DEVELOPMENT OF AN IOT-BASED IRRIGATION SYSTEM FOR AGRICULTURE USING ESP32

NURUL IZZATI BINTI REDZURAN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Ts. DR. SURAYA BINTI ZAINUDDIN
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan
Fakulti Teknologi & Kejuruteraan Elektronik dan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
suraya@utem.edu.my

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Supervisor Name : TS. DR. SURAYA BINTI ZAINUDDIN

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DEDICATION

To my parents, whose unwavering support and sacrifices,
to my friends, whose support kept me going,
to my supervisor, TS. DR. SURAYA BINTI ZAINUDDIN, whose advice shaped my intellect and made this journey possible.
I dedicate this project to everyone who had faith in me.

ABSTRACT

In the era of globalization, where technology and IoT in agriculture transform the traditional to modern irrigation into more effective and sustainable way. Water management remains an important tool to dealing with issues like water scarcity as well as shortage of lack of human labor. However, due to the lack of human labor and inadequate irrigation techniques, farmers especially, could not achieve these expectations. These lead to low yields apart from a lot of wastage of resources. Thus, the project is to develop an Iot based irrigation system for the agricultural industry using Esp32. This system which will monitor the level of soil moisture via Blynk App to control the water pump so that user can be control in any location through mobile application. The IoT irrigation system where Esp32 microcontroller is used to control the inputs and outputs of the system. It can have a Blynk application to control it as well as an Esp32 microcontroller also provide internet connectivity. It is connected to the LCD interface to allow the visualization of the process in real-time. Therefore, the project is to measure soil moisture states, and whenever it detects that the soil is dry, it will initiate the system. Then, Blynk app alerts the users which the user is controlling the water pump remotely and once the pump is on, the water is automatically distributed for agricultural productivity for sustainability. In conclusion, these development of an iot-based irrigation system for agriculture using Esp32 can surely go a further step with agricultural technology. In addition ,the system increasing crop yield while conserving important water resources, therefore giving a sustainable and innovative solution in modern agricultural practice.

ABSTRAK

Dalam era globalisasi, di mana teknologi dan IoT dalam pertanian mengubah pengairan tradisional kepada moden kepada cara yang lebih berkesan dan mampan. Pengurusan air pengairan dalam sektor pertanian mengalami kekurangan air serta kekurangan tenaga manusia adalah isu kritikal. Walau bagaimanapun, disebabkan kekurangan tenaga manusia dan teknik pengairan yang tidak mencukupi, petani terutamanya, tidak dapat mencapai jangkaan ini. Ini membawa kepada hasil yang rendah selain daripada banyak pembaziran sumber. Oleh itu, projek ini adalah untuk membangunkan sistem pengairan berasaskan Iot untuk industri pertanian menggunakan Esp32. Sistem ini yang akan memantau tahap kelembapan tanah melalui Aplikasi Blynk untuk mengawal pam air supaya pengguna boleh dikawal di mana-mana lokasi melalui aplikasi mudah alih. Sistem pengairan IoT di mana mikropengawal Esp32 digunakan untuk mengawal input dan output sistem. Ia boleh mempunyai aplikasi Blynk untuk mengawalnya serta modul Esp32 juga menyediakan sambungan internet. Ia disambungkan ke antara muka LCD untuk membolehkan visualisasi proses dalam masa nyata. Oleh itu, projek ini adalah untuk mengukur keadaan lembapan tanah, dan apabila ia mengesan bahawa tanah kering, ia akan memulakan sistem. Kemudian, aplikasi Blynk memaklumkan pengguna bahawa pengguna mengawal pam air dari jauh dan sebaik sahaja pam dihidupkan, air diagihkan secara automatik untuk produktiviti pertanian untuk kelestarian. Kesimpulannya, pembangunan sistem pengairan berasaskan iot untuk pertanian menggunakan Esp32 pastinya boleh melangkah lebih jauh dengan teknologi pertanian. Di samping itu, sistem meningkatkan hasil tanaman sambil memulihara sumber air yang penting, oleh itu memberikan penyelesaian yang mampan dan inovatif dalam amalan pertanian moden.

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Thank you to my friends for friendship and support. Motivation, words of encouragement and unconditional care have been your guides through the tough times and through my moments here where I felt everything was impossible.

“Last but not least, I wanna thank me. I wanna thank me for believing in me. I wanna thank me for doing all this hard work, I wanna thank me for having no days off. I wanna thank me for never quitting. I wanna thank me for always being a giver and trying to give more than I receive. I wanna thank me for trying do more right than wrong. I wanna thank me for just being me at all times.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE	TITLE	PAGE

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysian agriculture depends on erratic rainfall periods that substantially cause adverse weather and drought stress in crops during dry season. This unpredictable can cause crises such as severe water shortage, which it is difficult for farmers to provide the best environment and conditions important for crop growth and production [1]. The conventional methods of irrigation are quite simple but they do not solve such challenges effectively. Factors including evaporation and restricted rainfall also amplify water shortage, and another approach of supervising and regulating irrigation, depending on soil water intake time also takes more time and effort, which brings more pressure on farmers[1]. Considering these constraints, it is clear that Malaysian agriculture requires improved eco-efficient and water-efficient irrigation technology for better water resource management due to climate change [2].

An extended period of drought or heavy rain affects the production of crops in this kind of farming hence making the Malaysian agricultural sector very vulnerable to the fluctuations in weather conditions. Due to the changes in seasons one is prone to dry years whereby water becomes scarce and this in turn puts pressure on crops. Inadequate amounts of rainfall within key developmental stages might lower crop productivity and result in financial loses to the growers [3]. Surface irrigation is not so expensive because of its simplicity and low capital cost but it is widely used all over the world. Though these methods are time consuming and in-efficient through which much water is lost through runoff deep percolation and evaporation this results in wastage of water and also affects the soil structure and nutrients thus degrading the land and reducing its productive potential for cultivation [4].

Manually practicing irrigation is a tiresome and time-consuming process and it also requires many human labor. In this case, farmers notice the necessity to constantly monitor the soil moisture level ad change the irrigation frequency according to the results, which can often be incorrect and irregular. The process requires the operator to directly control the water supply and as such, it becomes very difficult to avoid either over watering or under watering the crops. Irrigation beyond optimum leads to water logging and root whereas minimal irrigation results in drought stress affecting crop productivity and produce quality [4]. Advantages irrigation methods of watering such as precision and the drip irrigation system are useful by providing water in a regulated way to the plant root area and thus minimize wastage while at the same time provide water needed for the plants growth [5].

Overall, integrating advanced irrigation systems with smartphone applications marks a significant advancement in agricultural technology [6]. By providing a user-friendly interface for remote access and control, smart irrigation systems can continuously monitor soil moisture levels, weather conditions, and other critical factors, automatically adjusting water distribution to ensure crops are properly hydrated while conserving water. These technologies offer farmers a more efficient, sustainable, and robust solution for managing their irrigation needs, ultimately enhancing agricultural productivity and resilience[6].

1.2 Global Issue

Some of the biggest concerns about world irrigation is that there is insufficient water and inefficient water utilization methods [7]. Irrigation in agriculture also consumes a large percentage of freshwater in many areas and compounds the fight for water resources [7]. Where water is used in irrigation, especially in the subsistence farming, other severe problems arise; Land over-extraction of water supplies, that is, drawing out of more water than is replenished in the aquifers; deterioration of water quality due to salinity and other chemicals [8]. Climate change also affects water availability in another way since it alters precipitation patterns, and it results in droughts and floods, as well as water stress in irrigation sectors [8]. Hence, farmers experience high levels of concern on the availability of irrigation water, thereby threatening crop production, food security and farmers livelihoods. These issues require establishing effective and efficient irrigation systems, using water-saving technologies in irrigation and encouraging the proper usage of water.

1.3 Problem Statement

Agricultural yields play a crucial role in many countries' economies. There are critical factors that need to be managed effectively to ensure that the yields received from the farm produce are as expected; includes electricity and water usage, and a proper irrigation schedule depending on crop demand. However, different standards on quality and food safety prove difficult for many growers especially those in the uneconomical position of poverty. These are the issues by limitations in human labor and the current state of irrigation techniques that give unsatisfactory yields and wastage of resources [9].

The lack of human labour significantly affect the yields of agriculture. Instead, small-scale farmers use labour to undertake activities such as observing the moisture levels of the soil, changing the frequency of irrigation, and controlling water supply. The conventional methods of farming heavily rely on manual labor and therefore are very slow, tiring and not very accurate due to fatigue. Additional, these problems are compounded by the labour shortage especially in the rural area whereby there is a shortage of human power to enhance task efficiency [10].

Moreover, current irrigation technologies which surface irrigation techniques have been observed to be less precise in the management of water and often cause wastages due to evaporation, runoff as well as deep percolation. However, farmers experience some difficulties with these techniques because they are time-consuming and require constant monitoring [4]

Advanced technology, such as smart irrigation systems that interface with smartphone apps, can help to overcome these concerns. These systems optimise the irrigation schedules and automate them, with the help of real-time data of soil moisture sensors and other parameters. In addition to minimizing the amount of labour needed and water consumption, this method helps deliver water to plants in the precise amount required for their growth to be optimized, thus improving the efficiency of agriculture in general [6].

1.4 Project Objective

The main objective is to propose a systematic approach for controlling and monitoring irrigation to ensure efficient water usage, optimal crop growth, and environmental sustainability. The specific objectives are outlined as follows:

a) To develop a remote soil moisture monitoring system allowing users to track field moisture levels in real time using Blink apps.

b) To implement a remote monitoring and control functionalities to enable users to manage irrigation systems from anywhere.

c) To validate the functionality of the developed system.

1.5 Scope of Project

This project develops and implements a cost-effective, iot irrigation system that integrates a smartphone app for remote monitoring and control, utilizing real-time data to optimize water usage and enhance agricultural productivity.

a) Create the Blynk Application to give a alert and that will notify users to the changes in soil moisture levels, allowing for prompt intervention if necessary.

b) Develop a prototype to measure soil moisture levels in small-scale agriculture and integrate it with a controling apps to activate a water pump.

c) Utilize a soil moisture sensors to provide real-time monitoring of environmental conditions.

d) Develop a user-friendly smartphone app that will allow user interface to control the irrigation system from a distance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As in agriculture, managing irrigation is like dealing with a concept that one is struggling to come to terms with when it comes to resource constraint on crop yields [11]. Water requirement, soil and other crop requirements are some aspects that must be considered by the farmers to make agriculture sustainable. This is because most areas of the world including India which undergoes irregular and unpredictable availability of water require having efficient methodologies of conserving water. While efficient use of water in irrigation or water management is wasted by improper use of the techniques of irrigation or poor water management, the rate of soil erosion is high, and the yields in farming low [11]. That is why such problems happen: the reliance on old-fashioned methods without real-time tracking.

To overcome these issues, modern irrigation systems employ advanced technologies, including IoT, to enhance their functionality. These IoT solutions offer the possibility to monitor the moisture content of the soil, climatic conditions, and water requirement of crops. This data can be strategically used by agriculture in achieving decisions regarding the irrigation schedule, water consumption and other recommendable practices [12].

Moreover, smart irrigation has the capability of automating the controls whereby farmers can remotely change the parameters of irrigation depending on the conditions. This also helps to serve the function of convenience and act quickly to external conditions such as rainfall or temperature changes [12].

This involves implementing IoT technology to improve the methods used in irrigation with the resultant improvement in crop outputs and the efficient use of water during the irrigation process [13]. This chapter will present a brief literature review and literature findings on IoT-based irrigation systems for agriculture system particularly those developed using the Arduino technology.

2.2 Overview of Irrigation System Evolution

Irrigation technologies over the centuries prove the amazing transition from ancient rudimentary methods to relatively advanced methods of the present-day world [14]. Irrigation is one of the earliest practices that the early civilizations, for instance Egypt, China, and India, set up by using natural resources like canals and dykes and using floods to irrigate crops [15]. These early methods were fundamental in supporting agriculture as well as assisting in the growth of the entire population.

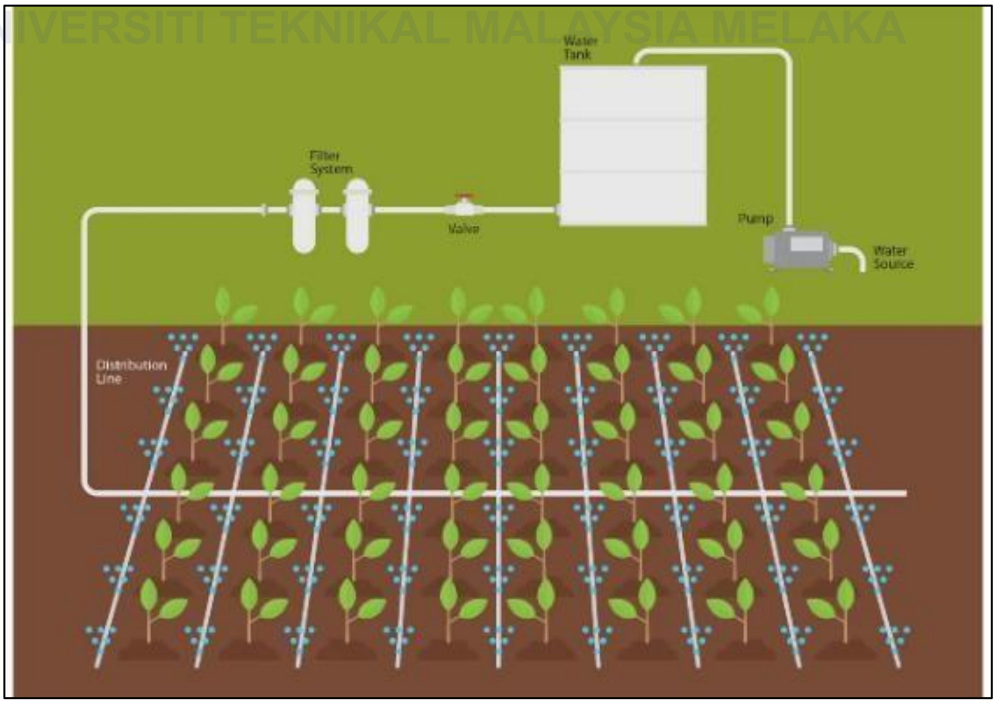

Figure 2.1 Example of Sprinkler irrigation

Among these advancements in the 20th century, sprinkler irrigation, which had been a significant change in water delivery to agricultural fields, could be listed. However, challenges like water wastage and its unequal distribution were still present, signifying that further development is needed. The developments in irrigational techniques in the late 20th century resulted in the use of automatic irrigational systems with sensors and timers for water operations. Although these systems enhanced productivity, reduced the lowered labor costs, these systems were not very effective in controlling and minimizing the utilization of water and enhancing adaptability to the variability of the climatic conditions [15].

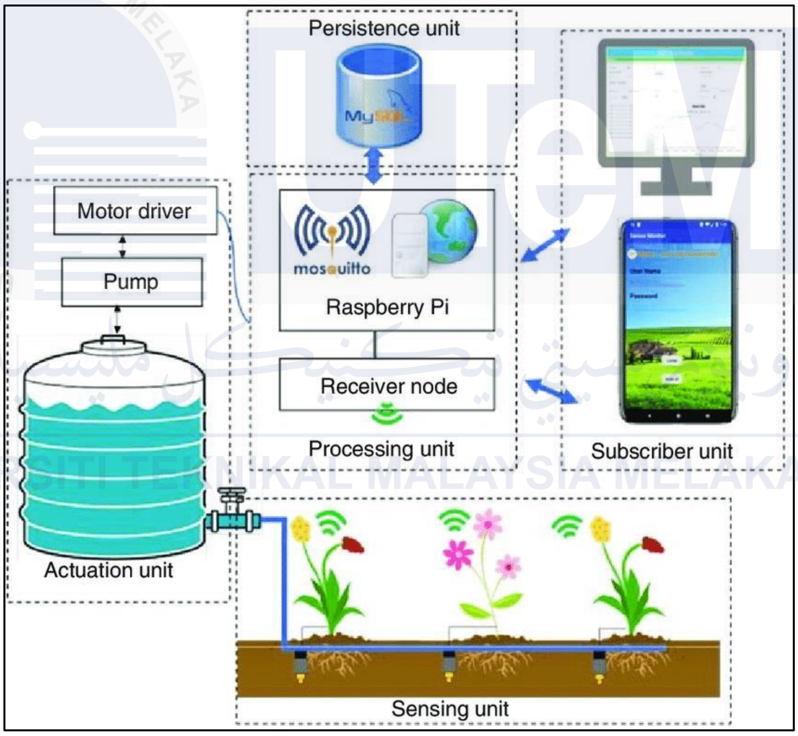

Figure 2.2 Example Smart Irrigation Systems

It was the beginning of a new era of agricultural practices in the 21st century when smart irrigation systems came into existence [16]. These solutions based on IoT, cloud computing and big data analysis allow for the accurate tracking, management and optimization of water usage in agriculture. Smart irrigation systems help farmers to get the necessary data regarding the moisture content of the soil, temperature, humidity, and other features of the environment [17]. This helps the farmer to develop irrigation schedules on occasions to water crops and ration the water which in turn increases food production and sustains farming.

Through incorporating the IoT technology, irrigation practices have been enhanced through giving a full solution to water management and using resources, providing an efficient way to support plant growth. Modern agriculture has made smart irrigation systems one of the key tools and constraints that may make water management difficult for the farmers [18].

2.3 Technology in Irrigation Systems

In the past decades, modern technologies are a part of the irrigation systems, acting more sustainable, more efficient and automated in farming practices. Through these technological advances, water resources can be better managed, crop yields can be optimized, and overall agricultural productivity increased. The wide spread of Internet of Things (IoT), automation, sensor networks, cloud computing and wireless communication has led to transformative changes in traditional irrigation practices. By creating more precise irrigation systems, these innovations also help to conserve water and decrease operational costs, promoting crop health and productivity overall.

2.3.1 IoT Technology

In irrigation systems, IoT technology offers control of water usage based on real time data gathered using sensors installed in the field. These are sensors that measure the soil's key environmental and soil factors including humidity, temperature, soil moisture levels, light intensity and weather conditions. By combining the above data with cloud platforms, the system can study the same and inform a farmer about the precise water demands of his crop at any given instance.

The data transmitted to a cloud platform via sensors is processed and analyzed to generate actionable insights. The system can determine, for instance, if the soil moisture has fallen below the appropriate level or if a weather event (like rainfall) is impending and may mean that irrigation does not need to be provided. This means that irrigation will only occur at the most appropriate time, eliminating over-watering or under-watering, both of which can harm crops and wastewater.

One of the major advantages of such IoT-based irrigation system is information retrieval remotely related to the irrigation process. In this way, it means farmers can have access to real time data and make irrigation decisions from anywhere like through mobile applications or web interfaces. With soil moisture, temperature, and humidity monitoring across their different areas of their farm, they can adjust irrigation schedules or manually override the system if needed. This flexibility makes it possible to help farmers monitor their crops in a more effective way, especially in large operations where manually monitoring conditions would be impractical.

With the data collected by the sensors the IoT system not just monitor, it can also be automated to control the irrigation. For example, if soil moisture falls below a certain threshold, the system automatically initiates the water pump to irrigate crops. The water supply will then turn on once the desired moisture level is reached and then shut off automatically. The range of automation they provide reduces the need for manual interactions, saving both time and labor whilst a sure means of providing water just where it's required and in an effective way.

Moreover, IoT systems commonly implemented in the irrigation sector consist of machine learning algorithms that could predict crop water demand by taking advantage of the historical data and predicting the weather. With knowledge gained from past irrigation cycles and ambient conditions, these systems improve their prediction and increase the accuracy of their irrigation scheduling. This provides a predictive capability that does not only optimize water usage but also protects against risks caused by variable weather patterns by ensuring the right amount of water can be provided to the crops even in the event of unexpected weather.

As the IoT system gathers more data over time, it gets better and better through machine learning and data analytics. As a result, the system becomes smarter, learning to deliver water more efficiently depending on types of crops, soil and conditions. Through this continuous learning process the system grows more and more efficient, achieving maximum crop health and yield at minimum water use. In the end, IoT irrigation systems ultimately conserve water, mitigate cost on operations and produce healthier, healthier and more profitable crops.

2.3.2 Automation in Irrigation Systems

Modern agriculture needs a crucial development in automation of irrigation systems that simplifies, makes more precise, and more effective use of water. These automated irrigation systems depend upon sensor data such as soil moisture, temperature, weather conditions, and use these without the need of human intervention. When the moisture level in soil goes below a certain level, the system turns on the irrigation so that crops do not get underwatering.

The major benefit of automation is that it can achieve extremely precise water distribution that only occurs in response to real time data, meaning that crops will only get wet when they need to. Automated irrigation systems are very beneficial, it actually saves on cost because one will not be over or under watering which can lead to water wastage and possible damage to plants or stress your crops and reduce yields. The system can be programmed with parameters such as duration, watering frequency, watering time of day to optimise for example, water use such as to water in the early morning or late in the day, when evaporation rates are lower.

Apart from soil moisture, automated irrigation also offers some powerful feature, such as data integration with weather. It can link weather forecasting platforms to a system and help an irrigation system to adjust its schedule prediction to the rainfall prediction. The forecasting automatically adjusts or delays watering if rainfall is forecasted, which means there’s no unnecessary irrigation and conserving water.

In large scale farming operations where irrigation can be time consuming and costly, automation has a lot to offer in terms of time and money. With the need to have less constant human involvement in automated systems, the farmers will be occupied with other things. Moreover, automated irrigation has an additional purpose of making water delivery easier and makes it repeatable and reliable over huge tracts of cultivated field resulting in healthier crops and higher yields.

Lastly, irrigation systems can be automated, which provides sustainability over time and labour not only because of saving them but also because of efficient use of water thereby avoiding wastage; this is a requirement to contemporary agriculture to be resource friendly.

2.3.3 Sensor Networks

Modern irrigation systems rely heavily on sensor networks that continuously and in real time monitor various environmental variables over large agricultural fields. These are sensor network consisting of multiple sensors being placed strategically in the field in order to measure the important parameters such as soil moisture, temperature, humidity and salinity. These sensors collect data that helps to know the actual soil and crop conditions and help irrigation systems to modify water delivery according to the specific crops needs.

With sensor networks, one of the major benefits is the ability to monitor soil moisture in different depth that is soil moisture at soil surface, middle root zone and deep root zone. Using this granular monitoring approach ensures irrigation being targeted specifically to soil layers, which is critical for effective use of water. For example, we might need water more now in the topsoil when it is dry, but perhaps later on if you're irrigating into different soil layers. Sensor networks apply water according to the distribution of moisture within the soil profile, which prevents over irrigation, causing wasted water, and under irrigation, causing harm to plant health.

Furthermore, sensor networks are scalable and customizable that can be extended to monitor large agricultural fields or customized for other crops and soil conditions. It offers flexibility that suits a wide range of agricultural settings, from the smallest farms to the largest, commercial operations. Wireless sensor networks (WSN) further reduce installation complexity by removing the requirement for complex wiring. As the WSNs make use of wireless communication means to transfer data, they can easily be installed and maintained and were cheaper especially in case of large systems.

2.3.4 Wireless Communication Technologies

Wireless communication technologies play an important role as a critical element in enabling the seamless transfer of data from one system component (such as sensor, controller and remote monitoring platform) to another as part of IoT based irrigation systems. These technologies facilitate the operation of such networks to allow the data collected from the environmental sensors like soil moisture and temperature sensor to be transmitted to the central processing units, such as microcontrollers or cloud platforms, for further analysis or processing.

One of the most used wireless technologies in irrigation systems with high bandwidth and reliable connectivity is Wi-Fi. This allows for continuous communication with sensors and controllers so real time data is transmitted to the cloud or control systems for analysis. Specifically, Wi-Fi use is especially important in the data processing of large amounts of data, for example, collected from multiple sensors, weather forecasts or crop performance metrices. Using sensor data from sensor networks, farmers can make real time decisions based on this data to optimize irrigation schedules, crop management, resource allocation, and more, as well as improve crop yields and reduce water waste.

For this reason, GSM (Global System for Mobile Communications) is the best option for wireless communication in areas where there is either a weak Wi-Fi signal or no Wi-Fi connectivity at all, especially those in rural and remote locations. Through their mobile phones, farmers can monitor and control their irrigation system remotely by leveraging data sent via SMS messages or phone calls through GSM. It is particularly beneficial for areas that are not served or where access to internet is limited, allowing basic operation of the irrigation system like its turn the irrigation system on or off, change the watering schedule or receive an alert. With GSM communication, farmers can use their irrigation systems whether they are in a distant or isolated location.

For short range, Zigbee, a low power, low data rate communication technology, is used for some of the irrigation systems. This is particularly effective for sensor networks that have low cost and energy efficient communication, hence suitable for deployment in battery powered sensors that need to run for long periods without requiring frequent recharging or maintenance. With Zigbee's energy efficiency it makes it particularly suited for large scale irrigation systems where many sensors can be deployed over large areas. Although Zigbee networks can transmit only a basic sensor data over a short distance reliably, it has maintained the transmission of data at a low cost.

Finally, we can summarize that IoT based irrigation systems rely heavily on wireless communication technologies such as Wi-Fi, GSM and Zigbee to provide the needed connectivity to facilitate data transmission, remote monitoring and automated control. The flexibility and scalability of these technologies makes them vital to modern, efficient and sustainable irrigation practices.

2.4 Previous Work

Several previous work focused on exploring how IoT solutions can be incorporated into traditional approaches to irrigation in order to optimise water usage and increase crop yields. These studies show that IoT has the potential to revolutionize the application of irrigation in agricultural activities since it can be automated to optimize the practice.

A smart sprinkle irrigation system design using ESP32 microcontroller with the combination of multiple sensors to monitor and control the irrigation in process is one such example. In this system, soil moisture sensors, temperature sensors and humidity sensors are deployed in different locations in the agricultural field to measure the condition of the soil continuously. The data collected is sent to ESP32 which processes the data in real time to decide when to turn on or turn off the irrigation system. The Blynk app works with the ESP32 to display real time data, control manually, receive notifications about soil moisture levels and humidity. The system can be controlled by the user directly (either in a manual mode, a semi-automatic mode or automatic mode), according to pre-set times, or automatically by the water supplier in a mode based on soil moisture levels. The system automatically brings the pump into the sequence to irrigate the plants when the moisture content decreases below that threshold. Therefore, this irrigation approach is not wasteful of water as compared to normal irrigation methods because each plant is made to receive the appropriate amount of water at the most appropriate time. The Blynk real time monitoring of the irrigation process with automation benefits the agricultural productivity and water conservation, so that we could be contributing towards a more sustainable farming [19].

Development of a prototype system consisting of wireless sensor networks (WSNs) and internet of things (IoT) for remote irrigation system monitoring and control was another research. Here we first propose a system that works in conjunction with soil moisture sensors and GSM module in the presence of Arduino Uno as microcontroller. Arduino Uno read the moisture content of the soil collected this from soil moisture sensors and sent it wirelessly. The system was interfaced with the mobile application to allow remote control and management of the irrigation schedule by the farmers through the GSM module. With the use of the smartphone, farmers can get information and notifications on the status of the soil, they can change the required irrigation schedule in order to make sure that their crops get enough water. The GSM module proffered a crucial benefit of remote irrigation systems monitoring and control enabling users to save time and effort for huge or far agricultural farms. The study indicated that the system enabled reduction of the use of water as well as its use in the right quantity meant to support crops thereby promoting good farming and high production [20].

The results from these studies is that IoT technologies are highly performance and advantageous in controlling the techniques of irrigation. The application of real time data and automation technologies such as IoT has brought efficient irrigation which has resulted in increased water conservation, healthier crops and enhanced agricultural sector efficiency [19][20].

2.4.1 IoT Technology in Irrigation Systems

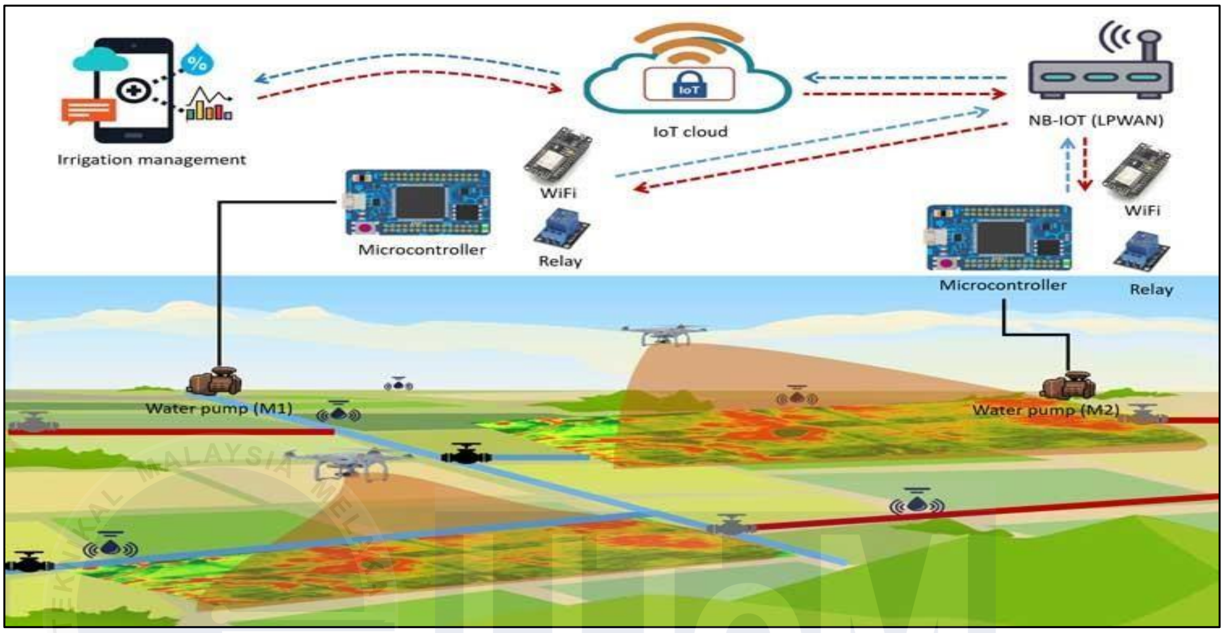

Figure 2.3 Example of IoT Technology in Irrigation Systems

IoT has played a revolutionary role in irrigation and has helped farmers to control and even enhance the availability of water producing enhanced production in agriculture. IoT gadgets include, for example soil moisture sensors for rating the soil dampness level, water flow metres for recording the water flow stream on fields, and weather stations for getting factual data from fields. It indicates that several environmental parameters are in a continuous tracking mode by the sensors. These include the moisture content sensors that help in estimating the water requirements for irrigation by measuring the amount of moisture available in the soil. Water flow metres record the amount of water utilized in the proceedings of the irrigation to ensure that the organization can notice and solve the existing inefficient aspects. Weather stations gather information on temperature, humidity levels, rainfall, and wind velocity, all of which are imperative in understanding irrigation requirements and planning. This data is transmitted to microcontrollers familiar as ESP32, Arduino or Raspberry Pi to analyze the information and decide when to water the plants.

These microcontrollers also contain an inbuilt program that analyzes the collected data to compute the right time to irrigate. This makes it possible to water the crops with the right amount of water at the right time hence reducing wastage and enhancing healthy growth. For instance, if the amount of moisture in the ground gets to a certain point, the system may turn on the sprinkler to ensure that the soil is in good condition for plant growth. Moreover, one of the major benefits of IoT-based irrigation systems is that they can be controlled and monitored remotely. Using technological integration, farmers are able to monitor and attend to the needs of crops through mobile applications or web interfaces in case they are not within the farm. This remote accessibility thereby enhances the convenience and functionality of irrigation management.

In comparison to previous research, both proved how IoT technology has transformed the irrigation systems and in the different methodology and aim. The previous work [19] developed a smart irrigation system with the help of ESP32 microcontroller integrating multiple sensors such as soil moisture, temperature, and humidity sensors, alongside the Blynk app for real-time monitoring and control. The method was offers manual, semi-automatic, and automatic irrigation based on soil moisture levels, with remote management through Blynk, enhancing water efficiency and crop management. This direct, automate watering based on real-time sensor data and offer remote management through Blynk represents an advancement in the automation and efficiency of irrigation practices, consequently helped in reducing wastage of water as well as enhancing the overall quality of crops [19]. On the other hand [20] developed a system that integrated WSN and IOT using Arduino Uno, Soil Moisture Sensor, GSM Module. Their technology was centered around the remote monitoring and control of the irrigation operation through the use of a smartphone app. The GSM module enhanced communication between the system and the mobile application, through which the farmers could control the irrigation schedule, monitor soil moisture level using SMS commands. This setup further showed how effective remote management was as farmers were able to easily intervene and modify practices from afar [20]. Both studies demonstrate the benefit of IoT in improving water use efficiency and agricultural productivity, although both focus on various strengths of IoT applications in irrigation: While [19] focused on time monitoring and providing manual, semi-automatic, and automatic irrigation control of irrigation and real- time monitoring with multiple sensors (soil moisture, temperature, humidity) with the ESP32 and Blynk Apps, [20] focused on control and monitoring using GSM technology. These two method demonstrate how IoT technology can handle multiple agricultural issues either directly or when enhancing remote control aspect [19][20].

2.4.2 Arduino-Based Irrigation Systems

There are several benefits of using Arduino-based irrigation systems, such as efficient use of water, better yields on crops, saving money, and being eco-friendly. Such systems incorporate real time data from the soil moisture sensors, water flow meters and the weather station to control water flow especially to crops in a very efficient manner. This level of accuracy minimizes wastage of water as well as promotes the healthy growth of the plants, thus increasing production. Soil moisture sensors can trigger specific irrigation on the condition that the soil is dry; therefore, they do not allow over-watering or under-watering situations. Moreover, these systems save time in the overall management of irrigation and reduce the demand for human labor hence the cost of Irrigation operations for farmers is reduced. Another element that can be integrated is a communication module that can be GSM or Wi-Fi, that will allow farmers to work remotely with irrigation and control it, also providing them with the comfort they need to manage the work. This remote capacity allows prompt interventions and changes that are so important for healthy crops. Thus, associated with Arduino methods, agriculture becomes more sustainable by efficient utilizing resources, water, and decreasing negative influence on the natural environment.

When comparing the studies that were previously conducted by [19] and [20], both researchers explained how IoT technology has transformed irrigation systems. However, they had different specialization areas as well as approaches to their research studies. [19] developed manual, semi-automatic, and automatic irrigation system, which was controlled by ESP32 Microcontroller with soil moisture, temperature, humidity sensors. Their practices aimed on controlling irrigation using real-time data from sensors, allowing the system to adjust watering schedules and flow based on soil moisture levels and environmental conditions. The ESP32, including its Wi-Fi module, functioned similarly to an Arduino, providing robust control and communication for the irrigation system. The ESP32 Microcontroller computed the information collected from multiple sensors and activated the irrigation system whenever the level of soil moisture was low, this improved water usage and the health of the plants. The system's integration with the Blynk app allowed users to monitor and control irrigation remotely, enhancing convenience and efficiency in managing water resources and ensuring timely irrigation without human intervention [19].

On the other hand, [20] aimed at integrating WSNs with an Arduino Uno and a GSM module for remote control features. It allows farmers to check the status of their soil moisture and change the irrigation timetable by sending SMS messages; in their conception, the emphasis is made on the availability of a remote-customized system. This system was most effective for large or distant fields of agriculture where observation could be challenging. Remote control of irrigation equipped flexibility since crops could receive the required amount of water although the farmer was not physically present on the farm. The study done by [20] showed that using IoT technology, efficiency and effectiveness in irrigation management can be enhanced through control and monitoring through the internet.

Both studies show that Arduino-based systems could enhance the amount of water used and produce agriculture crops, but they are aimed at different requirements and circumstances. The approach introduced by [19] deals with automation the timely and accurate delivery of water, making it ideal for conditions where continuous soil monitoring is necessary and rapid adjustments in irrigation rates are required. On the other hand, [20] on remote accessibility and user control has many advantages for those large or widespread farming operations which demand remote functions. These comparisons show how Arduino based irrigation systems may be modified to address most of the challenges Facing agriculture today, through direct automation or enhancement of remote control [19][20].

2.4.3 Wireless Sensor Networks Irrigation System

In case of IoT based irrigation system, WSN are a vital part of them because they are used for monitoring and controlling of data acquisition from the sensors deployed across the agricultural fields. One of the studies conducted by [19] designed a watering system with a help of WSNs that are connected to ESP32 microcontrollers, and hence the developed system is scalable and effective. Real-time soil moisture data was translated via soil moisture sensors, which sent signals to the ESP microcontroller that controlled irrigation in accordance with soil moisture readings. With the integration of the ESP32 and Blynk app we can remotely monitor and control in the irrigation process, thus increasing efficiency and water management. As a result, this design reduced the wastage of water while promoting health to crops grown. WSNs were installed with Arduino microcontrollers and Zigbee modules along with soil moisture and temperature sensors for the research study by [20].

The Soil moisture sensors were concerned with measuring the moisture content of soil, while temperature sensors measured the environmental temperature that is advantageous to calculating the rates of evaporation, as well as rate of growth of plant parts. The information from these sensors was wirelessly transmitted to the central node via Zigbee interface connected to the Arduino circuit, where scheduling control of irrigation and remote control via SMS command was done, ultimately leading to a reduction of the wastage of the water used in irrigation and enhancement of crop yields.

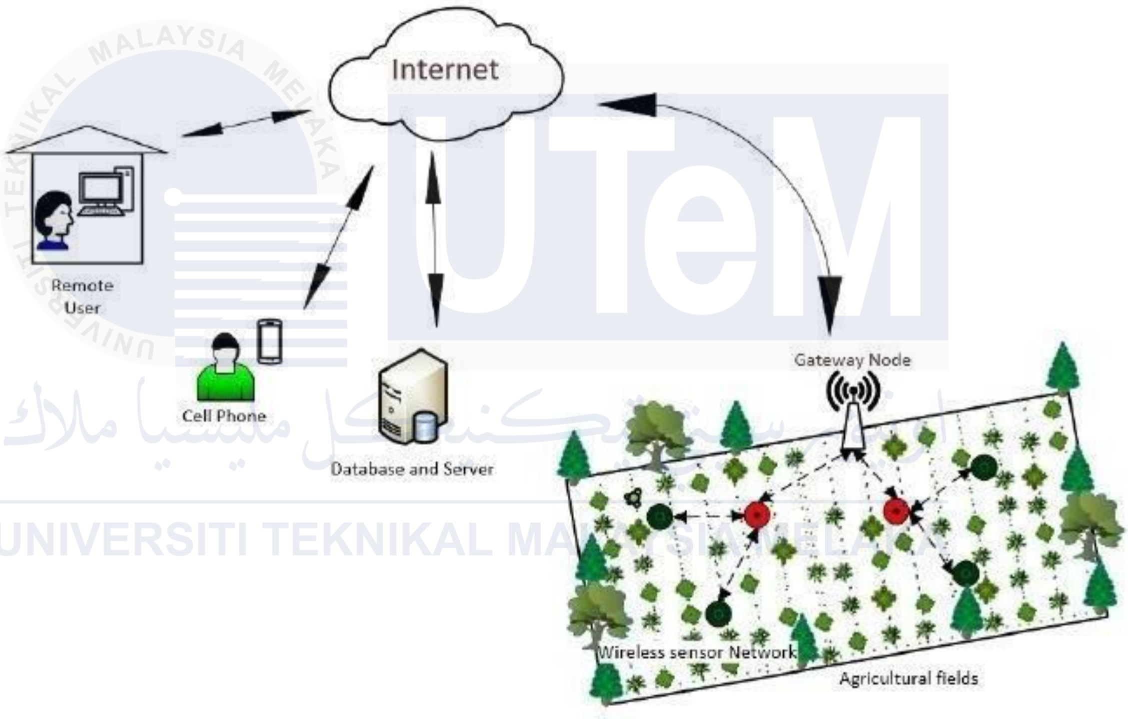

Figure 2.4 WSN Irrigation System

While both researches used soil moisture sensors as their primary tools for data collection, there were differences in communication technologies and other sensors used. [19] focused on direct integration with ESP32 microcontroller to process data real-time, and for automation of irrigation, highlighting scalability and efficiency. Conversely, [20] employed both soil moisture and temperature sensors which enhanced their system capability in comprehensively monitoring and responding to changes in the environment

[20]. They are using Zigbee modules in their study to enhance wireless communication reliability and range for the aspects of the remote control and monitoring which is crucial in managing large or remote fields. This method provided flexibility and was also reliable since crops were always able to get the required water without the farmer being present. Two studies were identified discussing successful implementation of IoT in improving the progressive methods of irrigation systems with [19] highlighting on instant automation and water saving and [20] on distant control, real-time climate, and accurate irrigation planning. These comparisons show the possibility of WSNs in increasing the yields though individual solution using IoT.

2.4.3.1 Soil Moisture Sensor

In IoT-based irrigation systems, soil moisture sensors play a crucial role since they enable the determination of the amount of water needed in the soil at a particular time. These sensors are supposed to measure the volumetric water content of the soil, a factor that plays a crucial role in proper plant growth. By placing these sensors at different depths and sites in the field, the farmers get a complete and accurate picture of the status of soil moisture in the different root zones. for example, moisture sensors would be installed at 10 cm, 30 cm, and 50 cm into the soil to measure moisture in the surface, middle root, and deep-root areas. When positioning is thus set up, it means that the irrigation system is capable of meeting certain water requirements for a particular crop or soil type.

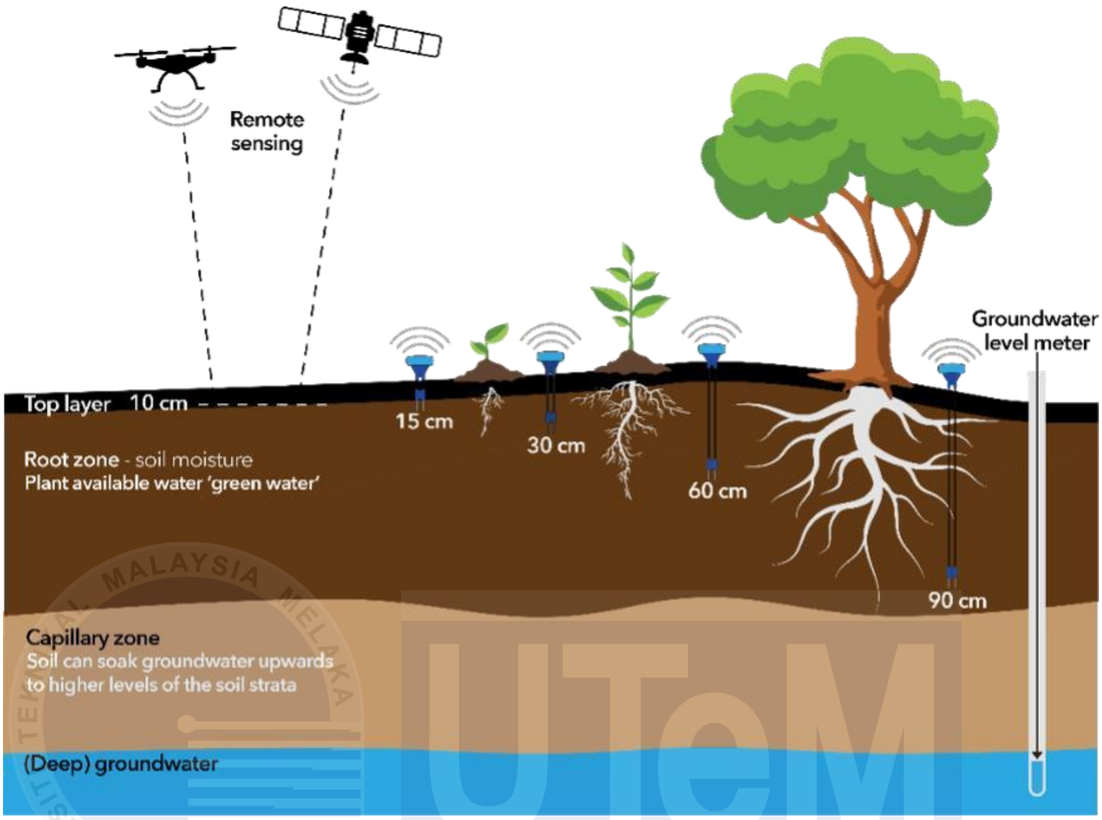

Figure 2.5 Example of Soil Moisture Distribution Across Different Root Zones

Soil moisture sensors however can send an electrical signal through soil. The resistance met by this signal is determined by the moisture content of the soil: Thus, if the soil is wet its resistance to flow of electrical current is less than that when dry, when the soil has high resistance. Then, the sensor calculates the resistance value of the soil and converts it into a serial signal which represents the internal status of soil humidity. An Arduino microcontroller processes the information which is the central processing unit of the system.

For this purpose, Arduino involves algorithms that are fixed to compute quantity of irrigation required depending on the moisture in soil. So, these algorithms are supposed to decide if the measured real time soil moisture is greater than, or equal to, or less than the set thresholds. In the case of this scenario, if the moisture level of the soil drops below a certain point (i.e. if the soil is too dry) then the Arduino enables the pump for irrigation. Then it sends signals which turn on water pumps and open control valves to water crops adequately.

If the moisture sensor reaches target soil moisture, the Arduino will keep water pump off and close the valves to end the irrigation. Water is also controlled in this manner just so it will be given to plants and soil only to those that are needed and therefore helps avoid wastage of water hence excludes over watering of plants which may lead to damaging of plant's roots or loss of nutrients caused by leaching.

The sensors are placed into the soil and measure soil moisture content, while the gathered data can be transferred over GSM, Wi-Fi or Zigbee modules for the remote control operation. Essentially this connectivity can be used by farmers to effectively monitor their irrigation schedules for access control options in real time whether from mobile app or from web interfaces. Using such a system, farmers can get alerts if the moisture level of the soil is low, review historic data trends, and set up changes in irrigation to act on in a timely manner, even if they are not out in the field. As a result, this remote capability is particularly critical for monitoring large farms or complex agricultural systems which may need frequent observation but cannot be manually monitored continuously [19][20].

2.4.3.2 Temperature Sensor

Temperature sensors are also part of IoT based irrigation systems, in order to deliver information about the surroundings which influence plant growth and water demand. Placed in various parts of the agricultural field, the sensors monitor the ambient temperature in the surrounding environment, which is important for the decision on watering crops. Temperature variation is useful in anticipating the rate of evaporation and assessing the climate factors that affect crops. The temperature sensors are usually placed at different heights and zones including the surface of the soil, the canopy top and the shaded and sunny area to get adequate temperatures. These sensors help in gathering data and vital information about how other environmental factors influence irrigation and crop water needs since, for instance, higher temperatures require frequent watering as the evaporation rates are high. Due to lower evaporation rates, irrigation has to occur less often especially in colder months of the year.

In previous studies, [20] did a work where they used temperature sensors along with soil moisture sensors. The data was collected from these sensors, and it was then transmitted to a central Arduino microcontroller using Zigbee modules. This allowed for modification of the irrigation schedule with respect to the current situation and conditions, leading to the rational use of water resources and the health of plants. New features were added to the system and made it possible to monitor remotely, whereby farmers could access the data and change them using the mobile applications, or web-based interfaces. It employed both temperature and soil moisture data in order to make better judgments about the irrigation hence saving on water and increasing on yiels from the agricultural fields [20].

2.4.4 Blynk Applications in Irrigation Systems

Blynk applications provide simple interfaces for the users to monitor and control and which in someway enhance the ability of smart irrigation systems to execute their functionalities. These applications allow farmers to get information, notification, and modify the irrigation system from anywhere that has the internet connection. One of them was on creating a Blynk application that interfaced with an Arduino based irrigation control system. This application uses real time sensor data to enable the user to set irrigation schedules, view system performance, and receive notifications regarding water levels and soil moisture. By integrating Blynk technology, farmers can improve the access and control of their irrigation system, therefore increasing efficiency and promotion of management studies in [22].

Figure 2.5 Blynk App showing soil moisture level

This way, with the help of real-time data display, farmers can monitor soil moisture, its temperature, as well as other relevant environmental factors for effectively managing water and making decisions. It alerts the farmers to changes or a problem and allows timely intervention to avoid crop stress or failure. Irrigation schedules that may be customised allow for instance change in cycles because of the specific crop as well as conditions in the environment. This allows for the crop to be supplied with the right amount of water that is required by the soil. Remote control functionality also cuts on time and labor as farmers might be able to operate irrigation using their mobile phones or laptops even when they are off the farm. In addition, data collection and data analysis provided by the applications of Blynk also facilitate in terms of understanding patterns and fine tuning of irrigation techniques improving the usage of water and yielding better agriculture productions. Blynk applications enable hosting of new interfaces in developing IoT based irrigation systems which enhance the ease, efficiency and effective management of the farm [22].

2.4.5 Real-Time Data Analytics in Irrigation Systems

With IoT (internet of things), real time data analytics are becoming a crucial element in modern irrigation systems. With these advanced systems, water usage is optimised, waste is minimised, and agriculture is made more efficient, allowing farmers to have current and reliable information about the environmental and soil conditions of their fields.

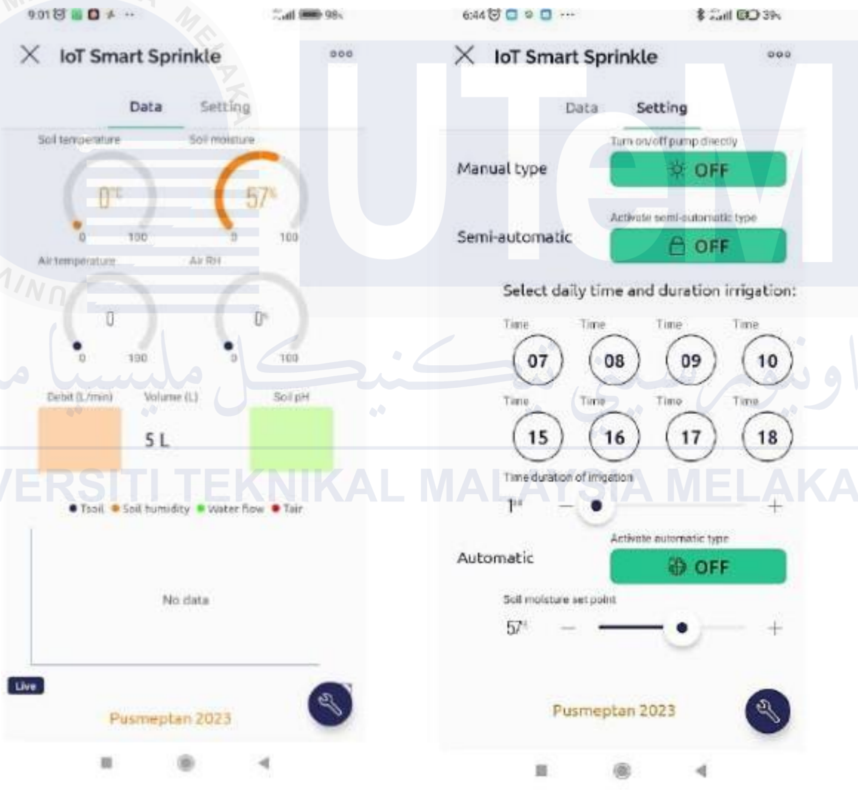

Figure 2.6 Result Blynk apps

In previous studies [19], propose the use irrigation system with multiple sensors such as soil moisture, temperature, and humidity to supply sprinkle irrigation. Through their research, they show how this real time data can be continually processed to dynamically stagger irrigation schedules. This data is then delivered to a cloud based platform where it is processed to provide the basis for immediate decision making and ensure that irrigation is activated only when required. The real time response capability of the system is achieved due to cloud architecture, which allows to deliver water precisely. The ability for irrigation to automatically adjust when soil moisture falls below an optimal threshold illustrates the value of real time analytics in reducing water wastage and increasing the efficiency of irrigation. The approach followed by [19]. emphasizes the capacity to track and react to changes in the environment, so that irrigation can take place at the right time and at the right levels to preserve water resources and cut down on excess irrigation cycles. The result shows in figure 2.6.

Figure 2.7 Result Weather Report

Another research is that of [20] for the use of IoT in smart irrigation through the use of Raspberry Pi as the controller. The system collects real time data from around a variety of sensors kicks the data and via local and remote processing, then uses predictive analytics to dynamically adjust the water flow to account for historical data patterns and real time environmental conditions. The utilization of cloud based platform enables remote monitoring and controls through portable application or web interfaces. In addition to facilitating the management of the irrigation [20], his study shows how predictive analytics can help systems to precompile, based on changing environmental conditions such as weather forecasts or historical trends, thereby improving resource utilization. The result shows in figure 2.7.

Figure 2.8 Result of Blynk App

Similarly, the previous studies of [22] discusses solar powered IoT based irrigation systems which is a more sustainable and energy efficient smart irrigation. A Blynk mobile app is used to monitor and control the irrigation process remotely in their system. This system also includes the collection of real-time data from sensors used in various fields and IoT technologies to provide the automation of irrigation with a sustainable system for water management in the agricultural field. Real-time data analytics and solar power work together to provide efficient irrigation and minimize energy expenses as well as its environmental impact. The application of IoT into smart irrigation systems would improve sustainability and scalability of such systems, making them a suitable choice in regions where the access to electrical power is limited. The result shows in figure 2.8.

The previouse studies of [19][20][22], show how real time data analytics allows for continuous monitoring of critical environmental parameters like soil moisture and temperature and can enable the irrigation system to rapidly adapt to changing conditions. These systems automate water delivery based on real time sensor data, ensuring crops are given enough water, thus avoiding over irrigation and ensuring water wastage is minimal. In addition, these systems have the capacity to predict future irrigation needs, enabling them to schedule irrigation according to weather forecasts, soil moisture levels and crop types, or simply put the latter to, helping the latter to become highly efficient[19][20][22].

The farmer can remotely monitor and control the system via cloud platforms, offering a greater flexibility and convenience to the farmer. The integration of IoT with real time data analytics not only makes irrigation management straightforward, but it also has great potential for better resource conservation and operational efficiency. By using these methods to make it safer and easier to apply fertilizers and pesticides to optimize yields, the advancements help advance the broader goal of sustainable farming by encouraging precision agriculture practices that reduce environmental impacts and improve crop yields[19][20][22].

Finally, the research by [19][20][22], reveals compelling evidences that real time data analytics in irrigation systems is transformative. Through IoT technologies, these systems ensure efficient water management, boost agricultural productivity, and even help sustain our modern farming practices. These findings underscore the need for linking real time monitoring and predictive analytics to drive optimal water use and develop a sustainable and resource responsive approach to irrigation.

2.5 Previous Recent Projects

Several previous recent projects were based on the application of IoT technologies in irrigation systems. The following is a summary of previous projects of their components, software, advantages and disadvantages which provide details about their development to agricultural methods.

Table 2.1 Table of Summary of Previous Recent Projects

References	Components	Software	Features	Advantanges	Disadvantages
[19]	ESP32 Microcontroller, Water pump, Soil Moisture Sensor,	Blynk App,Arduino IDE	-Remote control - Real-time monitoring - Automatic, semi-automatic, and manual irrigation modes	- Automated irrigation system - Scalability for various field sizes - Remote management via mobile app	-Network dependency - Sensor calibration limits - Power usage
[20]	Arduino Uno, GSM-GPRS modem, Sensor (Soil moisture ,temperature, humidity & weather), Water pump	Arduino IDE	-Automatic watering based on sensors -Remote monitoring -Data updates online	- Automated irrigation control - Real-time monitoring, Remote access - Efficient water management	-Reliance on stable network - Hardware failures, -High maintenance costs

[12]	Soil, temperature, humidity, weather sensors, Actuators, Arduino, Relay, Motor, LCD, Water pump	Arduino IDE	- Data collection on soil, weather conditions - Automation based on sensor data - Energy-efficient, Customizable, Scalable	- Improved water use efficiency - Enhanced irrigation control - Cost-effective solution	-Dependency on power source - Higher initial setup costs
[21]	Arduino Uno, Node MCU ESP8266, Sensors, Water pump	Mobile applications, IoT software	-Automatic watering based on soil moisture -Remote monitoring and control via IoT -Real-time data visualization -Alarm notifications	-User-friendly interface -Data-driven decisions	-Initial investment cost -Maintenance complexity
[22]	Node MCU Microcontroller , Sensors, Photovoltaic cells, Water tank, Pump, Pipes and valves, solar panel	Blynk Mobile App, Arduino IDE	-Real-time monitoring -Automated watering - Energy-efficient operation with solar power generation	-Water conservation -Solar energy -Remote control monitoring Improved yields	-High setup costs, -Maintenance needs, -Reliance on sunlight

[23]	Microcontroller, GSM Module, Sensors, Soil moisture sensor Water pump	Android-based software	-Automated irrigation control -Water conservation	Increased crop yield, Water use efficiency	Limited customization options, Reliance on stable internet connection
[24]	Sensors, Water pump, Microcontrollers	IoT platforms, cloud computing	-Monitoring soil, weather plant health	Improved productivity, Real-time data	Implementation costs, Technical complexities, Data security risks
[25]	Sensors (temperature, humidity), Microcontroller, GSM/GPRS modules, Water pump, GPS for location tracking	Android applications	-Automatic watering based on sensor inputs, -Remote monitoring control via mobile using GSM/GPRS - Energy and resource savings	Minimized human intervention, Optimal water application, Reduced runoff from overwatering, Improved crop performance	System features and scalability limitations, Economic affordability challenges for larger agricultural lands, Potential limitations in system capabilities beyond basic automation
[26]	Soil moisture sensors, GPS trackers, Microcontroller, Drones, Communication devices, Water pump	Cloud computing, IoT platforms	- Automated irrigation - Crop health assessment - Predictive analytics - Remote management	- Improved resource management - Increased crop yield - Reduced environmental impact	- High initial costs - Reliance on stable connectivity - Data security concerns

[27]	Soil moisture and temperature sensors, Irrigation control actuators, Arduino, Water pump	Arduino for automation and control, Dark Sky weather, API for weather forecasting and data retrieval	- Automatic irrigation based on crop needs - Remote field status access - Weather forecasting integration for optimized water use	Real-time irrigation information - Cost and resource optimization - Improved environmental quality - Increased irrigation efficiency - Reduced water issues	Moderate hardware and code complexity - Slight delay in system response - Limited flexibility in some aspects - High reliability but potential technical failures

2.6 The Purpose Project

The purpose of this project, which evolves from the previous literature review is to develop an IoT-based irrigation system for agriculture using Esp32. The components used in this project include ESP32 Microcontroller, LCD display, water pump, and soil moisture sensors. The ESP32, with its built-in Wi-Fi module, is programmed using Arduino IDE, and the system is controlled through the Blynk app. It is also used an application software known as the Blynk application. It enables the farmer to remotely track water needs accurately with its real-time soil moisture measurement. When the soil moisture level is low, the system transmits data and give notification through the Blynk app, the data will notify user to turn on the water pump, and it will automatically water the crops.

Also, by its design, the system user-friendly interface as well as to operate as it will not require a highly technical personnel or formal training for the farmers to comprehend it. Some of the benefits are affordability, efficiency, easy to use, expandability, and flexibility of the system. It encourages involved farmers to adopt environmentally friendly practices and decreases expenses. There can be the following weaknesses though; One must rely on, a steady internet connection and can be severely affected by hardware failure.

2.7 Summary

This chapter focuses on the development of an IoT based irrigation system using Esp32 which includes a built-in Wi-Fi module and acts as an Arduino, including Blynk applications and technologies. The growth in IoT technology has encouraged various uses aiming at enhancing irrigation techniques. Through a study of different methods and technologies, those aim to pinpoint the most effective component for irrigation projects. These technologies improve agricultural water management by leveraging IoT capabilities for better monitoring, control, and efficiency. This summary focuses on the need of using IoT into irrigation system design to promote better water conservation, productivity, and sustainability.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the methodology of developing an IoT-based irrigation system for argirculture using Esp32, that optimizes water usage and increases agricultural yields. The project overview is provided briefly, followed by a description of the steps involved in developing the IoT-based irrigation system, creating a mobile application for remote monitoring and control, and testing the system's performance. The methodology is divided into four sections: an overview of the project flow, a block diagram showing overall process, a full workflow description, and a thorough explanation of hardware and software components, including their functions and operations. This chapter ensures a thorough understanding of the project planning, the component that will been used then finally show the process of the developed system.

3.2 Project Planning

A project process for PSM 2 is outlined using the Gantt chart and flowchart; the process begins with Project Planning.

The project planning of the Gantt chart ensures all tasks are completed to ensure a successful ending. In total, this project is scheduled over a period of 30 weeks, be completed within one semester. However, this contribution is only related to the initial BDP phase which is the thirteen weeks Bachelor Degree Project. BDP 2 is the key to the success of completing the project with ease, thus making things easier in case of complications in future. A Gantt chart has been developed to guide the process of project planning. The Gantt chart for project planning process is a suitable tool for BDP 2 project development. It visualizes the project flow, and creates a schedule for the main tasks and their respective deadlines ensuring BDP 2 to be achieved. This way provides an effective framework for the ensuing phases of the project development. , Refer the Gantt chart in Appendix A for a visualization of the project timeline.

The key stages of the project are outlined in the flow chart. Refer the flowchart of the BDP project flow is in Appendix B. Project Planning and Component Selection are the starting points of the process, where the topic is decided, initial research is conducted to set direction, and the project paths are set with objectives. The next step involves Hardware Setup, which serves as the foundation for two parallel tasks: the Blynk App setup and system integration (software and hardware) initial coding. These tasks will run concurrently, so the project continues running properly. Once these parallel steps are completed, the system moves into Testing and Debugging to run testing to verify that the system performs as designed and to find errors. If the testing results are good (pass) then it proceeds to the next line, however, if testing results are bad (failure), it goes back to debugging to correct the errors. If the results, pass the tests, the project proceeds to Prototype Development. Final

Testing and Adjustment, the next phase is performed to assure that the prototype meets all requirements and performs as intended. Finally we have the Documentation and Reporting, which equates the final phase of the paper, that consists in providing a detailed description of the work done. Finally, the results of this structured process assist in the successful completion of this project.

3.3 Project Flowchart

The project flowchart, shown in Figure 3.1, outlines the step by step process for developing and operating an IoT-based irrigation system for argirculture using Esp32.

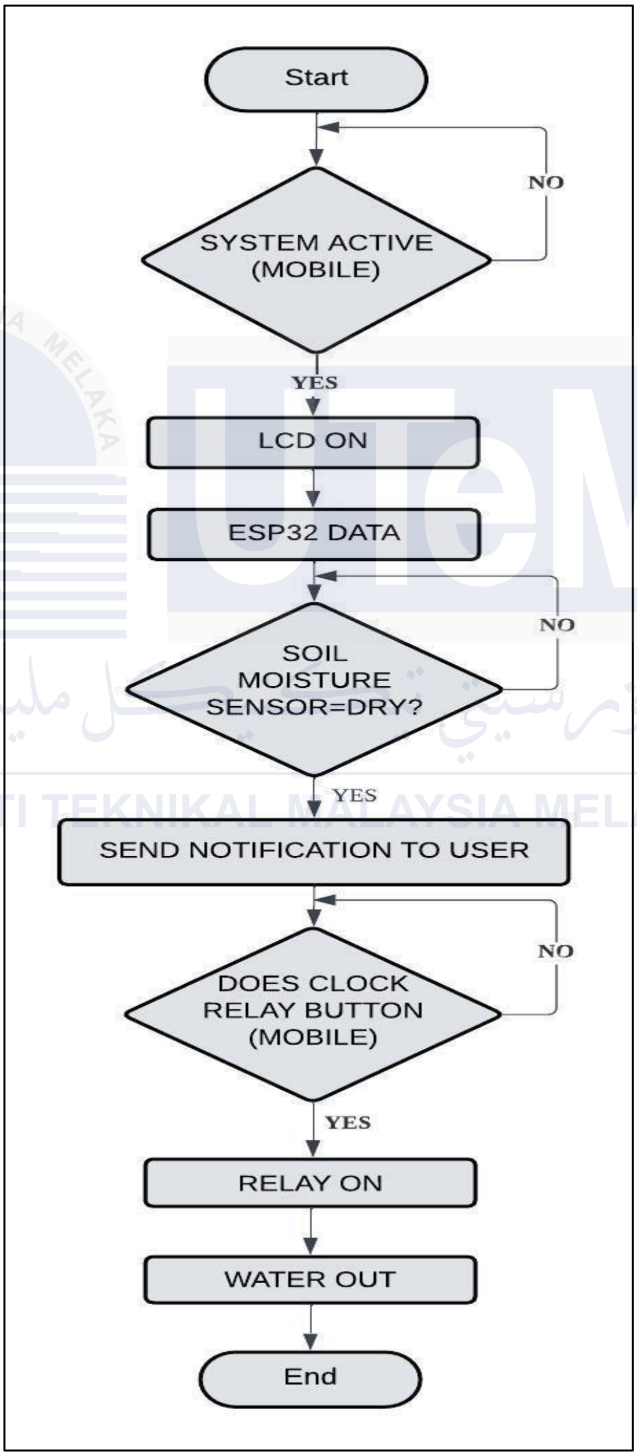

Figure 3.1 Project Flowchart

This flowchart shows how an IoT based irrigation system for agriculture works. The system initially verifies its state, and then activates the LCD panel to display information. Once this has been done, the ESP32 microcontroller gets some data such as the moisture levels of the soil to see if the soil is dry. The system sends a warning notification if the moisture level is too low. On the Blynk app, the user can then be notified that the plant needs to be irrigated. Upon receiving the notification, the user can decide to irrigate the plant, by sending signal to manually activate the water pump. With the use of the Blynk app that can turn on the relay to control the water pump to automatically distribute water to the soil.

In addition, the buzzer is activated at the time at which the irrigation process starts, to notify the user that the water is pumped to the plants. Once the moisture level is reached to the point desired, the system turns off the water pump deactivating the relay and the buzzer. It helps to properly manage water for your plants well. This loop keeps running and takes immediate action to keep maintaining ideal soil moisture for promoting plant well-being and conserving water resources.

3.4 Project Block Diagram

In Figure 3.2 presents the block diagram of the block in monitoring the irrigation system process. The basic block diagram shown below shows the initial power supply which provides a 5V DC to the rest of the system. The central processing unit of the system is implemented using the ESP32 microcontroller. Using Arduino IDE, we program the ESP32 that comes with a built in WiFi module. With the help of the Arduino IDE it is possible to develop and upload code to ESP32 that allows an internet connection to be completed through the Wi-Fi module. With Internet connection, the user can monitor and control the whole irrigation system remotely through interactions with Blynk application.

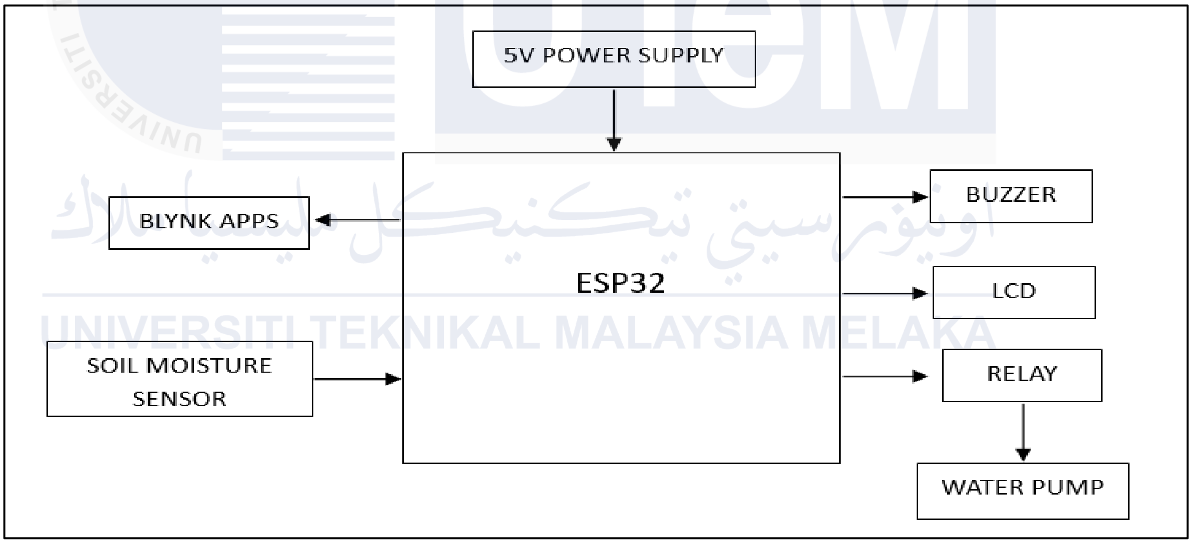

Figure 3.2 Block Diagram of Irrigation System

Moreover, the Blynk application also allows users to have real time data for soil moisture and control over the water pump from anywhere; all these enhancements contribute to making the irrigation process more effective and easily used. In the above figure you can see that the moisture sensor is directly connected to ESP32 microcontroller through dedicated ports detecting and monitoring moisture content in the soil. The ESP32 then processes the detected moisture level to know whether it's dry or wet. And the result is displayed on the LCD screen.

Apart from this, when soil is detected to be dry, ESP32 microcontroller sends signal to relay module to control water pump. The relay then turns on the water pump, which then distributes the water to the soil until it reaches the soil moisture level it wants. During irrigation the buzzer is triggered for an audible alert that water is being dispensed. When the moisture content in the soil rises high enough, the relay turns off the water pump, same thing with the buzzer.

This enables communication between the Wi Fi module on the ESP32 and the Blynk app in which we can remotely monitor the system as well as remotely control the water pump via a graphical user interface(GUI). Users can view the condition of soil through the Blynk app, and turn the water pump on or off when needed.

3.5 Development of Circuit Simulation

In figure 3.3 shows development circuit of an ESP32 microcontroller, a soil moisture sensor, an LCD display, a relay module, water pump, and a buzzer.

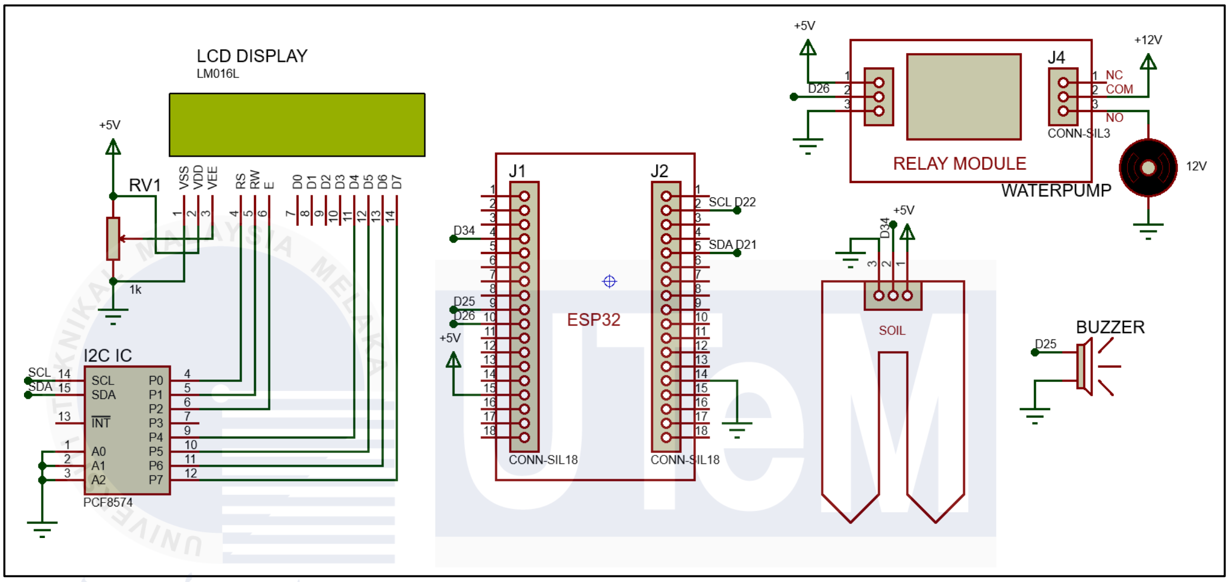

Figure 3.3 Development circuit

The central control unit is a microcontroller of the ESP32 type, with Wi-Fi capabilities, which is powering and communicating with sensors and modules. IoT based irrigation systems suitable for this configuration provides automated monitoring and control of soil moisture.

The soil moisture sensor will measure the moisture content of the soil. An analog input pin is connected to the ESP32. For example its VCC pin is powered by ESP32's 3V3 and GND pin is grounded to some ground pin of ESP32. The ESP32's D34 pin that the sensor's signal pin is connected to, and this allows the sensor to send its readings to the microcontroller for processing.

An I2C interface connects the LCD display which will be used for real time updates on system status. D21 and D22 pins of the ESP32 are connected to LCD’s SDA (data) and SCL (clock) pins. The display brightness can be adjusted to make it visible in different lighting conditions using a potentiometer. The I2C interface is easy to plug in, and reduces the number of GPIO pins needed.

A water pump relay module is then connected to the ESP32’s D26 pin which controls water pump. And its VCC and GND pins are soldered onto the ESP32's 5V and ground respectively.

The ESP32 can control the high power 12V water pump through the relay that acts as a switch. The ESP32 will turn on the water pump once its relay is activated, when the soil moisture drops below a predefined threshold. This buzzer is wired to the ESP32 D25 pin and is used as an alert mechanism. It also includes audible alerts when the water pump is activated, alerting that irrigation is running. This allows users to quickly obtain an understanding of the flow of water throughout the system's operation. In this scenario, the ESP32 acts as a power and communication node for sensors and other modules. The data is collected from the soil moisture sensor, the relay is controlled to turn on the water pump and there is displaing real time condition from the LCD display and buzzer.

3.6 Hardware Specification

The IoT based irrigation system uses several components to monitor soil moisture content and control the irrigation very effectively. The ESP32 microcontroller is the system core which is responsible for processing power and communication between standalone parts. The ESP32 is advanced enough for Wi-Fi that it can be used to remotely monitor and control the system via the Blynk app, which allows you to interact with the system from anywhere in the world.

Soil moisture sensor is a sensor which continuously measures moisture content of the soil and sends the data to be processed by the ESP32. As the moisture level falls below a specified concentration (ex: 20%), the system will trigger the water pump through a relay module. With the relay module, the ESP32 can safely control high power devices like a water pump to water plants more efficiently when they need it.

A 16x2 LCD display is incorporated into the system to provide real-time feedback, such as the current soil moisture level ("SOIL: System status is there along with any alerts and if most of them fall under DRY" or "SOIL: WET"). This visual means for people to monitor the performance of the system can be very clear to users. Moreover, there is a buzzer in the system to feedback an audible alert every time the water pump is in process. As soon as the water pump starts to operate this buzzer turns on, to indicate that irrigation has begun. While the pump is active, the buzzer stays on, and when the moisture level reaches a predefined threshold (e.g 35%), the buzzer turns off, indicating that irrigation is not needed anymore. With this, integration of Wi-Fi module and Blynk app, the user can monitor the soil moisture level and remotely control his irrigation system.

Each component was tested independently to verify that they worked correctly, and to verify how the system works as intended to manage irrigation based off of real time moisture data. Figure 3.3 shows hardware configuration.

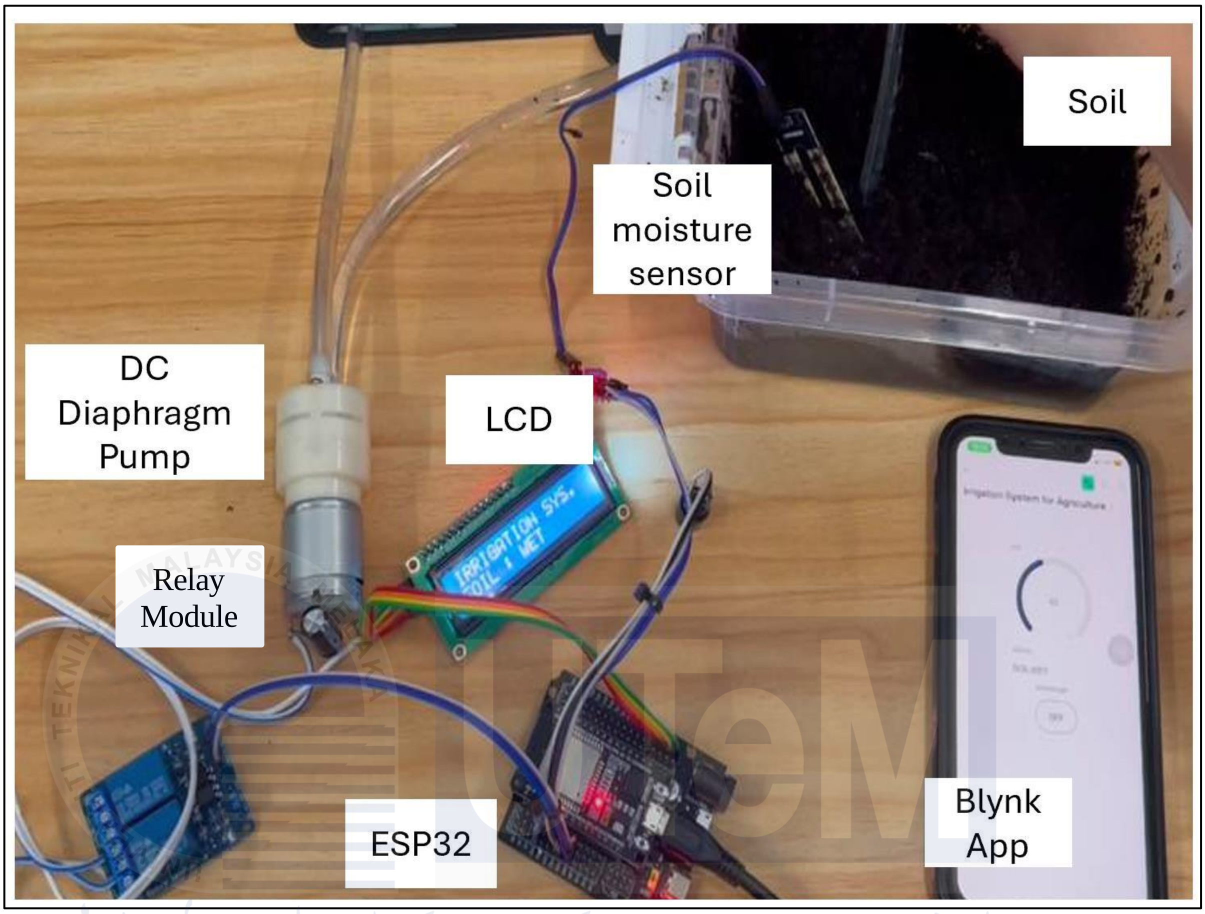

Figure 3.3 Hardware Configuration

3.6.1 ESP32

The ESP32 is a Microcontroller which has Wi-Fi Module and Bluetooth Integrated with a dual core processor operating from up to 240MHz based on Tensilica Xtensa architecture. It’s a very versatile little board: 34 digital I/O pins (of which 14 are usable as PWM outputs), 15 analog inputs, and 16 MHz clock speed! The frequency of ESP32 is 240 MHz, its useful for complex task especially where wireless communication is involved. In the back of the board there is a USB programming connection, a power supply connection, and AC to DC adapter jack, a battery connection, and a reset button. The board can be used with different requirements and the board is equipped with power options in the form of

USB, battery, and external adapter. The power supply for this system utilizes a power bank, thereby making the ESP32 portable and operational at all times.

With the Arduino Integrated Development Environment (IDE), the ESP32 can be easily programmed to write, upload and debug the code whenever needed. Through the Blynk application the irrigation system is able to be monitored and controlled remotely, and Internet connectivity is provided by the ESP32. In addition, the relay, water pump and the buzzer are also controlled by the same microcontroller (ESP32). This enables real time continuous data transfer, which allows the user to monitor soil moisture level remotely and to control water pump, which leads to minimization of water wastage and the plants stay health. In Figure 3.4 shows the ESP32 Microcontroller.

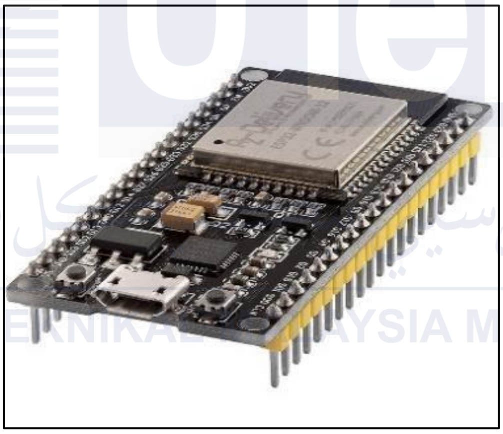

Figure 3.4 ESP32 Microcontroller

3.6.2 Soil Moisture Sensors

The Soil Moisture Sensor can therefore be described as a simple, effective tool commonly employed to detect moisture in the soil. As such, the Soil Moisture Sensor is a simple, effective tool used to detect moisture in the soil. It is operating through two massive external plates functioning as a probe acting as a variable resistor. The concept is simple: The larger the signal or reading, the lower the resistance, the more water in the soil, the larger the contact between the pads. To make the sensor work and power the sensor, there are two ports (VCC and GND) that need to connect to an Arduino or any similar development board. The SIG output is then proportional to the soil moisture level, and the microcontroller can read it. To give it better performance in a wet environment the sensor is further provided with gold finishing (ENIG) in the final PCB. What's the purpose of this sensor, then? It supplies real time, precise data on soil moisture levels, which is necessary for controlled irrigation systems that help to save water and helps improve plant growth. The Soil Moisture Sensor is used to monitor the soil moisture levels in two conditions: wet and dry soil. In case the soil is dry (less than 20% moisture), the system activates water pump to irrigate the plants. The system will not trigger the water pump in wet soil (greater than 35% moisture), informing that the soil is already well moistened, and will then continue tracking the moisture levels. In Figure 3.5 shows the Soil Moisture Sensor.

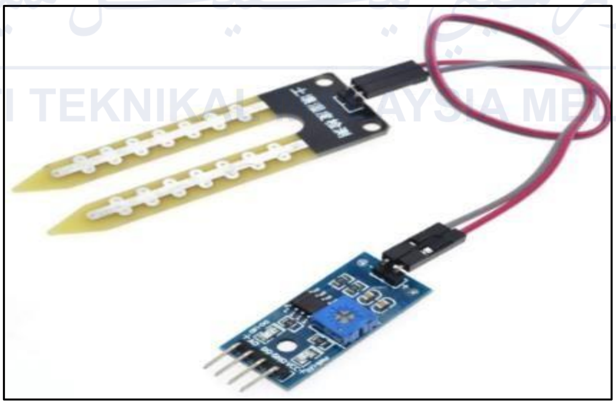

Figure 3.5 Soil Moisture Sensor

3.6.3 DC Diaphragm Pump

A DC Diaphragm Pump is a reliable and efficient fluid transfer device working in the range of a voltage: 6-12V. It has a diaphragm mechanism , which expands and contracts alternately, which creates a vacuum sucking fluid and throws it out from the discharge port into a discharge port. This results in an energy efficient solution for fluid pumping applications with volumetric flow rates on the order of 1-3 l/min and a current consumption of 0.5-1.5 A. A quiet operator, it runs in very low noise level places. It's constructed from durable, corrosion resistant materials that will withstand many conditions. The DC diaphragm pump can be offered in a submersible and a non-submersible model, and is mainly used in water pumping, medical devices, laboratory systems and small scale irrigation systems where precision and reliable fluid handling is required.

The DC Diaphragm Pump is used as a project for irrigation purposes. If the soil moisture is less than the set threshold (that is, the Soil Moisture Sensor signals dry soil) it sends a notification to the user via the Blynk app. The app triggers the ESP32 microcontroller, which in turn triggers the relay to turn on so as to power the water pump. The water is then shipped by the pump to the plants. Along with this, when the user gets to know that the water pump is active, this is notified by a buzzer. While the water pump is on, the buzzer will keep sounding to indicate that the irrigation is continuing. The system automatically shuts off the water pump and buzzer when the moisture level in the soil reaches high enough level. It is an efficient irrigation system that helps in saving water as well as the plant. In Figure 3.6 shows the DC Diaphragm Pump.

Figure 3.6 Diaphragm Pump

3.6.4 LCD Display

The 16 x 2 LCD Display is used to provide real-time visual feedback to show soil moisture levels, system status (i.e., 'SOIL: It will also display any Alerts, plus the current value for WET' or 'SOIL: DRY'. The line width of the display is 16 characters which is suitable for displaying little amount of data for e.g. sensor reading, system state, user prompt on two lines respectively. The LCD is a HD44780 or similar controller based LCD with a parallel interface, usually 4 or 8 bit, or via an I2C interface. It operates at 5V. This 5x8 dot matrix is used to present each character on a 5x8 dot matrix output which is clean and readable. The backlight also comes equipped with an optional contrast adjustment knob connected to the V0 pin.

It shows the real time soil moisture condition on the LCD display. When the moisture level is above the defined threshold (35%), the display shows "SOIL: The reading appeared as WET, and indicated sufficient moisture in the soil. When the moisture level falls below the threshold (20%) , the display shows "SOIL: It showed DRY indicating the need of irrigation. The display included in this device allows the user to easily monitor the status of the irrigation system through the LCD and be user friendly to manage the water consumption. In Figure 3.7 shows the LCD Display.

Figure 3.7 LCD Display

3.6.5 2-Channel 5V Relay Module

The 2-Channel 5V Relay Module is a very practical and convenient board to control high voltage and high current load such as motor, solenoid valve, lamp, or AC loads, useful for home automation, industrial control, or any electronic system. This can be easily interfaced with microcontroller used to control external device by simple digital signal. Relay's terminals (COM, NO and NC) feature screw termial to ensure a secure and reliable connection towards external circuits. Additionally, it has built in LEDs which indicate the relay status so you have visual feedback of the relays. It supports TTL level control signals, is compatible with 5V microcontrollers, and can drive a maximum switching voltage of 250VAC or 30VDC with a maximum switching current of 10A for NO (normally open) and 5A for NC (normally closed). This relay module is compact in size, measuring 50mm x 38mm x 17mm, providing an efficient and safe method of switching high power devices and isolating the control from load circuits electrically.

In the IoT based irrigation system, 2 Channel 5V Relay Module is used to control the water pump. The relay module is connected to a microcontroller like an ESP32 that monitoring of soil moisture level going through a sensor at all times. The microcontroller triggers the relay that leads to the water pump, which irrgates the soil when the moisture level goes below a specified level. But if there is enough moisture the relay is off and the pump does not run. Furthermore, the users can remotely control the water pump using the Blynk app by pressing a button in the app. The Blynk sends a signal to the ESP32, when the button is pressed, which switch on the relay and hence the water pump. This setup is convenient and efficient to manage irrigation and water usage anywhere in real time. In Figure 3.8 shows 2-Channel 5V Relay Module.

Figure 3.8 2-Channel 5V Relay Module

3.7 Software Specification

These are the software components needed in this irrigation system for programming, to control the hardware and for the monitoring of the entire system remotely. The main software tools and platforms used in this project are the Blynk application which enables smartphone control and monitoring and the Arduino Integrated Development Environment (IDE) which is used to program the ESP32 board. The Arduino IDE analyzes data originating from the sensors and controls the hardware, and simultaneously the Blynk application displays data and manages the water pump to enhance the irrigation process.

3.7.1 Arduino IDE

The ESP32 microcontroller acts as the core processing device, incorporating the hardware like the relay module, water pump, a buzzer, soil moisture sensor, etc. The Arduino IDE is used to program the system to collect real time data from the soil moisture sensor. When the soil moisture level reaches a predefined threshold, the sensor monitors the level continuously and displays the status through the LCD screen. Further, it offers connectivity through which the user can monitor as well as control the system remotely using a Blynk app.

A code is written which help ESP32 microcontroller to connect with Wi-Fi network using SSID ('EttyPhone') and password ('Etty0305'), as shown in Figure 3.9. The connection with Blynk app is established via Blynk.begin() function, which will enable the system to communicate with Blynk, for real-time monitoring and control. The current status of the irrigation system, like soil moisture and system notifications are displayed on the LCD display. The soil conditions are continuously being monitored by the soil moisture sensor, which is connected to pin 34 of ESP32.

```
CODING.ino
#define BLYNK_TEMPLATE_ID "TMPL678jBYWDQ"
#define BLYNK_TEMPLATE_NAME "Irrigation System for Agriculture"
#define BLYNK_AUTH_TOKEN "1n_DKsa7z6p0vQ4zwcRkDBZTE5dKlY6C" //NEW

#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16,2);

char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "EttyPhone";
char pass[] = "Etty0305";
```

Figure 3.9 Blynk connection with Arduino IDE

The system operates by measuring moisture level over time. If the moisture level drops below 20%, indicating dry soil, the system triggers a visual alert on the LCD screen, displaying a "SOIL: Dry message, then send a notification to the Blynk app. Water pump, which is connected to pin 26 of relay module, is running and buzzer connected to pin 25 of ESP32 is playing audible sound. If the moisture level is below 35%, the water pump is activated. When the system gets to 35% or above in moisture level, then the water pump turns off automatically. Users can also manually control the water pump via the Blynk app. The buzzer sounds when the system initiates irrigation and the pump is active, it will stop when the moisture level is adequate.When the system initiates irrigation, the buzzer signals that the pump is active, and it will stop once the moisture level is adequate.

When the water pump is running, the buzzer will stay on, which means that the system is irrigating. When the moisture level is higher than 35% (wet soil), the water pump is stopped, buzzer is stopped to indicate that the irrigation is over. Soil conditions are monitored continuously to apply water only when needed, saving water and improving irrigation efficiency. The additional coding for the IoT-based irrigation system can be seen in the Appendix C.

3.7.2 Blynk Application

The Blynk app is an integral part of the operation model and enables user interaction and system functionality enhancement in this IoT-based irrigation system. With a mobile interface, the app permits users to remotely monitor and control the irrigation system system. The system integrate smoothly with ESP32 microcontroller and other hardware parts for collecting real time data and controlling. The Soil Moisture Sensor connected to Virtual Pin V1 is a key widget on the mobile interface, showing the real time soil moisture levels in percentage from 0% (dry) to 100% (wet). This is useful for users to be able to evaluate when the soil is hydrated at any time.

The LCD Display widget, linked to Virtual Pin V2, offers a clear text update showing whether the soil is "SOIL: DRY" or "SOIL: WET," further simplifying soil condition monitoring.

Additionally, the app also has an On/Off button that is attached to virtual pin V0 which can manually control the water pump. So users can start and stop the pump anytime that's needed to water the plants without any limitation. The Blynk App integration with the system further enhances its usability, making the solution practical and efficient for precision irrigation, and easy to manage from a mobile device. In Figure 3.10 shows Mobile Interface Blynk.

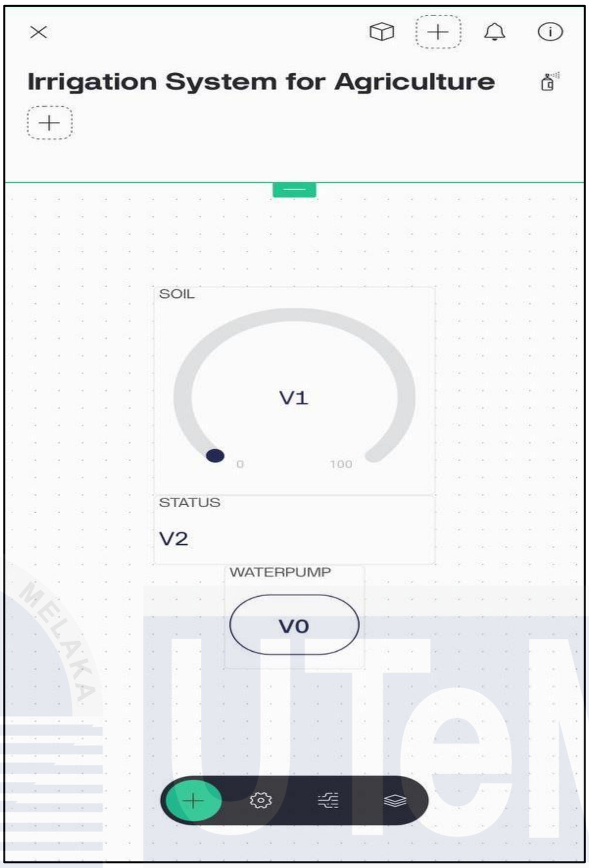

Figure 3.10 Mobile Interface Blynk

3.8 Summary

In this chapter, give an overview of designing an efficient, seamless, IoT based agriculture scheme for irrigation using Esp32. This is a simple but effective methodology that improves system performance. The system allows to remote control and monitor the entire irrigation process. The system consists of well known components such as ESP32 microcontroler and Wi-Fi module, along with Blynk app with real time data and control. It aims to keep things as simple and practical as possible for the system in terms of accessibility and designing for users. It monitors soil moisture levels in order to improve irrigation efficiency, conserve water, and help keep plants healthy by utilizing the water pump remotely.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

In this chapter, the result and analysis of developing an IoT based irrigation system for argirculture are explained. The system was evaluated using real-life conditions during the analysis. The remote water pump was designed to operate based on soil moisture levels, transmitted real time data through Blynk IoT platform. Various conditions were tested to verify its accuracy of moisture detection and efficiency in water usage in order to irrigate the right amount of water and conserve water in the right way so that the plant grows healthily

4.2 Result and Analysis

The modules were integrated to develop a prototype of an IoT-based irrigation system for agriculture. The system was tested under two main moisture conditions: two types of soil that are common in agricultural irrigation, dry soil and wet soil. These tests were used to analyze the results and evaluate how the system is able to detect soil moisture levels and trigger irrigation, and how effective the system is for communicating with the user through Blynk app.

4.2.1 The Developed Prototype

The prototype, a mini irrigation system, was constructed from lightweight and highly durable polystyrene foam board. Specifically, the project consists of two separate soil containers, one for dry soil testing and one for wet soil testing. The water pump is located outside the project box and connected to a water tank made from a bottle which stores the water to be used for irrigation. The ESP32 microcontroller is inside the compact project box, a relay to control the water pump, a buzzer to indicate the water flow, and an LCD display on the front for real time soil moisture level.

The system is powered by a power supply 5v, and an adapter 12v is used to trigger the relay and power on the water pump. Figure 4.1 shows the developed prototype.

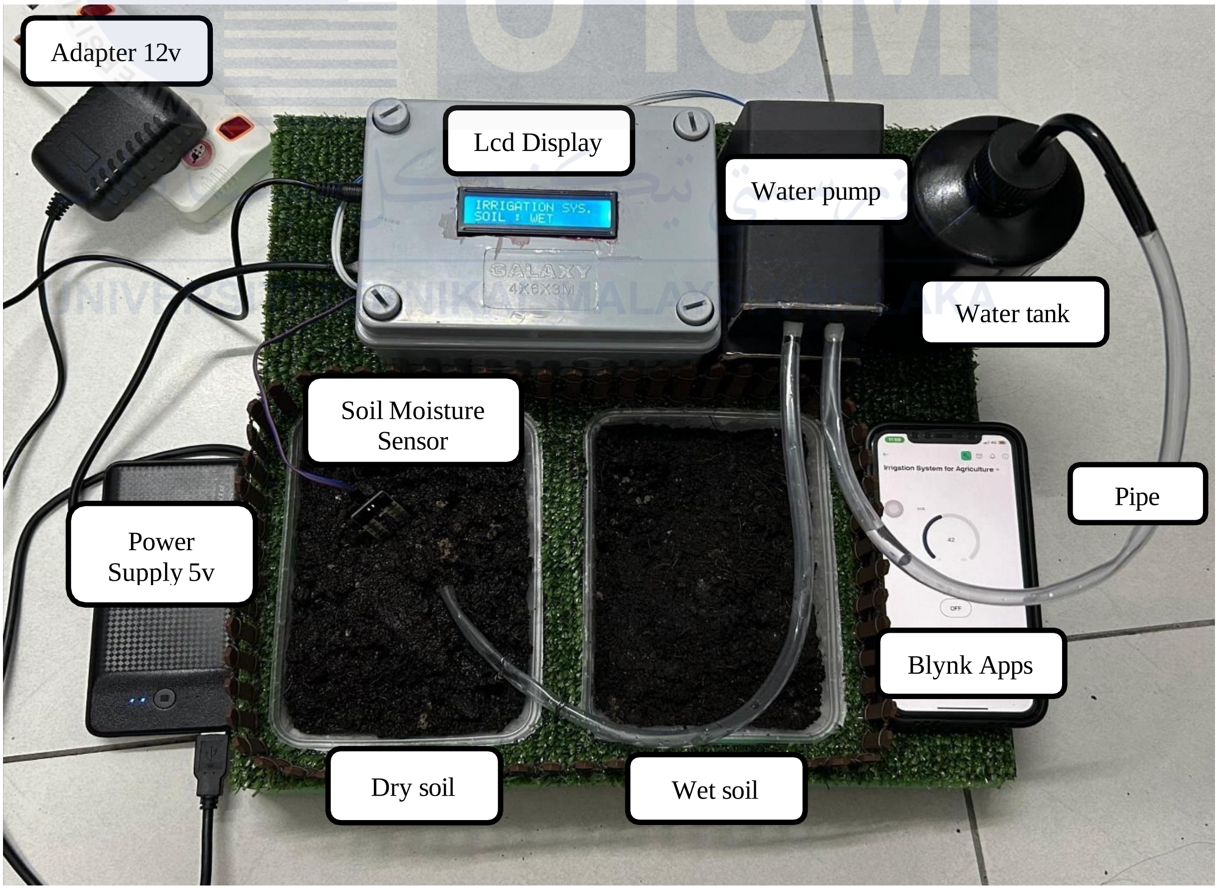

Figure 4.1 Developed Prototype

4.2.2 Validation of the Developed Prototype

Then after the programming of the IoT based irrigation system was completed, the function of the system was verified using Arduino IDE. Integration of the system with the Blynk app was also successful in achieving real time monitoring and control of soil moisture levels. If the soil moisture decreases to a specified point which is defined to indicate dry soil, the system notifies the user by sending a warning notification through the Blynk app. In Figure 4.2 shows warning notification on Blynk Apps.

In particular, the moisture sensor detects the moisture level at the soil when the moisture content falls below 20% and trigger a notification on the Blynk app to notify the user with a specific message such as "SOIL MOISTURE DRY." This then prompts the user to act, for example to activate the water pump manually from the Blynk app. The notification system provides real time notification of the irrigation needs to the user and the user is able to monitor the soil moisture remotely and take informed action. When the user will get a dry soil notification, users can turn on the water pump via the Blynk app so that the water rises to the plants.

The irrigation control system provides the user with a real time notification of the irrigation need, so that the user can monitor the soil moisture from remote distance, and make an informed decision. After the notification of dry soil, the user can activate the water pump via the Blynk app and the plants will adequately watered.

Figure 4.2 Notification on Blynk Apps

4.2.2.1 Validation Scenario 1 : Dried Soil

In dry soil condition, the system periodically monitors the soil moisture levels by attaching the ESP32 microcontroller and soil moisture sensor. This sensor provided real-time feedback on the moisture content of the soil, allowing the system to accurately determine when the soil was too dry. The system was programmed to trigger irrigation when the moisture level fell below a predefined threshold, set at 20%. Specifically, this threshold was chosen as a point at which the soil got too dry, and watering was necessary to keep plants healthy under optimal conditions. Users were able to have complete control of their irrigation decisions, eliminating the possibility of overwatering or underwatering.

In other words, When the moisture level drops below this 20% threshold, the system sees the soil as 'dry' and issues an alert. In Figure 4.3, the LCD display showed the message "SOIL: DRY," clearly needed to irrigate. In addition, it also notified the user via the Blynk app that the soil moisture needed to be irrigated. The user received this notification and took appropriate action as well as managed the process of irrigation.

Figure 4.3 LCD display Dry Conditions

When the user received the notification, the user was able to control in full, the irrigation process. By holding their phone over the 'On/Off Button' linked to the water pump on their Blynk app, they could manually activate the water pump. It enabled the user to choose when the watering process would begin, rather than starting it automatically, and therefore verifying that the system watered the plants only when necessary. This feature gave the user the flexibility to decide when to start the watering process, ensuring that the system watered the plants only when necessary. In Figure 4.4 show the warning notification on Blynk App.

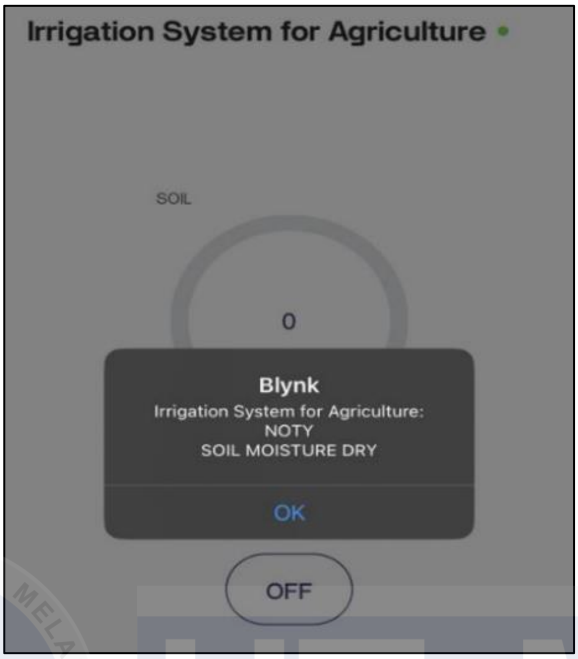

Figure 4.4 Notification on Blynk App During Dry Conditions

4.2.2.2 Validation Scenario 2 : Wet Soil

For the wet soil condition, the system reacted as the user accessed the water pump wirelessly through the Blynk app. The ESP32 microcontroller controlled the relay and powered on the water pump on the user's action. While the pump distributed water to the soil, the moisture content started rising, and the system kept up real time monitoring of the moisture levels. The buzzer was activated to indicate the irrigation has started and the water pump is operating, and will deliver water in the soil. The system continued to monitor the moisture level, and if the moisture level exceeded 35%, the system regarded the soil as "wet." The ESP32 would automatically turn off the relay when the moisture level reached above 35% and deactivate the water pump. Figure 4.5 shows the LCD display updating wet conditions. When the soil had enough moisture, hence no further irrigation was needed, as indicated by "Wet".

Figure 4.5 LCD Display Wet Conditions

When the water pump was turn off, the buzzer also went off telling that irrigation process had ended. The Blynk app updated in real time with confirmation that irrigation was indeed stopped and soil finished at the desired moisture level. This approach ensured efficient water usage by running the pump only until the soil moisture was optimal, reducing the risk of over-watering. Figure 4.6 shows the Blynk App Display wet soil conditions.

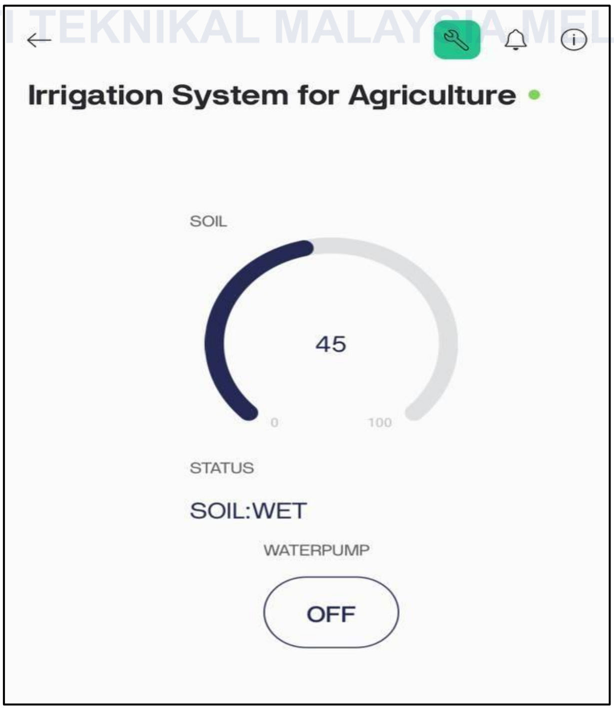

Figure 4.6 Blynk App Display During Wet Soil Condition

4.2.3 Moisture Analysis Using the Developed Prototype

The IoT-based irrigation system was evaluated under two primary conditions: It is designed to monitor dry soil and wet soil, all of which are monitored in real time using the Blynk app. In both possible situations, the system observed the levels of soil moisture, and made actions, such as irrigation 'ON' or 'OFF', automatically adjusted, as well as displayed through the Blynk app. This work analyzes how well the system detected changes in soil moisture, responded to varying conditions, and allowed the user to manage irrigation. However, the system has been evaluated on its efficiency, responsiveness and how well the system supported interaction for the user interaction to ensure optimal irrigation control.

Table 4.1 showed data analysis from two testing scenarios: Dry Condition and Wet Condition, which presents the relationship between soil moisture levels and the corresponding system responses on the LCD display and the relay status.

Table 4.1 Data Analysis from Two Scenarios

Soil Moisture Reading (%)	System Response (LCD Display)	Relay Status (Water Pump)	Blynk App Notification
0	SOIL: DRY	ON	Notification sent
10	SOIL: DRY	ON	Notification sent
28	SOIL: DRY	ON	Notification sent
38	SOIL: WET	OFF	No notification
46	SOIL: WET	OFF	No notification
50	SOIL: WET	OFF	No notification

From the table, it can be observed that when the soil moisture level fell below the defined threshold of 20% indicating the soil to be dry. The LCD display showed the message "SOIL: It stated "DRY", clearly a demand for watering. The system also notified the user via the Blynk app that irrigation was needed. The user receives the notification and activated the water pump using On/Off Button in the Blynk app, which starts the run of the irrigation process by switching on the relay (Relay ON). This control gave the user the freedom to choose when to initiate the watering, thus making sure that the plants were watered only when required and not if they were already moist.

However, the system would interpret the 28% soil moisture read, which was above the 20% threshold, yet borderline dry to dry, as dry and prompt irrigation. The LCD display showed "SOIL:'DRY'". The notification was also sent by the Blynk app to the user, remind to turn on waterpump for the irrigation of the process. In this borderline case where it was neither wet nor dry, unlike with the soil wet enough, the system triggered an action to water the plants to make sure they get water before it's too dry.

Meanwhile, when the soil moisture level exceeded 35%, which further revealed that the soil was wet enough, the system shut down the irrigation. The LCD display switched to "SOIL: 'WET' was displayed, indicating no further watering was required.

The system also automatically turned off the water pump (Relay OFF). It also helped us during the irrigation process; the buzzer was activated when the water pump was on to indicate watering. Once the water pump stopped, it turned off and indicated that the irrigation was complete. But unlike in Scenario 1, there was no notification sent to the user. Instead, the Blynk app interface updated in real-time, displaying the current soil moisture level as a percentage and showing the status as "SOIL: “WET". With this update in the app, the user no longer had to manually intervene or wait for notification to see the soil’s condition.

Table 4.1 shows how the system efficiently manages irrigation by adjusting to real-time soil moisture levels. When the soil is dry, the system alerts users, lets them control the irrigation and start it; when the soil is wet, the irrigation automatically stops; and real time update will be displayed on users' phones on the Blynk app, thus saving water usage and maintaining the optimal plant health.

4.3 Summary

In this chapter, the development and successful test of the IoT based irrigation system which can monitor soil moisture level and control the water irrigation is explained. To test the performance of the system, it was integrated with a ESP32 microcontroller, a relay module, a soil moisture sensor, and a Blynk app and tested under real life conditions. The system accurately detected dry soil, activated the water pump, and showed warnings on the LCD in the testing condition. Real time monitoring and control of the water pump was made possible by Blynk app. Based on the results, the system proved to successfully utilize the soil moisture data to monitor and distribute irrigation according to the plant's requirements hence healthy plant growth with the optimal use of water.

In dry soil and wet soil the system works successfully. The Blynk app notified the user, and when the soil was dry, the user activated the pump that was able to automatically distribute water to the crops. The moisture levels were also protected by the system from overwatering that might arise by deactivating the pump when the desirable moisture levels are reached. The integration of the Blynk app was successfully integrated to meet user convenience like remote control and notifications. Furthermore, users will be able to remotely manage the irrigation system from a distance and get prompted by it for greater effectiveness and better convenience for users. The project successfully accomplished the objectives and provided a simple, user friendly solution, for precision irrigation, so the water usage is fully optimal and healthy plants are grown.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis aims to develop an IoT-based Irrigation system for agriculture using Esp32. This will involve the use of an ESP32 microcontroller to monitors soil moisture, controls a water pump via a relay, alerts with a buzzer, displays data on an LCD, and supports remote control through the Blynk app.

Firstly, the primary objective of this system will aim to create a remote soil moisture monitoring system to enable the user to monitor the field moisture level in real-time using the Blynk mobile application. With all these components integrated, the system displays the real-time soil condition on an LCD for warning message and Blynk app for remote monitoring. Once the level of moisture in the soil drops to the predetermined level, the system notifies the user whether the soil is dry or wet. In cases where it is dry, it alerts the user via the Blynk app that they need to turn on the water pump. After that the user will be able to control the pump from a distance leading to the dispensing of water. This helps in minimizing wastage of water and at the same time ensures that crops are watered adequately, hence increasing their growth rates.

Also, the operations of the irrigation systems can be managed remotely using Blynk mobile application, thus enabling users to easily manage irrigation systems from any location. This functionality will allow users to quickly act and make changes after receiving notifications while on their mobile devices. The remote functionality will help the users to observe on a real time basis the moisture content of the soil, get notified instantly, and control the irrigation system from a distance. By such elements of the remote monitoring and control of the irrigation systems, the system will enhance specialized capacities of the farmers in handling the irrigation systems efficiently.

Finally, all the system functionalities are validated to ensure the work in order of various scenarios. During the validation process, the feasibility of using soil moisture sensors in measuring moisture levels, the ability of the system's response to changes in the soil moisture level, the performance of the remote monitoring and control functions, and how well components of the system are integrated will be determined. These tests is conducted to make sure that the system operates as was intended.

Overall, this project has successfully developed IoT-based irrigation systems in agriculture using ESP32. Hence, it is hope that the idea may help to increase agricultural productivity by increasing the efficiency of water use in agricultural production.

5.2 Potential for Commercialization

IoT-based Irrigation system for agriculture using Esp32 proposed in this project has great commercial value, which can greatly promote the development of the modern agricultural field. This is due to increasing concerns about water availability for irrigation purposes as well as enhanced farming methods needed in agriculture. These resources include flexibility of the system in managing and monitoring the irrigation process from a central point, which comes hand in handy for large-scale farmers or those who manage several fields at once, effectively cutting down on labor costs. The method is more effective for small to medium sized farming as most of the components used are easily accessible. However, the reduced water usage, as well as the improved crop yields lead to economic benefits; other benefits which also make the technology appealing. Farmers can easily manage their systems using the Blynk app without the need for any technical expertise, which makes it possible to deploy many systems due to low barriers to entry. By generating real-time alerts and notifications if the parameters have changed, the users can therefore make better decisions, hence efficient irrigation in the long run.

Moreover, flexibility can be enjoyed as the system setup can be planned and constructed in accordance with the size of the agricultural activity, thereby suitable for planting crops and tending to gardens, small farms, and even large commercial farms. Also, the developed system can learn several more IoT devices and sensors easily and, thus, can be regarded as one universal instrument for electronic farming. The system is also a good number of steps towards ecological friendly farming that saved water and reduced wastage which had impacts on the conservation of important water bodies and ecosystem. For the consumer and authorities who are conscious about environmental concerns, the environmental aspect can be the pull factor. Further, to the user or the grower the system can be readily configured to meet the user's specific needs. For example, the watering schedule may be changed according to the specific crop type or perhaps the addition of more sensors for better control is possible due to the system's modular design. Because it is highly utilizable, it becomes more favorable with farmers in different areas and using different approaches in cultivation.

In conclusion, generally, it may be deemed that the element of commercialization of this irrigation system is quite high. The environmental effect being positive, cheap, harmless to health, highly extendable and able to solve significant current problems within the agricultural industry makes it a product with huge market appeal when it is released onto the market. What is more, its functionality and ability to meet market demand can be enhanced and reshaped, which in turn will create proper ground for commercialization and significant advancements toward making agriculture more environmentally friendly.

5.3 Future Works

For future improvements of the IoT-based Irrigation system for agriculture using Esp32 and overall performance can be enhanced as follows:

i) Integration with Advanced Sensors: Additional sensors such as temperature and humidity sensors will be added to the system to provide increased accuracy as far as the soil and environmental data are concerned. This enables better irrigation control with weather conditions in real time.

ii) Data Analytics and AI Integration: The system can, by using machine learning algorithms, predict future irrigation needs by using historical data. This will help in taking up water more optimally and better irrigation schedules..

iii) Mobile App Enhancement: The Blynk app interface can be further developed to allow users to personalize settings such as threshold for moisture level and pump schedules. It will offer insights and analytics on water consumption and soil health as well.

iv) Automation with Weather Forecast Integration: Enhance the system by considering local weather forecast and use this information to automatically adjust irrigation schedule according to the predicted rainfall thus minimizing loss of water.

v) Energy Efficiency Optimization: Used the solar panels in the system to run the water pump and sensors so irrigation can become more sustainable and energy efficient in remote areas.

vi) Additional Sensor Integration for Multiple Zones: Used a soil moisture sensors onto each of irrigation zone, thus allowing to independently.

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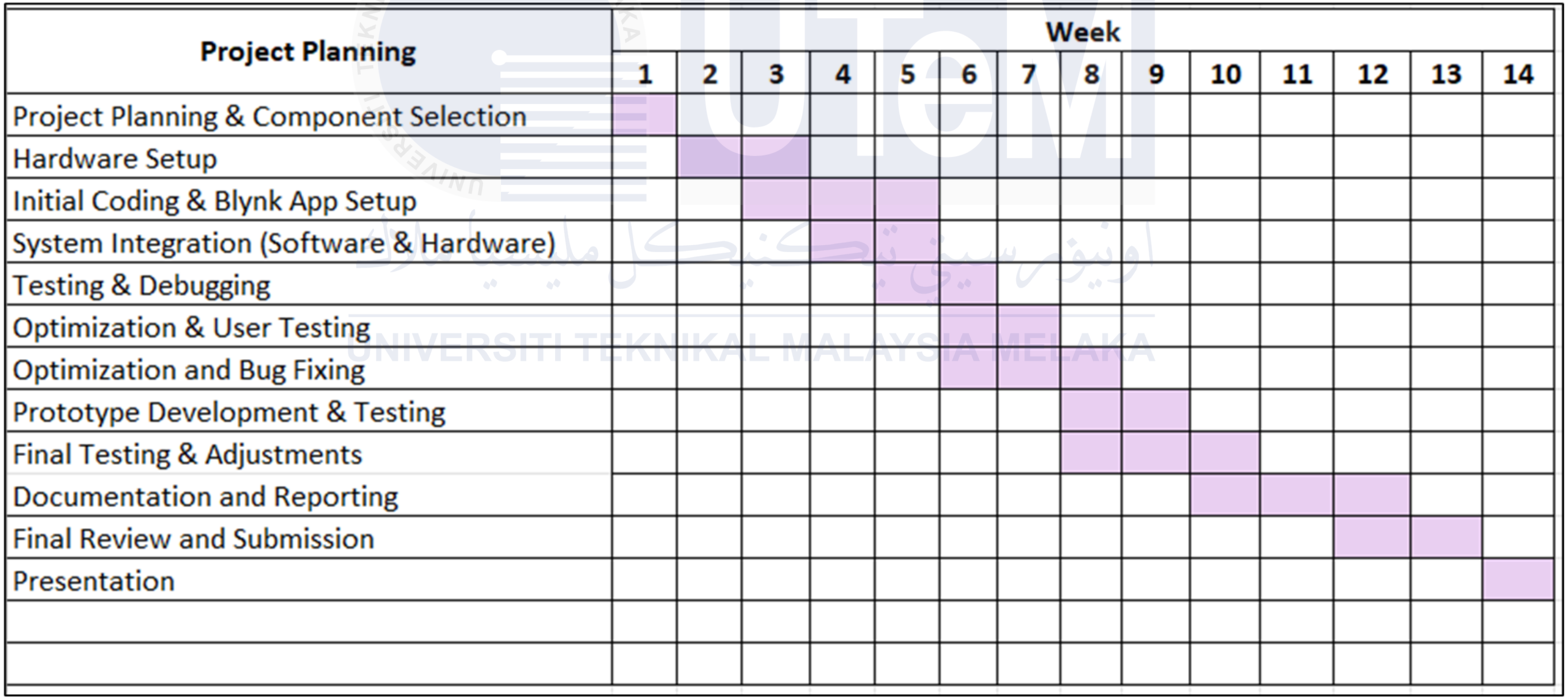
APPENDICES

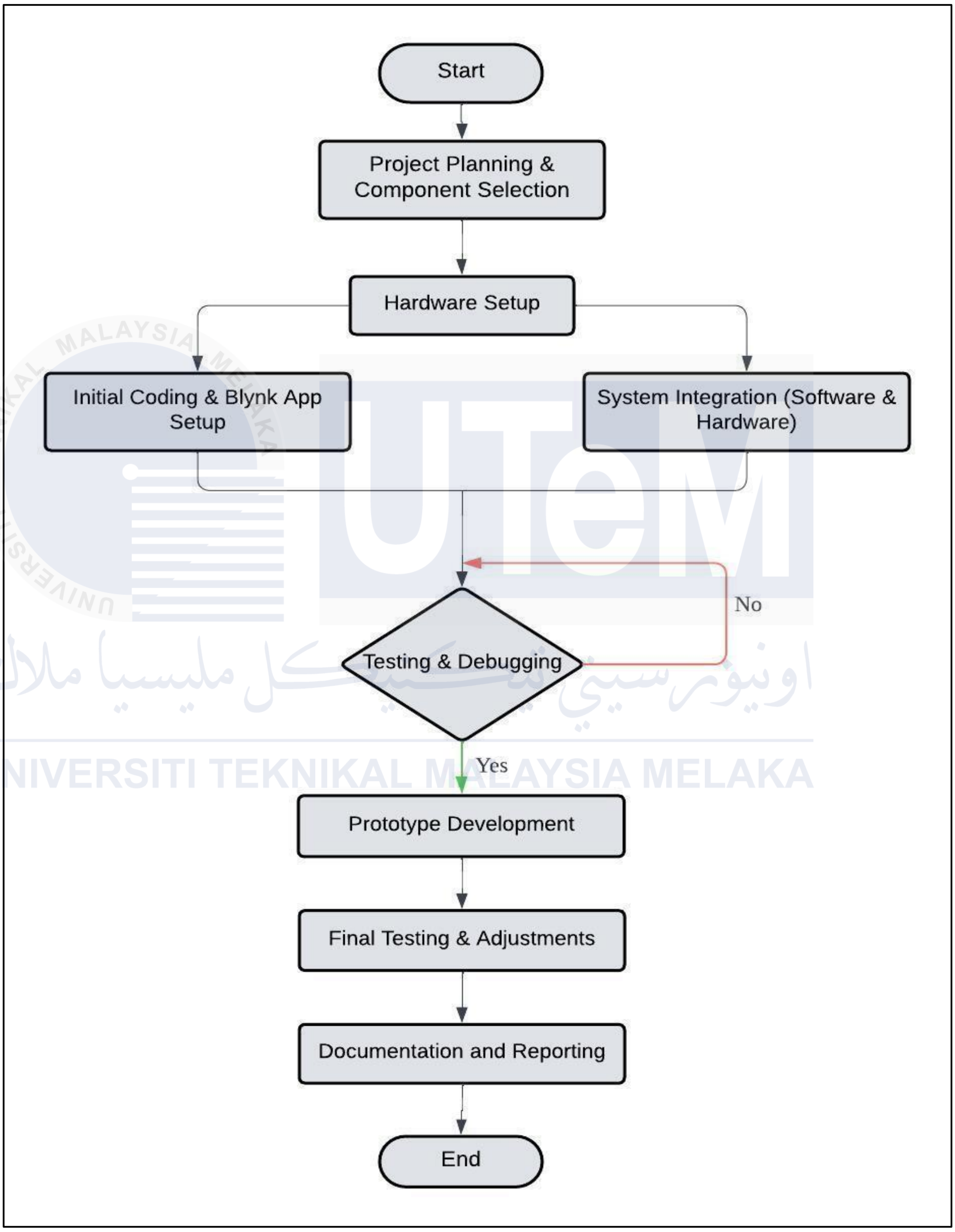
Appendix A

<u>Gantt Chart for Bdp 2</u>



Appendix B

BDP2 FlowChart



Appendix C

Coding Arduino Ide

```
#define BLYNK_TEMPLATE_ID "TMPL678jBYWDQ"
#define BLYNK_TEMPLATE_NAME "Irrigation System for Agriculture"
#define BLYNK_AUTH_TOKEN "1n_DKsa7z6p0vQ4zwcRkDBZTE5dKlY6C"
//NEW

#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16,2);

char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "EttyPhone";
char pass[] = "Etty0305";

#define waterpump   26
#define buzzer     25

int noty = 0;

BLYNK_WRITE(V0) {
 int buttonState1 = param.asInt();
  if (buttonState1 == 1){
      digitalWrite(buzzer,HIGH);
      digitalWrite(waterpump,LOW);
  }
  else {
      digitalWrite(buzzer,LOW);
      digitalWrite(waterpump,HIGH);
  }
}

void setup()
{
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
  lcd.begin();
  lcd.backlight();
  pinMode(34,INPUT);
  pinMode(buzzer,OUTPUT);
  pinMode(waterpump,OUTPUT);
  digitalWrite(buzzer,LOW);
  digitalWrite(waterpump,HIGH);
```

```
  lcd.setCursor(0,0);
  lcd.print("IRRIGATION SYS.");
}

void loop()
{
  Blynk.run();
  float soil = analogRead(34);
  soil = (1-(soil/4095))*100;
  Serial.println("SOIL:" + String(soil) + "  ");
  Blynk.virtualWrite(V1, soil);
  delay(500);
  if(soil < 20){
    lcd.setCursor(0,1);
    lcd.print("SOIL : DRY ");
    Blynk.virtualWrite(V2, "SOIL:DRY");
    if(noty == 0){
      noty = 1;
      Blynk.logEvent("noty", "SOIL MOISTURE DRY");
    }
  }
  else  if(soil >= 35){
    noty = 0;
    lcd.setCursor(0,1);
    lcd.print("SOIL : WET ");
    Blynk.virtualWrite(V0, 0);
    Blynk.virtualWrite(V2, "SOIL:WET");
    digitalWrite(buzzer,LOW);
    digitalWrite(waterpump,HIGH);
  }
}
```