoke detectors in today's world. When it came to detecting visible and invisible particles in order to detect smoke and fire, these two types of detectors used two completely different operating principles. This sensor is typically included as part of the vehicle's overall safety package in the vast majority of cases (Gautam et al., 2021).

In this project, the MQ-2 smoke sensor is being used to detect smoke. Sensors in the MQ series gas sensors detect the presence of a specific gas in the air by heating the electrodes of the sensors. This sensor can detect flammable gas in any range from 300 to 10 000 parts per million and the heater uses 5 volts.

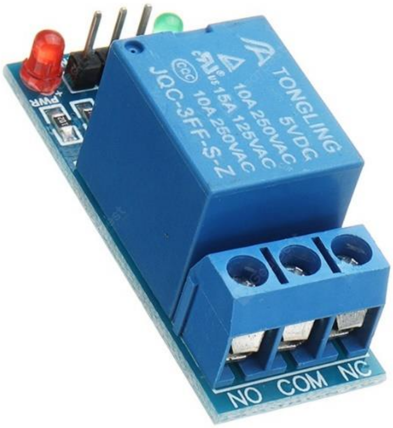

Figure 2.13 5V DC relay module

This relay module on figure 2.13, which is also known as a relay interface board, has the capability of controlling the ESP32, Arduino, and PIC microcontrollers directly. To control the relay, it uses a *low-level* triggered control signal between 3.3VDC to 5VDC (Martin et al., 2018). The triggering for a relay is utilised in automation control circuits to operate normally open or normally closed contacts (Chen et al., 2019). The relay module control circuit includes the main transistor, a protection diode, an optocoupler and control input pins. This module able to connect microcontroller as the control circuit and provide voltage potential to power the relay. There are also a couple led to indicate that the module has power and when the module is activated.

A buzzer as shown on figure 2.14, which is a modest and productive component, can be used to incorporate sound features such as buzzing or beeping into a variety of projects and other applications. The two-pin structure makes it ideal for use on a breadboard due to its small size and portability. It is an audio signalling device that is incorporated with electronic transducers as well as a basic actuator which will generate loud sounds to alert living beings in the surroundings. It controlled by the microcontroller. There are two types of buzzers, one is active buzzer and passive buzzer. For operation, the buzzer requires DC voltages as an input because it has an internal oscillator that assists in the production of the beep sound. Additionally, passive buzzers perform the function of electromagnetic speakers, emitting sound whenever the input voltage alterations. An alternating current signal is required in order to produce sound. All Piezo type buzzers are powered by a piezoelectric element at their core. These piezoelectric elements are made up of a combination of piezoelectric ceramic and metal plates that are adhered together (Moriyama et al., 2022). A vibration plate is a type of metal plate that is used to dampen vibrations. Ceramic plates have electrodes on both sides that are used to conduct electricity, and these electrodes are made of carbon. When it comes to the field of piezoelectric materials, the piezoelectric effect and reverse piezoelectric effect are both well-known phenomena. Mechanical strain causes the piezoelectric plates to generate an electric field, which is then connected to the positive and negative terminals of the buzzer. The piezoelectric plates are then connected to the positive and negative terminals of the buzzer. The piezo ceramic elements expand and contract in opposite directions when an alternating voltage is applied (Suciati et al., 2019). This piezoelectric material property is used to rapidly vibrate the ceramic plate and generate sound waves. When there is no voltage supply across the input pins of the buzzer, it is in rest. While a +5V of voltage supply is applied, the metallic membrane is in excited state (Kader et al., 2018). The conversion of the buzzer in between the rest state and the excited state or vice versa assemble the output from the buzzer.

Figure 2.14 Passive electronic buzzer

2.4.2 Software Implementation

In fact, even for professionals, software development is a difficult task that frequently requires the use of a large number of tools for code creation, building and testing. An integrated development environment (IDE), also known as a software development tool belt, is a framework application or service that integrates many of these functions into a single framework application or service.

The use of an integrated development environment (IDE) simplified software development by enabling the deployment and management of multiple tools at the same time. Text editors, code libraries, compilers, and test platforms are examples of tools that can improve overall developer productivity. Through one graphical user interface, an IDEs enables sources code writing and editing, translation into readable language for computer and software testing to solve issue or bugs. IDEs eliminate time spent choosing, configuring and even learning various tools (Studio, 2018). An integrated development environment (IDE) can also include programmable editors, object and data modelling, unit testing, and the ability to create automation tools.

The IDE that a developer chooses is determined by the type of application that they intend to develop and the tools that are most important to them. Additionally, an IDE can be open source or commercial, can be a stand-alone application or can be part of a package, and can be web based, cloud based, or mobile in nature. It can also be language specific or multilingual (Althar & Samanta, 2021).

The term IDE stands for integrated development environment and simply put it is a program that allows developer to write code and to flash onto microcontroller (ESP32) or any other Arduino compatible board (Zou et al., 2018). As shown in figure 2.15, in order to use the ESP32 as a microcontroller in the Arduino IDE, the board and package libraries must be installed in order to ensure that the Arduino IDE and the ESP32 are compatible with one another.

Figure 2.15 Arduino Intergrated development environment (IDE)

Following that is the microcontroller, the figure 2.16 shows the ESP32 is a family of microcontrollers designed and developed by ESPRESSIF systems, a company based in Shanghai. ESP32s are famously known for being a low-cost microcontroller with an integrated Wi-fi and Bluetooth radio for wireless and internet of things applications. Over the last couple of years, ESP32 have gained a lot of popularity in the maker community (Pravalika & Prasad, 2019). This is mainly because they are one of the cheapest ways to implement Wi-Fi, Bluetooth and BLE and DIY electronics projects.

Figure 2.16 Node MCU ESP32 microcontroller

The ESP32 first launched back in late 2016, and since then the number of ESP32 users has steadily increased over the years. The support for ESP32 firmware development keeps getting better as more hobbyists and hardware designers adopt expressive chips in their projects (Babiuch et al., 2019). Writing a firmware for ESP32 has never been easier but this issue has solved by an Arduino IDE. It makes developer to integrate robust web functionality into their project. The ESP32-D0WD chip is at the heart of the ESP32-WROOM-32 MCU Modules in figure 2.17, which are designed to work with the ESP32-D0WD chip. The CPU clock frequency in this SoC, which has two CPU cores that can be controlled independently, can be adjusted from 80MHz to 240MHz.

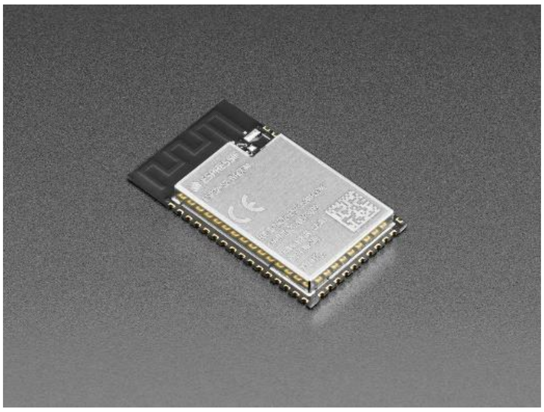

Figure 2.17 WROOM module for ESP32

2.5 Wi-Fi Technology

In 1980s, our personal computers had begun to enter our lives for good. But during that time, computers were connected to the internet through the infamous Ethernet cables. Thus, make user tired of tripping over all those cables since wanted to start sending data using radio signals. Those early attempts, however, were futile because it all bounced back on walls, furniture, and anything else that got in the way of a computer's way Dr John O'Sullivan, an electrical engineer who is also known as "The Father of Wi-Fi," was a pioneer in wireless technology during the 1970s. When he and his team were working on this project, it was during this research that they came up with a complex set of equations known as the Fast Fourier transform, which they used to detect radio signals from distant black holes in space. On the other hand, those black holes were not detected by them (Morales-Caporal et al., 2020). It was surprising to learn that 20 years later, Dr O'Sullivan and his colleagues decided to give wireless networking another shot, and it was those long-forgotten complex equations that played a critical role in the development of the Wi-Fi standard (Gomez et al., 2019).

Nowadays, wireless internet helps to send and receive files, pictures, and messages. Wi-Fi is a wireless network that transmits data between a router and a receiver using radio waves (user devices). These frequencies are measured in gigahertz, which is the smallest unit of measurement. While utilising Wi-Fi routers, data is transferred at speeds of 2.4 or 5 GHz per second, depending on the model. Furthermore, Wi-Fi technology works at extremely low voltage. Wi-Fi uses non-iodizing wavelengths of radiation that are harmless to the human body.

2.6 Wi-Fi vs Bluetooth Technology

Wireless communication technologies Bluetooth and Wi-Fi are both wireless communication technologies, and even though their identities, functionality, and other characteristics distinguish them from one another. Bluetooth technology allows for short-range wireless communication between electronic devices such as smart televisions, smartphones, laptops, and other similar devices. Bluetooth technology is used to accomplish this. The conventional wireless transmission uses only one frequency with the fixed channel same as tuning a particular radio station (Iqbal et al., 2018). But this type of wireless transmission has three problems, interference, jamming and interception. In order to address these issues, the Bluetooth use FHSS method which stands for Frequency Hopping Spread Spectrum. Bluetooth send and receives radio waves in a band of 79 different frequencies or channel centred on 2.4 GHz. Pairs of devices constantly shift the frequency 1600 times a second. This makes Bluetooth technology highly resistance to the interference.

Computers, laptops, and printers can all communicate with one another using wireless networking technology, which uses radio waves to facilitate high-speed data transfer between them. The terms "Wi-Fi" and "internet" are not synonymous in this context. They are related, but they are not the same. The internet is the language, and Wi-Fi is the signal that allows us to communicate with our connected devices in that language. This global network of connected networking devices communicates using the internet protocol suite, which is a subset of the internet protocol suite (Mesquita et al., 2018). Figure 2.18 explains a range of network objects embedded with sensors, software, and other information technology for communicating and transmitting information over the web. The Wi-Fi is an individual or private network which uses the radio signals sent from a wireless router to a nearby devices which translates the signals into data that we can see and use (Darroudi et al., 2019).

Figure 2.18 Wi-Fi technology embedded system

The devices shown in figure 2.18 transmit a radio signal back to the router, which may be connected to a wide area network, which is commonly referred to as "the Internet," for further processing. Generally speaking, Wi-Fi refers to the protocol or set of rules that governs how data can be transmitted over a radio network. The protocol is called “IEEE802.11” and there are several versions of that protocol which are available like 802.11A, 802.11B and 802.11AX is the latest one. The Wi-Fi router transmits at a frequency of 2.4 GHz and 5 GHz and across one of several channels per frequency. 2.4 GHz band meant for the long distances may have 14 channels whereas the 5 GHz band may have 44 channels, but it works for short distance (Coroamă et al., 2019).

Table 2 Comparison between wireless technology

Characteristic	WiFi	Classic Bluetooth	BLE
Signal Rate	54 Mbps	1 Mbps	720 Kbps
Normal Range	100 m	10 m	10 m
Transmission Power	20 dBm	10 dBm	1 dBm
Energy Consumption	100–50 mA	57 mA	15 mA
Hardware Cost	high	medium	low

As a conclusion, the Bluetooth devices consumes less battery in comparison to the devices which are connected to the Wi-Fi. The Wi-Fi uses 2.4GHz and 5GHz frequency band which is used to connect devices to the local area network and wide area network which also called the internet. Bluetooth only works with 2.4GHz. The Bluetooth uses FHSS method to communicate with the connected devices. The Wi-Fi refers to a protocol or set of rules. The protocol is called IEEE 802.11. Due to high productivity of Wi-Fi, employee can work more productively because his or her work can be done easily at convenient location within the coverage area of Wi-Fi network. Wi-Fi also gives faster speed compared to the Bluetooth. Downloading and uploading is good in Wi-Fi compared to the other network. The comparison of wireless technologies in terms of signal rate, range, transmission power, energy consumption, and device cost are shown in table 2.

2.7 Related Work

The Smart Office Automation System using Raspberry Pi was proposed (Murthy & AjaySaiKiran, 2018). The objective of this project is to control room temperature, humidity, and electrical loads by using sensor that connect with android mobile for monitor. In this project, Bluetooth and Raspberry Pi was used to control the office. By using the Bluetooth that connect with android mobile, they can monitor and control the loads. Through this project, the user can control light, C02 and temperature. There are some limitations for this project which can only control device in short range and the local database is use. Besides, the office security also cannot detect the motion of workers in the office (Sakaci et al., 2018) has done research with title Smart Office for Managing Energy of Lighting Control System. An energy-saving light-control system is designed and simulated in that report in order to reduce overall consumption. By incorporating artificial intelligence, it may be possible to more effectively manage and track a building's energy usage. The developed design, which uses fuzzy logic to control the lighting system, significantly reduces energy consumption while maintaining occupant comfort. Preliminary designs for one floor of the office building were simulated and validated using LabVIEW. According to the findings, the developed system saves 30 percent on energy consumption.

According to (Gomez et al., 2019), they proposed an intelligent system for office environments using the Internet of things. They have proposed the use of RFID tagging system and raspberry pi 3 to manage a smart office. The sensor used in this research paper is LM35, a temperature sensor. Besides, the application of IoT, MQTT is used to control and monitor the devices. However, the wireless connectivity on the board of raspberry pi 3 is limited to only Wi-Fi and Bluetooth. (Gufron et al., 2020) presented a Prototype Design of Smart Office at IAI-BBC base on LoRa. It proposed the prototype design of a smart office in IAI-BBC based on LoRa. This paper proposed to use the LoRa module as it covers long range distances, so the electronic devices are able to be monitored. However, there is a limitation on the distance for sending data using the LoRa as it only reaches up to 220 meters as it loses connection when the distance is more than 221 meters.

(Zou et al., 2018) proposed a novel lighting control strategy to observe the real status of the occupancy in an office for energy saving. As the lighting system developed expeditiously from the past, lighting consumes the global energy of 19%. From that percentage of electric light energy, 75% are from residential and commercial buildings which have released nearly 1.9 x 109 tons of carbon dioxide. Hence, with the application of multiple occupancy sensors for the detection of occupancy in an office will reduce the wastage of energy. The office will be illuminated by the lighting system if the illuminance level is less than the recommended illuminance level which is calculated from the probability of occupancy status. Users can choose to turn the light to be fully on if there is insufficient light in the office. However, as this paper only focuses on minimization of energy consumption, the output of the sensor is flickering when it is not stable. In addition, when the status of the occupancy varies, it results in the delay in the sensor output thus causing delay in lighting output. (Devalal & Karthikeyan, 2018) mentioned that as IoT became the demands in this new era, embedded systems become a dominant element in our lives as it is used in the field of business, industry, electronics, and more. LoRa is capable of data transmission over a long distance as it is a long range protocol. Besides, the battery consumption of LoRa networks is low by comparing to other communication technologies as the nodes in the LoRa network only communicate when there is data to be sent in asynchronous mode else there will be no transmission occurs. The LoRa network gateway has a high capacity as it receives data from a huge number of LoRa nodes. In addition, the LoRa network is offering high security where it integrates with two layers of security which is network security and applications gateway while most of the communication technologies only integrate with a single layer of security.

There are several IoT applications using LoRa technology such as streetlight monitoring, smart parking system and more. However, LoRa has limitations where it can be used only when the applications require a low data rate and it will limit the number of data that can be transmitted within a specific time frame.

(Shetty et al., 2021) has done research represent the implementation of new idea to automatically control and save energy. The occupancy and movement of office staff was controlled the appliances and office cubicles. Every staff will have RFID tag that will show likely occupancy of the office and in web application it shows yellow. Next, when enter and seating into cubicle it will show green. By using web pages, the on/off the utilities can be control. On this research, it focuses on security and controlling in office cubicles. This project use led as light, servo motor as fan, load cell, current sensor and ultrasonic sensor that connect at node MCU. Smart Home Energy Management Systems (SHEMs), a technology that transforms electrical home appliances and sensor networks into autonomous equipment to ensure a green living environment in smart cities, were investigated by researchers (ALiero et al., 2021). SHEMs are a technology that transforms electrical home appliances and sensor networks into autonomous equipment to ensure a green living environment in smart cities. Specifically, this paper investigates how different forms of power generation technology can be associated with the SHEM system in order to achieve a balance between the supply and demand of energy in the building sector.

In order to create future inventions of home appliances, it is recommended that existing building design and sensing technologies be improved. Researchers (Gu et al., 2020) carried out a survey on Smart Buildings and Homes that used Low-Power Wide Area Networks to collect data (LoRaWAN). According to the results of this survey, LoraWan can be used to remotely control the energy consumption of devices in the home or in commercial buildings from a distance. In the LoraWan architecture, transducers, actuators, and sensors are used to convert energy from one form to another through conversion. A fully automated control and monitoring system will make life easier while also increasing its enjoyment factor. Alternatively, it allows for a reduction in electrical consumption to be accomplished.

(Tayyeb et al., 2019) presented a sensor-based Smart Office control system for use in the workplace. In this project, a PIC Microcontroller is used to communicate with both Windows and Android applications. Along with controlling lighting and fan settings, it can also control the temperature and exhaust systems. The temperature sensor (LM35) is connected to the microcontroller via Bluetooth and provides the controller with the temperature reading it receives. It is possible to operate air conditioning controls in both manual and automatic modes. In Visual Studio, window software is programmed, and in Lab View, the structure of a window application is designed and built. His computer allows the staff to control the lights, fans, air conditioner, and heater using a single remote control. The manager's room, as well as the rooms of his staff, can be selected from the manager menu of the menu application.

Several researchers (Prasetyo et al., 2018) presented a prototype of a smart office system that was built upon the security system. The Internet of Things (IoT) was defined in this project as a network of interconnected smart devices, such as smartphones, internet-connected televisions, sensors, and actuators, that are all connected to the internet through a single network infrastructure. Metal detectors, fire detectors, earthquake sensors, and keypad sensors are all available as options for a security system installation. The waterfall model used in this project is based on an IoT builder based on an Arduino Mega 2560, which was developed by the author. It accomplishes two objectives: First and foremost, it serves as a security system for the office, which can be monitored and controlled from anywhere in the world through the Internet. As a secondary feature, an autonomous robot powered by a Raspberry Pi can monitor the security of the office during the night by following a predetermined path through the building. In accordance with recent research (Havard et al., 2018) on Internet of Things-based smart buildings, An Internet of Things (IoT)-based sensor monitoring project is described in this paper, along with the development and results obtained through the use of IoT technologies. When it comes to automatic control, both central heating and individual room heating must be taken into consideration. In a smart building, the use of sensors to detect and raise alarms is a requirement for safety. In addition, the use of carbon monoxide sensors can help prevent people from dying as a result of the gas. A smart building can detect the presence of an occupant as long as a window is left open. Security guards and building occupants each had their own app created specifically for them. LoRaWan networks are capable of operating over long distances (up to several kilometres), eliminating the need for a repeater, as is the case with Wi-Fi networks. The Lora interface's spread spectrum modulation allows it to pass through walls more easily than other types of interfaces. To transmit information, a low-range protocol and Lora data concentrators were used in conjunction with each other. Sensors and actuators can be controlled from a distance, and data can be transmitted to LoPy via Wi-Fi or Bluetooth.

Using wireless communication in the Internet of Things to reduce electrical energy consumption is discussed in (Alrikabi et al., 2020). The primary objective of this paper is to manage the energy consumption of buildings. In order for the system to begin operating during the typical working day, it had to be installed and tested. If the system detects a device that is still in use, it will send an alert to the system administrator to investigate. The Arduino Mega serves as the primary controller for the system, and eight-channel relays serve as the electronic switches for the system. In addition, the SIM88L GSM module was used to facilitate communication in notification scenarios, which was very useful. This application was created with the Android Studio Development Environment to allow users to control a wireless device through GSM communication. It was also mentioned that one limitation of the project is the fact that only one device can connect to the system at a time.

(Xu et al., 2019) in Developing, Implementing, and Deploying a Smart Lighting System for Smart Buildings The system was implemented and deployed in nine distinct types of production smart buildings, including residences, commercial agency, factory, and multi-story complexes. This will enable the buildings to be free of blackspots or dark zones. By utilising LoRa, the mesh network that was designed and implemented was able to increase the likelihood of existing wireless connectivity throughout the building. It has been proposed by (Wang et al., 2019) that a new smart sensing system for environmental monitoring be developed that makes use of LoRaWAN technology. A large number of sensor nodes are connected to one another through the use of a low-power communication technology known as LoRaWan. Atmega 1284p is controlled by RN2483 LoRaWan communication unit, which is also used as microcontroller. The sensor design makes use of a BME3280 temperature and humidity sensor, an LM386 loudness sensor, and a

GL5528 lightness sensor, among other components. The messages from the sensor nodes will be sent to the cloud through the gateway (TTN). The sensor node's battery voltage level was monitored over the course of three months, and it was discovered to be decreasing as a result of the weather. The Cayenne cloud provides access to the date that has been measured. Sensor nodes benefit from the wide-area wireless connectivity provided by LoRaWan.

As reported in the paper Smart monitoring and control of appliance using LoRa-based IoT system published by (Ahsan et al., 2021), the primary disadvantage of an existing system is its high battery power consumption. The growth of the LoRa market can be attributed to the increasing demand for low-cost and energy-efficient remote monitoring and control systems. Lora has a maximum range of 12 kilometres and is equipped with GPS. LoRaWan is capable of dealing with data loss due to the fact that each gateway can support 1000 nodes. I created a smart Internet of Things system using the ESP32 module. Lora offers a wireless communication module for long-range (3km-12km) communication as an alternative to short-range (10m-100m) communication technology. Multi-level buildings are used to test indoor LoRa signal propagation for Round-Trip Time (RTT) and Packet Delivery Rate (PDR) as part of the Performance Evaluations of LoRa Wireless Communication in Building Environment. In the field of data acquisition and communication, LoRa is a well-known technology due to its long-distance transmission, low energy consumption, and stable penetration within a smart building. Those who use LoRa in smart buildings will stand to gain significantly from these findings. Therefore, LoRa's signals will have difficulty propagating in densely populated areas where there is a high level of signal loss such as cities.

To meet the low-cost, simple-to-implementation, and architecture goals of LPWAN, (Eridani et al., 2019) developed a Lora Network Architecture using Simple LoRa Protocol Smart Gateway using the Raspberry Pi 3b+ with SLP as an intelligent gateway (Low Power Wide Area Network). The smart gateway from SLP is designed to work with LoRa technology. Access to the monitoring system is only possible through the use of a Local Area Network (LAN).

In the hardware design, an Arduino UNO with LoRa shields and dummy sensors as end devices are used to transmit the information from the dummy sensor to a remote location. The findings revealed that the smart gateway is capable of handling both LoRa communication and the surveillance system. The addition of an additional feature for the purposes of encryption and decryption is possible though.

For detecting human presence and estimating number of employees in a workplace at Aalborg University in Denmark using an IoT LoRa monitoring system for the indoor environment, as stated in their paper (Adeogun et al., 2019). Sensors used to detect occupants include those that measure the temperature, pressure, and humidity of the atmosphere, CO2, total volatile organic compounds (TVOC), noise characteristics, and PIR motion. It wasn't entirely automated: they also recorded the location of glass windows and the number of people manually. Between 6 p.m. and 6 a.m., no occupants can be detected in the sensors' recorded measurements, and thus those are discarded. The network can accurately determine office occupancy to a precision of up to 94.6% and 91.5% for binary and multi-class problems, respectively. As a result, when used for network training, the accuracy is only 54%, which may be due to the use of a single environmental parameter.

(Firouzi et al., 2020) created an Autonomic IoT Gateway for Smart Homes Using Fuzzy Logic Reasoner. For the first time, a two-level intelligence architecture has been developed to reduce latency, optimise network bandwidth, and shift some of the burden of computing from the cloud to the edge devices. Based on our results, we can conclude that a low-level intelligence IoT gateway can significantly reduce latency in a smart home scenario, as demonstrated by our results. This was done with the help of a Raspberry Pi 4 (Model B). PCB Antenna, Wi-Fi, Ethernet, and Bluetooth are all used as communication interfaces in this study.

Data loggers are being developed by (Guaman et al., 2018) for river water level monitoring stations in the Andean region. With the help of Wi-Fi and LoRa technology, the LoPy4 microcontroller is used in conjunction with a water level sensor (WL400). Data can be sent over long distances while using less power thanks to this technology. Greater ranges were made possible by Lora's use of Lora technology.

After that, it transmits data via LoRa and configures the data logger via Wi-Fi. This is a prototype for remotely monitoring things. FiPy and Pysense are comprised of two boards that work together. The Pycom Development Board is the name of this group (Voisin-Grall et al., 2019). In order to keep an eye on the environment, a prototype was created that utilised Internet of Things sensors and wireless protocols. Users would be able to access all of the data collected by the sensors in real time without the need to run wires all over the place, which would save time and money. They also make use of the Pycom development board FiPy as well as the Pysense sensor shield to monitor weather conditions such as temperature and humidity as well as altitude. LTE Long Range (LoRa) and Wi-Fi are two wireless protocols that are used to transmit sensor data from sensors to gateways, which then transmit the data to the cloud. An additional tool, a cloud-based dashboard, was developed to present the information in an understandable manner.

All the summaries have been compiled in the table 3 below based on recent projects and articles. The table included the project description, as well as its benefits and drawbacks.

Table 3 Summary of the related work

References	Project description	Advantages / Limitation
(Murthy & AjaySaiKiran, 2018)	To control room temperature, humidity, and electrical loads by using android mobile through Bluetooth connection	1. MCU used is expensive (Raspberry Pi) 2. Local data based is used 3. The size of controller is huge
(Sakaci et al., 2018)	To control all the lighting system by using artificial intelligence and applying fuzzy logic control	1. Required more sensor to mount for each room 2. Can reduce energy consumption without compromising the occupant’s comfort
(Gomez et al., 2019)	A detailed smart office system focusing on door access, lighting,	1. Required more sensor

	illumination, ventilation, heating, and reconstruction is being developed to conserve energy and increase employee satisfaction	2. The system can't integrate with the IoT technology 3. Can save energy up to 30% energy consumption
(Gufron et al., 2020)	To design smart office concept by using LoRa communication	1. LoRa can send data only 220 meters 2. Required LoRa server 3. The respond time a bit higher compared to other communication system
(Zou et al., 2018)	Design a novel lighting control strategy to observe the real status of the occupancy in an office for energy saving	1. Required Wi-Fi module to transmit data 2. Sensor is flickering then affected the lighting output
(Devalal & Karthikeyan, 2018)	Use a dependable dual configuration non-conventional source of energy for storage and utilisation for a LoRa-enabled device or a LoRa Gateway to be powered up	1. Data packet size only 50 bytes 2. Can send data up to 10KM 3. Required LoRa Server
(Shetty et al., 2021)	Create a smart workplace system that can control and monitor electronic devices and automate them based on when each employee comes and goes from the work area	1. Each user need to have a RFID tag 2. Temperature sensor not suitable for long term use (LM35)
(ALiero et al., 2021)	Design a system that transforms electrical home appliances and sensor networks into autonomous equipment to ensure a green living environment	1. Need modifications on existing electrical appliances 2. The initial cost a bit higher

(Gu et al., 2020)	Improve existing building design and sensing technologies	1. LoRa WAN technology can reduce energy consumption 2. All the actuator and sensor energy can be used to other form
(Tayyeb et al., 2019)	Design a system that consists of multiple sensors to control electrical appliances in the office	1. Temperature sensor used not suitable for a long term 2. Use Bluetooth communication to send data to windows and android application.
(Prasetyo et al., 2018)	Design a prototype of a smart office system based on security system	1. All the sensor are connected with internet connection
(Havard et al., 2018)	An IoT based on sensor monitoring devices	1. Need to open the windows to detect presence of human 2. LoRa communication can pass through wall
(Alrikabi et al., 2020)	Using wireless communication technology to reduce electrical usage in a building	1. Controller that used consume less energy 2. Transmit data through GSM communication. 3. Only one device can connect at one time
(Xu et al., 2019)	To assist solution providers in creating their own architectures for smart buildings, create a framework	1. Create a resilient LoRa mesh network that can withstand changes in the environment 2. Consist of Amazon Web Services

(Wang et al., 2019)	Designing smart sensing device for environmental monitoring through LoRaWAN communication	1. Use TTN as cloud 2. Consume less energy
(Ahsan et al., 2021)	Smart monitoring and control electrical appliance at the office by using LoRa based IoT	1. High battery consumption 2. LoRa range of 12KM 3. Equipped with GPS
(Eridani et al., 2019)	Design a LoRa network monitoring system employing a smart gateway that communicates using the simple LoRa protocol	1. Required gateway for the server 2. Compared to LoRaWAN this system has a higher rate of packet loss
(Adeogun et al., 2019)	Create a system for detecting human presence and estimating number of occupants in an office	1. The accuracy of the binary has increased to 94.6 percent
(Firouzi et al., 2020)	Developing an IoT gateway for smart home by using fuzzy logic reasoner controller	1. Required PoE to power up the system 2. Can improve network bandwidth
(Guaman et al., 2018)	Designing a smart water level monitoring and data loggers	1. Data can send over long distance while using less power. 2. Data configuration by Wi-Fi
(Voisin-Grall et al., 2019)	Develop a prototype the include sensors and wireless protocol which is Pycom development board to transmit data from sensor to cloud using Wi-Fi	1. Controller that used is expensive 2. Able to send data such as temperature, humidity and pressure

2.8 Summary

This chapter provides a high-level overview of the Internet of Things, smart office systems, and the advantages of using a conventional smart office system. In addition, the chapter includes a brief discussion of the differences and similarities between Wi-Fi and Bluetooth, as well as the design of a smart office, which includes both hardware and software components. It also includes information on a related project, an Internet of Things-based control system for energy savings in workplaces. The workings of this project will be explained and discussed in greater depth in the subsequent chapter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology that was used in this study, which includes system design and implementation details for the IoT@workplace system, as well as a simple workplace prototype, will be discussed in detail in the following section. Also included are descriptions of the component selection process and how the components are integrated into the overall design, which are necessary to achieve the objectives that have been set forth in the proposal.

3.2 Flowchart of Methodology

Based on figure 3.1, The study initiates with analysing the common issues that have arisen in the implementation of the existing workplace or office system. Recently published journal articles, book chapters, and research papers are used to compile all of the information and components. The next phase is design, which includes component selection and cost estimation, as well as system architecture and schematic diagrams.

The following step is to develop and put into effect the design that has been suggested. Using the office prototype as a guide, calibrate each sensor in accordance with the specifications of the design. Following that, the Blynk application's GUI (graphical user interface) is being developed in order to improve and optimise the system, as well as the design of the prototype. Following that, testing has been conducted in this phase, during which all parameters must be verified and the function of each sensor must correspond to the initial setup. Finally, it is necessary to finalise the prototype's system and design. During this phase, all diameters must adhere to the prototype design and ensure the system operates properly.

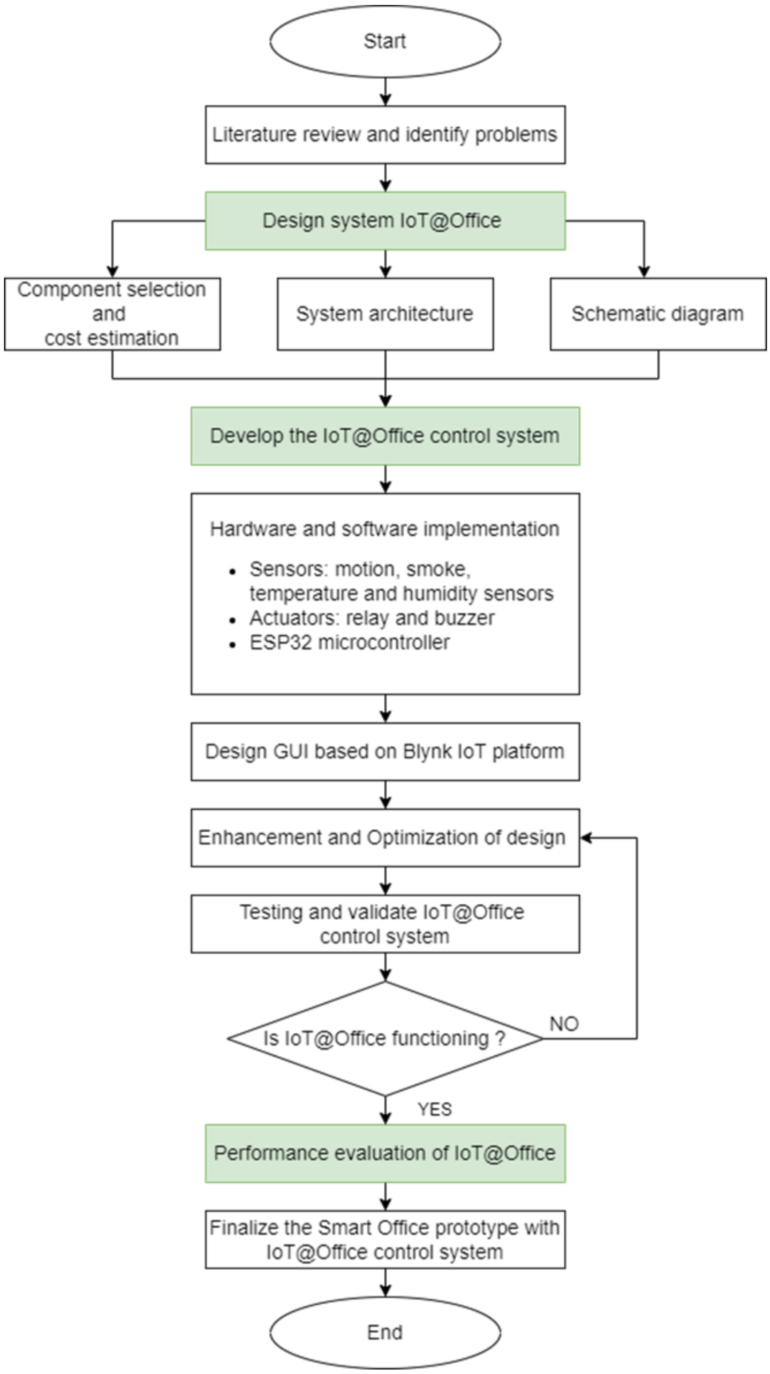

Figure 3.1 General flow of the methodology project

According to the current system configuration, the lighting system consumes a significant amount of electrical energy. As a result, businesses are forced to pay for the excessive electricity consumption that they engage in. The design of an office prototype and the implementation of an Internet of Things@workplace system are the primary concerns, but materials and components are also taken into consideration.

3.3 Literature Review

To determine the issues and limitations with the existing smart office system as well as its energy consumption, a review of existing products, papers, journals, and articles was carried out during this phase in order to identify any potential issues or limitations. A study has been carried out in order to identify the issues with the current system in the office. The first issue is the existence of unnecessarily high levels of energy consumption and consumption waste. The system will be solved through design sensing, which will employ multiple sensors to detect when an employee is present in the office, thereby reducing energy consumption.

The second issue is that the current smart office has limitations in terms of the range of connectivity that it can provide, which is particularly problematic. As a result of the restriction, the user is unable to monitor and control the appliances in the office. This project will put in place a control system that will allow remote monitoring in smart offices with the help of Wi-Fi, which is a wireless communication technology.

Furthermore, the Internet of Things (IoT) technologies are absent, the user interface is unintuitive, the wireless transmission range is limited, and the cost of current smart office automation systems is prohibitively expensive. In order to address these issues and minimise the limitations of existing systems, this project introduces IoT@Office as a hybrid (local and remote) easy-to-implement and cost-effective automation system solution. IoT@Office enables users to control their workplace quickly and easily through a user-friendly interface based on the Blynk IoT platform integration via Android smartphones regardless of time or location via a user-friendly interface.

3.4 Energy Efficiency

Energy efficiency is one of the most underappreciated energy solutions available today. In order to provide the vast majority of our services, we must rely on the use of energy. Greater efficiency is achieved by using less energy to complete the same task. In energy efficiency, the useful work or energy output to the corresponding energy input ratio is a common way to express the relationship between useful work and energy output.

The greater the energy efficiency of a system, the less energy is required to produce the desired output from the system.

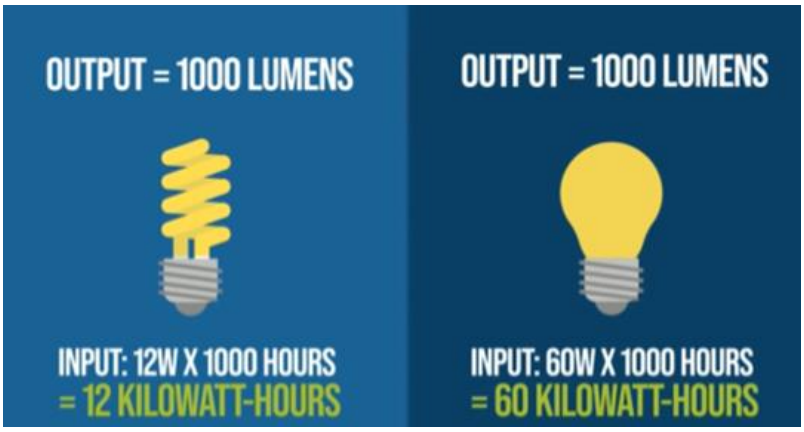

Figure 3.2 Comparison between energy efficiency with bulb

Consider the following illustration, figure 3.2 shows a 12-watt compact fluorescent light next to a 60-watt incandescent lamp. They both produce the same amount of light when measured in lumens, which is the unit of measurement used in this comparison. If the CFL bulb is used for 1000 hours, it will have consumed 12 KW hours of electricity. A standard incandescent bulb, on the other hand, will have consumed 60 kilowatt hours of electricity. Most electricity bills are charged per kilowatt hour (KW/H). This energy saving across appliances will result in cost savings. Increasing energy efficiency means delivering the same service using less energy or delivering a higher useful output for the same input energy. Energy efficiency can lead to energy conservation. Improving energy efficiency in buildings, transportation and other energy intensive processes is one of the most important ways.

We must reduce our emissions of greenhouse gases into the atmosphere if we are to make a significant dent in the global warming problem. Unfortunately, global improvements in energy efficiency have been declining. Through investing in energy efficiency across sectors especially workplaces and advocating only through energy efficiency policies can we reduce emissions while creating millions of jobs in the renewable energy sector.

3.5 General Flow of IoT@Office

Our main objective is to design a system that can help to decrease expenses and increase energy efficiency while keeping workers comfortable.

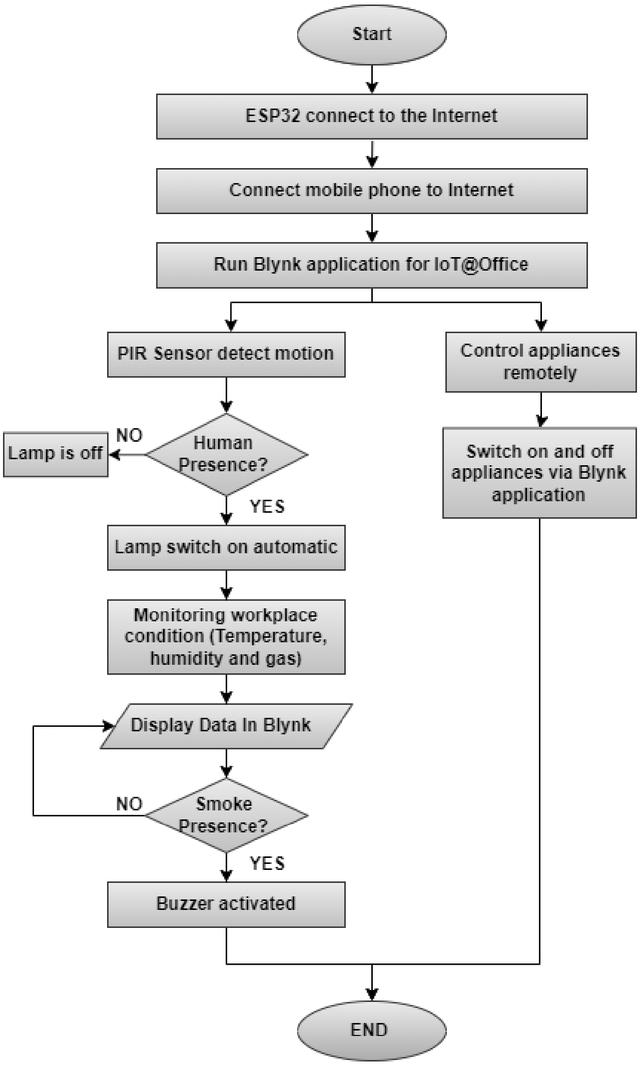

Figure 3.3 The flow chart of the entire system

The project flow can be illustrated using a flow map (figure 3.3), which is commonly used to depict the project's stream and phases. Starting with the establishment of an internet connection, the ESP32 microcontroller will make use of the Wi-Fi communication system. Immediately after connecting the ESP32 to the Blynk application, the system begins to operate and each sensor sends data to the microcontroller, allowing the microcontroller to keep track of all of the parameters. If a motion sensor detects the presence of someone nearby, the light will turn on. The purpose of this feature is to reduce the amount of energy consumed by the office to a bare minimum.

Aside from that, the smoke sensor will determine whether or not there is smoke in the area and will relay this information to the controller. Activation of the buzzer will signal the presence of smoke in the area, which will serve as an alarm. Using the temperature sensor, which serves as an input device, the controller can read or monitor ambient temperature and humidity, and the information is transmitted to the controller.

The final step is to use the Blnyk application to control the light from a remote location. Users can access and control all of the data and processes in the system through the use of a smartphone or a computer.

3.6 Prototype Design

A focus on the necessities of an office is demonstrated by the design depicted in figure 3.4 below, which includes the workstation, meeting room, pantry, and reception area, to name a few features. Its dimensions are as follows: 30 inches in length, 20 inches in width, and 7 inches in height for the prototype design. In the following step, the lighting in the office is controlled based on the occupancy status, which is determined by motion detection from two HC-SR501 motion sensors installed in the space.

Smoke sensors such as the MQ2 are used to detect the presence of smoke or gas leaks, and they emit an 80dB alarm to alert workers to the presence of a problem. The DHT22 temperature sensor is used to keep track of the temperature and humidity levels in the office environment.

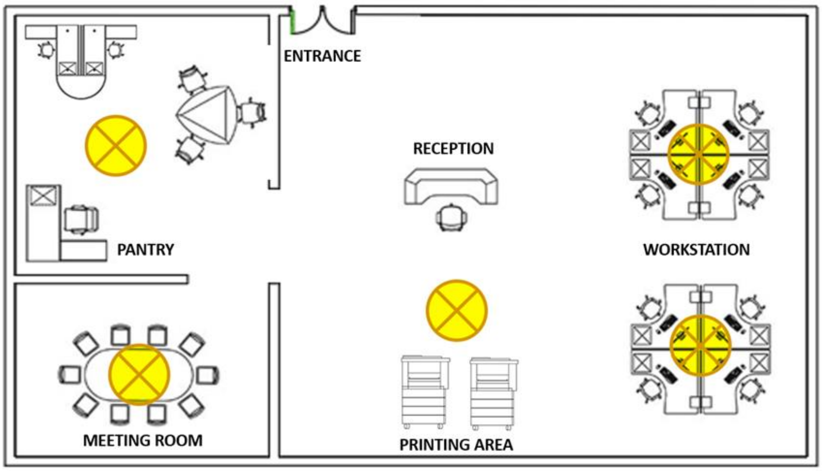

Figure 3.4 Floor plan of the smart office prototype

The sensors are placed in a control box which is installed at the centre of the office area and mounted at a high position to detect the office occupancy status for monitoring and remote purposes. The centre of the control box is installed with a 25mm round hollow pipe and a 4’’ x 6’’ control box is placed at the centre of the smart office prototype. Generally, the smart office prototype is implemented with the IoT@Office control system.

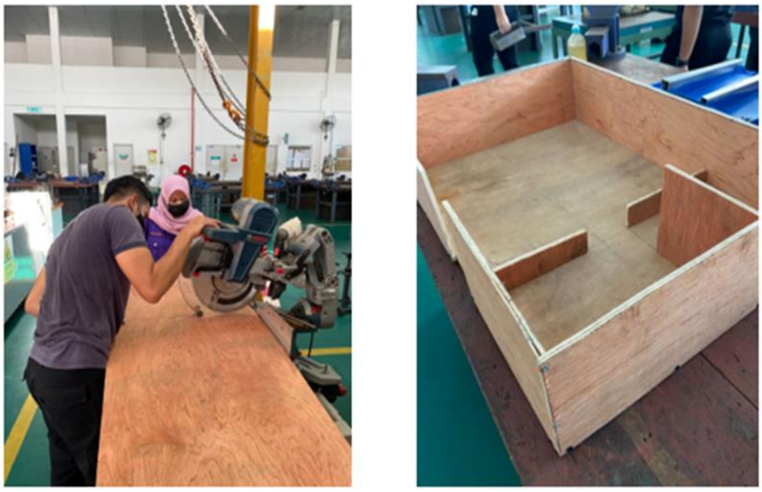

Figure 3.5 Fabrication process

Figuratively, figure 3.5 shows the fabrication process used to create the office prototype design. Plywood was chosen for this project because it is both inexpensive and simple to work with.

3.7 Overall System Framework

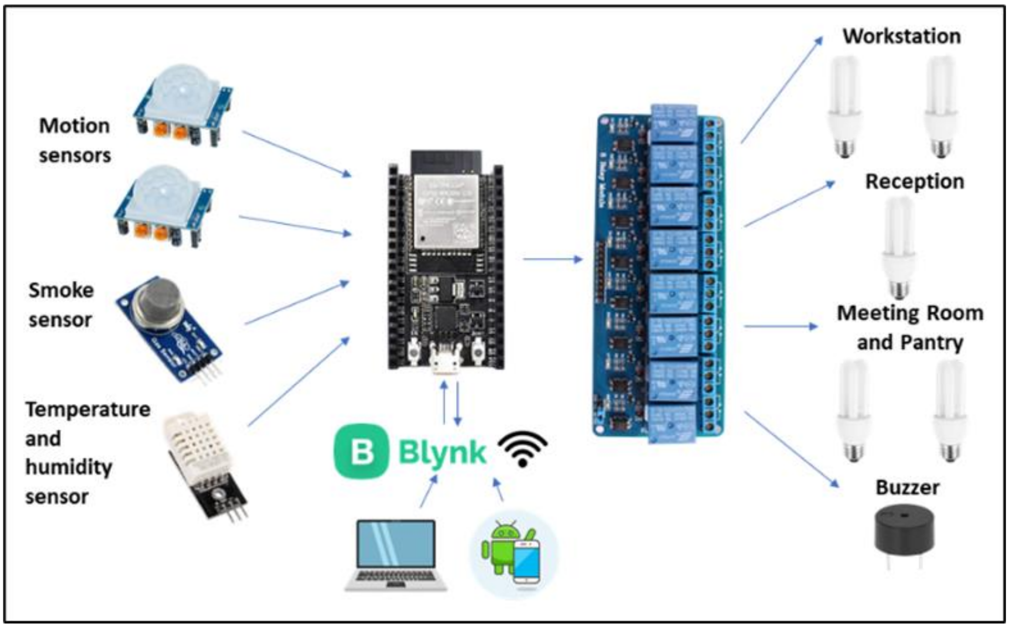

Figure 3.6 System architecture of IoT@Office

An overview of the IoT@Office control system's overall system architecture is depicted in figure 3.6. Asynchronous transmission of signal data from all sensors to the Blynk application will be accomplished by using the ESP32, which will respond to the system by turning on/off lights and displaying the temperature, humidity, and smoke values in the smart office prototype. The ESP32 includes Wi-Fi that is linked to the Internet. The embedded system's linkage can be adjusted or modified based on the user's network access system. Users can track and control the smart office prototype's equipment using whatever Android smartphone or tablet that really can control the lighting system and supervise temperature, humidity, as well as smoke intensity.

All the sensors are connected as inputs to the GPIO pins of the microcontroller ESP32 while the actuators are the outputs. For instance, when the motion sensor detects motion, it will trigger the lights of that particular area in the office. The light will automatically switch off when there is no continuous motion detected after a certain period. Other than that, the smoke sensor will detect a high concentration of smoke or gas leakage then it will trigger the buzzer to alert the occupants in the office for safety purposes.

The developed programming inside the microcontroller is the brain of the entire system. Sensor and actuator components are being used in the prototype's development. This system's actual implementation can be improved by incorporating numerous sensors and actuators, as well as safety systems to ensure the overall security of the system and workplace.

3.8 Circuit Design

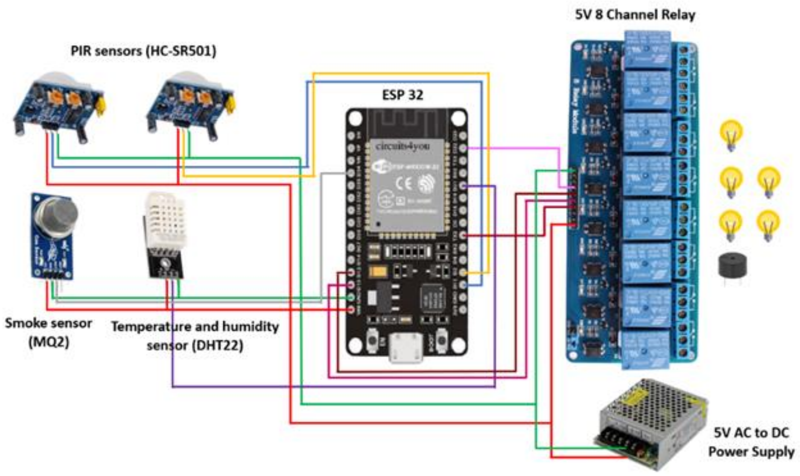

Figure 3.7 Circuit Schematic of the system

As shown on figure 3.7, a full circuit design has been constructed in Fritzing software. An eight-channel 5V DC relay module acts as an actuator to control the bulbs, and a buzzer. The relay is activated or deactivated in response to signals received from the ESP32, in which the user or sensors send commands. The relay board overcomes the controller's control voltage limitation, allowing 5 V DC electricity to be used to control 240 V ac appliances.

3.9 Component selection

Various sensors are used in this study for a variety of applications. The HC-SR501 PIR sensors are used to detect occupancy or detect any motion in the office and transmit the signal received to the ESP32, which responds accordingly. For this project there are two units of PIR sensors used to detect occupancy on each side of the office. The received signals from the PIR sensors can be used to switch on/off the lights by indicating the motion of the workers in the area of the office.

A DHT22 in figure 3.8 temperature and humidity sensor is used because it has a relatively high measurement accuracy compared to the DHT11. The DHT22 temperature sensor has a temperature range of -40 to 125 degrees Celsius and 0.5 degree accuracy. Only between 0 and 50 degrees Celsius, the DHT11's temperature range is only accurate to within a 2 degree margin (Adhiwibowo et al., 2020). The DHT22 significantly outperformed the DHT11 across every way, including temperature range, temperature accuracy, and humidity range and accuracy. The only disadvantage of the DHT22 is its relatively higher price, but we are paying for spec wise. Other than that, this temperature and humidity sensing component will enable the user to stay updated on the office's status simultaneously.

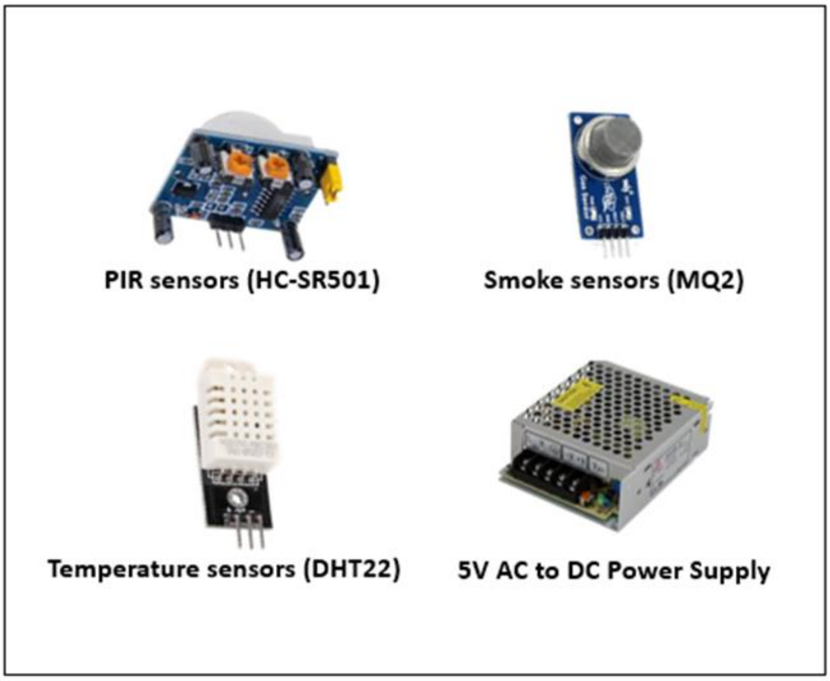

Figure 3.8 Various of sensor that used for the project

A MQ2 smoke sensor in figure 3.8 is used to detect and activate the buzzer when combustible gas or smoke is detected in the office or workplace (Ilham et al., 2021). This sensor monitors gas levels in the air and outputs measurements in the form of analogue voltages. The sensor operates in temperatures ranging from -20 to 50°C and only consumes less than 150 mA when operated at 5 V. The sensitivity of the MQ2 sensor is decided by the Sensor Resistance (Rs/Ro) ratio, sensor value throughout CO/smoke exposed, and the current or 10 kOhm is the starting sensor resistance. Using the RS/Ro ratio, a value in parts per million is calculated (PPM).

This sensor is intended to enhance the safety of smart offices in the occurrence of a gas leak or a fire. For instance, the buzzer which indicates the fire alarm in the office will be triggered when the smoke sensor detects a certain high level of concentration of smoke for safety purposes.

The main part for this system is the micro-controller which is ESP32. The ESP WROOM 32 is a dual-core, 32-bit micro-controller module that is part of the ESP32 series. Each CPU cores can be individually controlled. It can support clock frequencies of up to 240MGHz. The ESP WROOM 32 has multiple power mode. The devices have integrated Wi-Fi, Bluetooth and Bluetooth Low Energy. I/O pins (both digital and analogue) are plentiful on the ESP32 microcontroller (Kurniawan, 2019). There are up to eighteen 12-bit analogue to digital converters in this device, which can be used simultaneously. In addition, two 8-bit digital-to-analogue converters are included with the package. As shown in figure 3.9, the MCU has ten capacitive touch sensor inputs, four SPI bus channels, and two I2C bus ports to accommodate various applications. Besides that, it also has 2 I2S bus connections which is a bus connection that can carry audio. The device also contains 3 UARTs for serial communications.

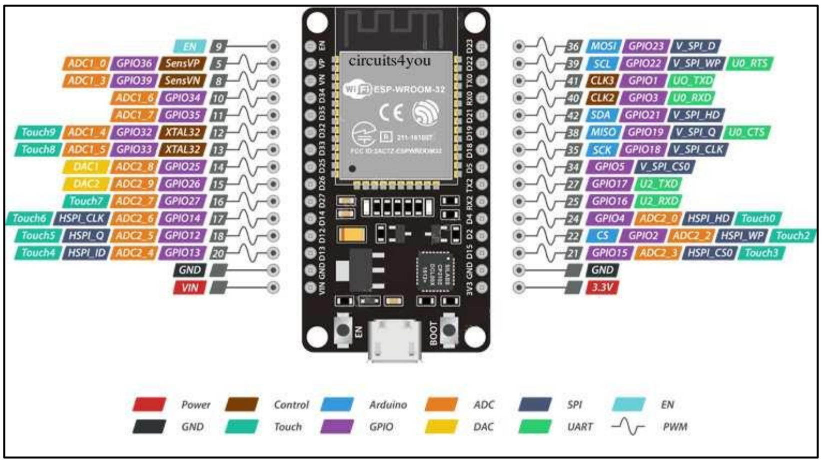

Figure 3.9 ESP32 Dev Board Pinout

An interactive graphical user interface (GUI) is created in the software implementation phase to allow the smart office prototype to be monitored and controlled.

The GUI is an Android smartphone-based interface using the Blynk application that is available in the Google Play Store. Figure 3.10 shows the example of established GUI for the IoT@Office control system.

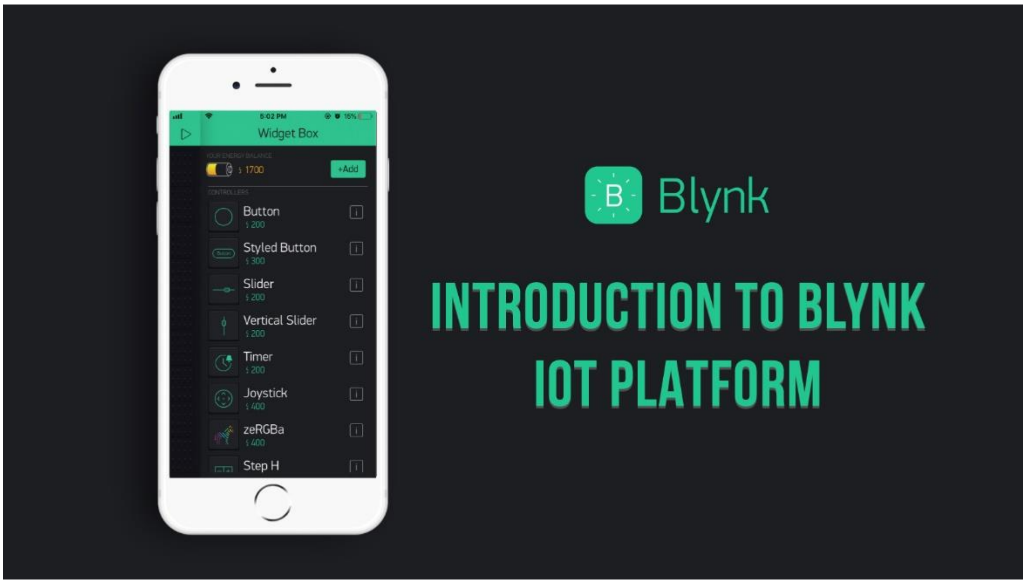

Figure 3.10 Blynk Application

IoT@Office control system is monitored and controlled by Blynk (figure 3.10), an Internet of Things platform that allows the smart office system's graphical user interface (GUI) to be quickly and easily built from Android devices. Blynk is a free and open source Internet of Things platform licenced under the MIT licence that is designed to be simple to use by both developers and consumers (Durani et al., 2018). The Blynk app makes it simple for smartphone users to interact with microcontrollers through the use of a simple interface. By establishing a Wi-Fi connection between the ESP32 and the Blynk, the IoT@Office control system is able to display sensor data in real time.

3.10 Problem Occurs

In the course of the testing process as shown in figure 3.11 below, several errors and issues arise. In order to use the relay, you must first connect it from its load to its relay port. The load is not operating in the manner that is desired. Following the troubleshooting procedure, the load must be connected to a single relay and cannot be combined with another in order to function properly. In short, a new relay with a total of eight channels must be installed in order to resolve this problem. Aside from that, some components are unable to function properly after integrating all of the sensors and linking them together with the relay device. As a result of the microcontroller's insufficient power output, this occurs. A 5V DC power supply must be connected to the entire system in order for the energy consumed to be used as efficiently as possible in order to resolve this problem. As a result, the issues that arose during the initiation phase are addressed and resolved.

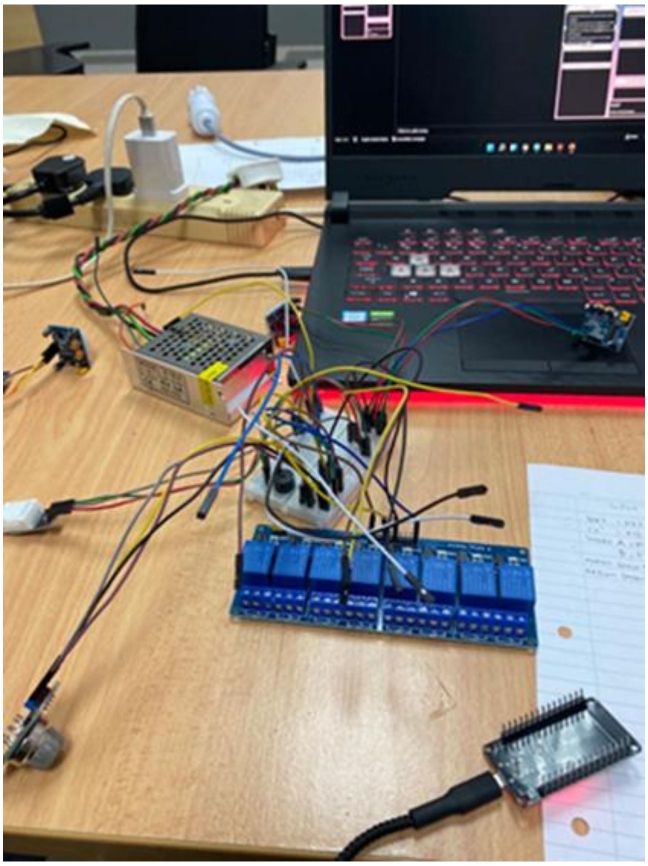

Figure 3.11 Troubleshooting the system on problem that occur

3.11 Cost Analysis

Table 4 Cost for the prototype design

NO	ITEM	PRICE (RM)
1.	ESP32 board + USB Cable	RM 28.00
2.	MQ2 Gas and DHT22 Temperature and Humidity Sensor	RM 26.49
3.	Jumper cables	RM 16.20
4.	HC-SR501 PIR Sensor	RM 10.19
5.	White paint	RM 20.30
6.	8 Channel Relay	RM 16.80
7.	Donut Double Sided Board	RM 5.00
8.	Junction Box	RM 6.50
9.	E27 Batten Lamp	RM 1.50
10.	5V DC Power Supply	RM 13.58
11.	Plywood	RM 28.00
TOTAL		RM 172.56

3.12 Summary

As a conclusion, this chapter's summary explains in precise detail how the project was designed, built, and implemented. The flowcharts, system architecture, and flowcharts for the project were all explained in great detail here. Prototype building was also explained, including circuit design and component selection as well as GUI and programming coding for the smart office system.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this section, we will take a look at the hardware that was used to build the prototype, as well as how well it performed. The results of the experiment served as the starting point for the discussion.

4.2 Fabrication of Prototype

Figure 4.1 shows the construction of the workplace prototype, and it is made from plywood. The main part of the prototype, which is the base, is made from plywood with thickness about 3mm and the entire construction and the partition is 2 mm of thickness. A mitre saw is used to cut the plywood into exact dimensions and size into pieces, then all the entire pieces of plywood being attached by using a 6'' drywall screw. The main idea of using plywood as a prototype material is surely it is cheap and affordable compared to other materials. It is also easy to work on, for example to cut or drill a hole also it is commonly used and easy to get at any hardware or machinery store.

The controller box is made from polyvinyl chloride (PVC) and it is weatherproof. The size of the box is six inches long, four inches wide, and three inches high. The prototype in figure 4.2 shows the model is painted in whiter colour to enhance its look and to extend the lifespan of the prototype. All the sensors, micro-controller, relay and DC power supply are all mounted in the junction box. The lamp holder is E27 batten type AC and it is all connected by 1.5mm2 size of the cable then connected to the relay inside the junction box.

Figure 4.1 Early stage on fabrication prototype

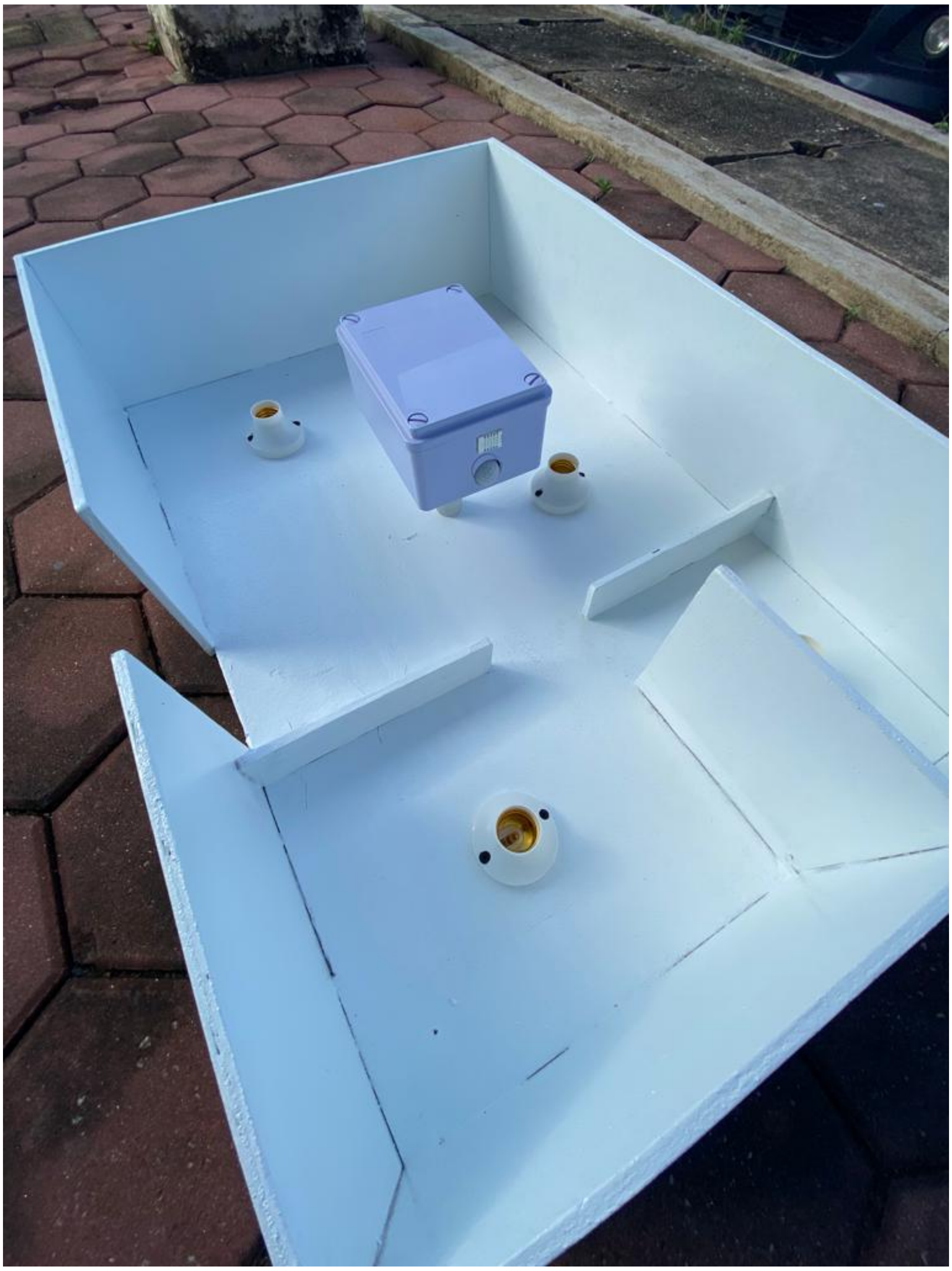

Figure 4.2 Prototype painted in white

The prototype depicted in figure 4.2 has been painted white in order to improve its appearance as well as to extend the life of the prototype.

In the figure 4.3 and figure 4.4 show the fabricated smart office prototype with implementation of the IoT@Office control system. IoT@Office has successfully automated and remote controlled the office lights based on occupancy status and at the same time monitored the temperature and humidity, and smoke level in the office via the Blynk application in android mobile devices.

Figure 4.3 A top view of the Smart Office prototype

Figure 4.4 A side view of the Smart Office prototype

Figure 4.5 Workstation area inside the prototype

Figure 4.6 Meeting Room area inside the prototype

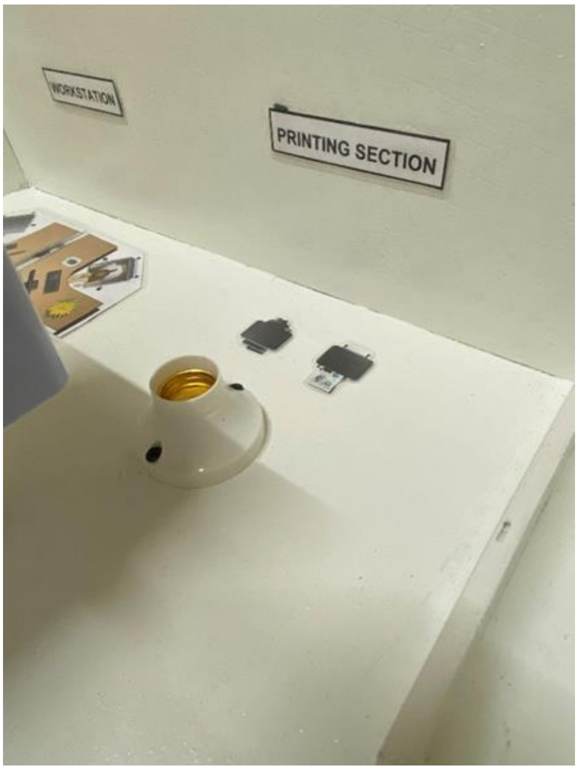

Figure 4.7 Printing section area inside the prototype

Figure 4.8 Pantry area inside the prototype

For this system design, we already installed two units of e27 batten lamp to indicate the load on the working station area, as shown in figure 4.5, and for the meeting room area, as shown in figure 4.6, we installed one unit of E27 batten lamp and some decoration to simulate a meeting room. The printing and pantry section in figure 4.7 and 4.8 were both installed with a single E27 batten lamp and some decorative elements.

This prototype uses an E27 batten lamp holder for its lighting system. There are lamp holders in every home, factory, and workplace. Secure light bulbs and connect them to the electrical supply. Certain lamp connectors come equipped with a switch for turning on the light source, while others do not. With a wide range of shapes and sizes, lamp holders can support a variety of other fixtures' accessories or components, such as light shades. Other names for these components include lamp holders and bulb holders; they are also known as light sockets and light fixtures.

Figure 4.9 E27 batten lamp holder

When it comes to lamp holders, they must be able to accommodate a wide range of different bulb sizes and shapes. The E27 as shown in figure 4.9 shows the lamp bulb and holder, which is the E14's bigger brother, has a socket with a diameter of 27mm. It is possible to use them for both indoor and outdoor lighting applications.

4.2.1 Circuit Design

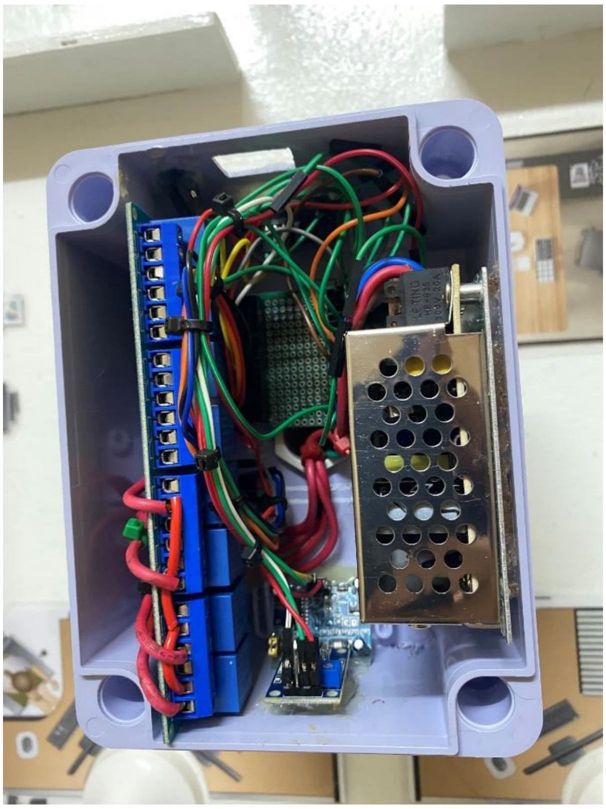

Figure 4.10 Circuit wiring inside the controller box

The main wiring for the system is located in this control box, which is depicted in figure 4.10. It is made up of an 8-channel 5-volt dc relay, a DHT22 temperature and humidity sensor, a MQ2 smoke sensor, and two units of the HC-SR501 PIR sensor, among other components. A 240V AC to 5V DC power supply has been used for powering up all of the sensors and the controller, while an alternating current (AC) power supply has been used to illuminate the bulb. The size of cable that used for lighting purpose is $1.5mm^2$.

4.3 Monitoring and Controlling Result

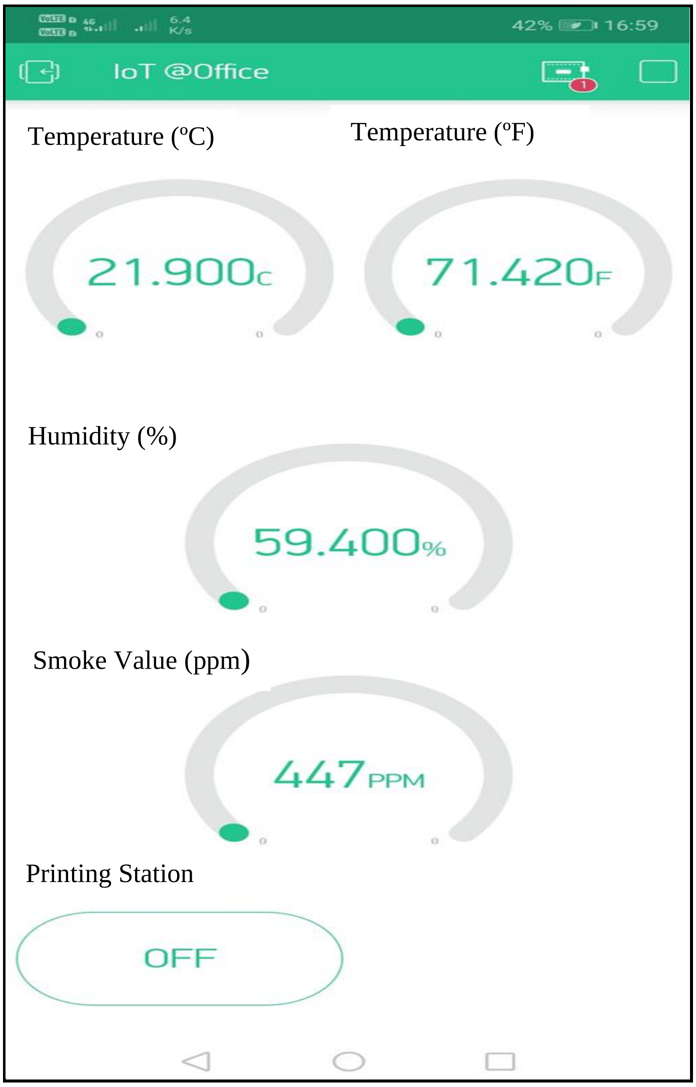

Figure 4.11 Temperature, Humidity and Smoke value inside Blynk Apps

The figure 4.11 shows value of temperature, humidity, and smoke value via Blynk Application through Wi-Fi connection regardless of time and location. IoT@Office has successfully automated and remote controlled the office lights based on occupancy status.

Figure 4.12 ON button that indicates light are turn ON

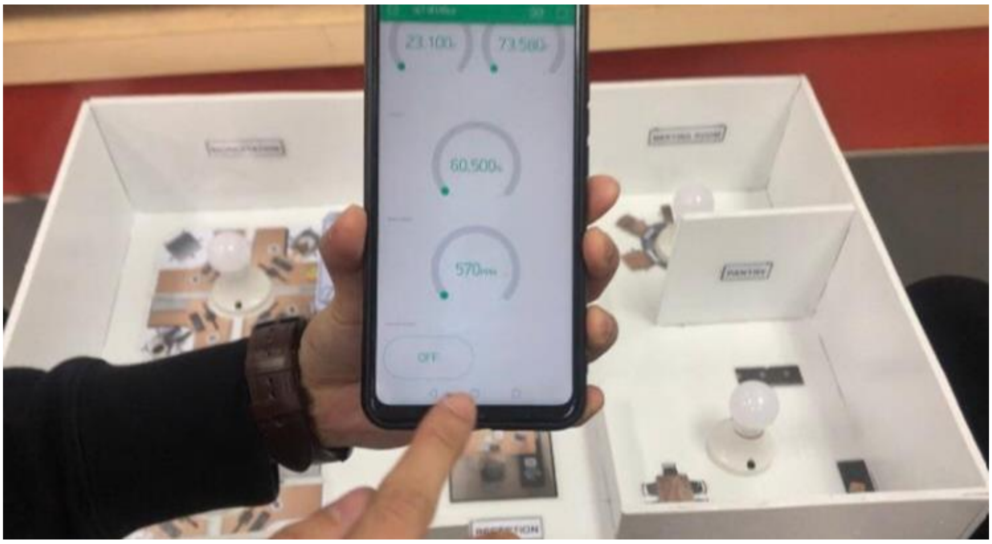

Figure 4.13 OFF button that indicates light are turn OFF

As shown in figure 4.12, when the prototype's lamp is turned on, the Blynk application's graphical user interface (GUI) will also turn green. While in figure 4.13, you can see that when you turn off the prototype's light, it disables the green button.

4.4 Performance of PIR Sensor

The PIR sensor is used to detect any motion within the prototype area that falls within the sensor's specified range. However, for this model, the HC-SR501 PIR sensor, the working principle is as follows: when motion is detected, the output will remain HIGH (1) for the duration specified by the TIME setting on the potentiometer. As a result, any load connected to the output will become LOW after a specified period, even if there is movement after the time period specified on the potentiometer. The concept is that the lighting system should remain switched ON (HIGH) after the time period and will be switched OFF (LOW) if there is no movement following the time period.

This condition does not accomplish our goal. Thus, in order to resolve this issue, the interrupt, delay() and millis() functions must be added to the ESP32's programming. Because a pin's current value does not need to be checked on a regular basis, the interrupts' function is employed. An event will be triggered, which means a function will be called, with interrupts. To use this function in the Arduino IDE, the function name must be written as shown in the following figure 4.14 below:

```
attachInterrupt (digitalPinToInterrupt (GPIO), function,
                              mode);
```

Figure 4.14 Coding for Interrupt function

The implementation of a delay function is the next step. The application of this method appears to be a straightforward solution to the issue at hand. There is only one input parameter, which is an integer number of one digit. These milliseconds represent the amount of time a line of code must wait before continuing on with its execution after it has finished. It is necessary to use the millis () function in order to determine how many milliseconds have passed since the process began. As a result, the final code for this problem is as follows figure 4.15:

```
if (currentMillis - previousMillis >= interval) {

           previousMillis = currentMillis;
```

Figure 4.15 Coding for Millis function

In essence, the code is executed by subtracting the current time from the pre-recorded time (previousMillis) and then running the resultant code (currentMillis). (previousMillis) is updated, and if the remainder is greater than the interval, the interval is extended if necessary. Any code outside of the first (if statement) should continue to function normally because this snippet is non-blocking.

4.5 Summary

To summarise, this chapter describes in detail how to create the prototype described in the previous section. On top of all that, prototype fabrication is required, which includes circuit design as well as material selection. Furthermore, all of the data and results that have been obtained are displayed on this page as well. Finally, there is a discussion of the obtained results as well as the sensor performance, which is included.

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a result of this Senior Design Project 2, a successful control system based on the Internet of Things (IoT) at the workplace has been developed (SDP2). A pre-established Wi-Fi network is used by the ESP32 microcontroller and the IoT@Office control system to keep the internet connection up and running on the IoT@Office device. End users can gain access to the developed control system, which uplinks sensor signal to ESP32 and downlinks used command to ESP32, through a simple web interface.

Consequently, the Blynk app on an Android mobile device can be used to control the lights in the office and monitor the temperature, humidity, and smoke level in the smart office prototype, all from a single location. It is the goal of Blynk to provide users with the most up-to-date information available. On the Blynk GUI, there are buttons that allow users to turn on and off the lights. The Blynk control system is used by the IoT@Office control system because of its user-friendly interface. The implementation of the IoT@Office control system in this project will reduce energy consumption because the lights in the office can be controlled remotely and automatically ON/OFF from the smart office monitoring and automation algorithm, which will reduce the amount of electricity consumed.

Additionally, the Internet of Things@Office control system for energy saving in offices and remote control of the power source over the Internet can be used to avoid unreasonably high increases in the electric bill, as previously mentioned.

5.2 Recommendation for Future project

According to this study, the IoT@Office control system can be improved by incorporating a wireless communication technology known as LoRa, which has a greater transmission range and consumes less power than other wireless communication technologies. In addition, additional sensors can be used to assist in detecting the occupancy status of the office as well as for safety and security purposes, thereby enhancing the smart office system's overall functionality and effectiveness. Last but not least, printed circuit boards can be used to optimise circuits in order to save space while also reducing the likelihood of connection losses or short circuits occurring.

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APPENDICES

```
#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <DHT.h>
#define DHT_SENSOR_PIN  21
#define DHT_SENSOR_TYPE DHT22
#define timeSeconds 10
BlynkTimer timer;

// Declaration for PIR (HC-SR501)
const int RelayWP = 13;
const int motionSensorWP = 26;
const int RelayMR = 12;
const int motionSensorMR = 25;

// Timer 1: Auxiliary variables
unsigned long now = millis();
unsigned long lastTrigger = 0;
boolean startTimer = false;

// Timer 2: Auxiliary variables
unsigned long now2 = millis();
unsigned long lastTrigger2 = 0;
boolean startTimer2 = false;

// MQ2 Smoke Sensor
#define MQ2 34
#define Buzzer 17
int sensorValue = 0;
boolean state = false;

// Initial setup for Blynk
int pin_1  = 32;

// Initial declaration for DHT22 Temperature sensor
DHT dht_sensor(DHT_SENSOR_PIN, DHT_SENSOR_TYPE);
```

```
// Initial setup for Blynk code and WIFI
char auth[] = "EGxgdSJapTfpJWs3FDKTGJa4J2hnT7Y7";
char ssid[] = "novacc2";
char pass[] = "azzs12345";

// If movement (PRESENSCE)
void IRAM_ATTR detectsMovement()
{
  digitalWrite(RelayWP, HIGH);
  startTimer = true;
  lastTrigger = millis();
}
void IRAM_ATTR detectsMovement2()
{
  digitalWrite(RelayMR, HIGH);
  startTimer2 = true;
  lastTrigger2 = millis();
}
void setup()
{
  Serial.begin(115200);
  Blynk.begin(auth, ssid, pass);
  dht_sensor.begin();
  pinMode(pin_1, OUTPUT);
  pinMode(pin_1, HIGH);
  // PIR Motion Sensor mode INPUT_PULLUP
  pinMode(motionSensorWP, INPUT_PULLUP);
  pinMode(motionSensorMR, INPUT_PULLUP);
// Set motionSensor pin as interrupt, assign interrupt function and
set RISING mode
  attachInterrupt(digitalPinToInterrupt(motionSensorWP), detectsMove
ment, RISING);
  attachInterrupt(digitalPinToInterrupt(motionSensorMR), detectsMove
ment2, RISING);
// Set Relay to LOW
  pinMode(RelayWP, OUTPUT);
  digitalWrite(RelayWP, LOW);
  pinMode(RelayMR, OUTPUT);
  digitalWrite(RelayMR, LOW);
  pinMode(MQ2, INPUT);
  pinMode(Buzzer, OUTPUT);
  timer.setInterval(1000L, sendUptime);
}
```

```
  void loop()
  {
    Blynk.run();
    timer.run();
    float humi  = dht_sensor.readHumidity();
    float tempC = dht_sensor.readTemperature();
    float tempF = dht_sensor.readTemperature(true);
     if ( isnan(tempC) || isnan(tempF) || isnan(humi))
    {
      Serial.println("Failed to read from DHT sensor!");
    }
    else
    {
      Serial.print("Humidity: ");
      Serial.print(humi);
      Serial.print("%");
      Serial.print("  |  ");
      Serial.print("Temperature: ");
      Serial.print(tempC);
      Serial.print("°C  ~  ");
      Serial.print(tempF);
      Serial.println("°F");
      Blynk.virtualWrite(V3, humi);
      Blynk.virtualWrite(V1, tempC);
      Blynk.virtualWrite(V2, tempF);
    }
  // Current time
    now = millis();
  // Turn off the LED after the number of seconds defined in the timeS
econds variable
    if(startTimer && (now - lastTrigger > (timeSeconds*1000)))
    {
      Serial.print("None");
      digitalWrite(RelayWP, LOW);
      startTimer = false;
    }
    now2 = millis();
    if(startTimer2 && (now2 - lastTrigger2 > (timeSeconds*1000)))
    {
      Serial.print("None");
      digitalWrite(RelayMR, LOW);
      startTimer2 = false;
    }
    delay(2000);
```

Appendix B: IoT@Office Prototype

Appendix C: Gannt Chart for SDP2

Table 5 Gannt Chart for SDP2

NO	ACTIVITY	SEPTEMBER				OCTOBER				NOVEMBER				DECEMBER				JANUARY			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	SDP II Briefing																				
2	Material and Equipment Purchasing																				
3	Project Fabrication																				
4	CHP III: Methodology																				
5	CHP IV: Result and Discussion																				
6	CHP V: Recommendation Conclusion																				
7	SDP II Thesis Format Briefing																				
8	Software and Hardware Combination																				
9	Project Fabrication Finishing																				
10	Poster and Technical Report Evaluation																				
11	SDP II Project Presentation																				
12	First Draft Thesis Submission																				
13	Logbook and Technical Report Submission																				