VIETNAM NATIONAL UNIVERSITY – HOCHIMINH CITY
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IOT-BASED APPLICATIONS FOR WATER RESOURCE MONITORING SYSTEM

BY

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A THESIS SUBMITTED TO THE SCHOOL OF ELECTRICAL ENGINEERING
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Under the guidance and approval of the committee, and approved by its members, this thesis has been accepted in partial fulfillment of the requirements for the degree.

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HONESTY DECLARATION

My name is Nguyễn Trung Tín. I would like to declare that, apart from the acknowledged references, this thesis either does not use language, ideas, or other original material from anyone; or has not been previously submitted to any other educational and research programs or institutions. I fully understand that any writings in this thesis contradicted to the above statement will automatically lead to the rejection from the Control Engineering and Automation program at the International University – Vietnam National University Ho Chi Minh City.

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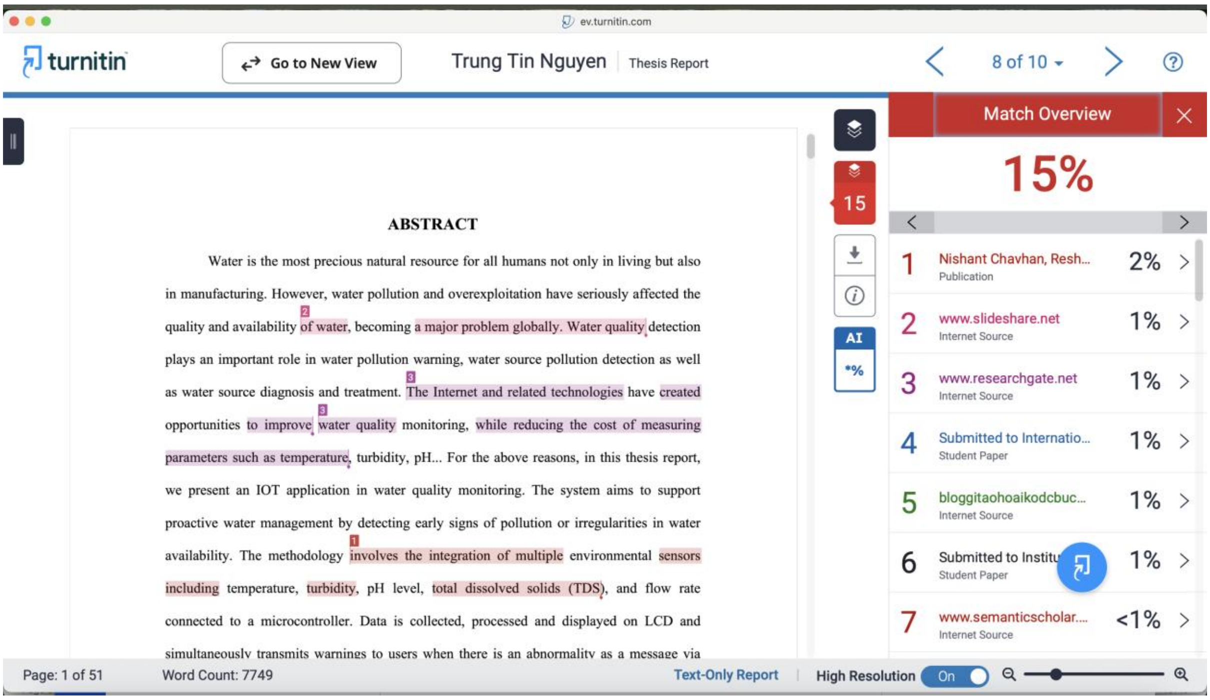

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ABBREVIATIONS AND NOTATIONS

GPRS:	General Packet Radio Service
GSM:	Global System for Mobile Communications
IoT:	Internet of Things
ISO:	International Standard Organization
NTU:	Nephelometric Turbidity Units
Ppm:	Parts per million
TDS:	Total dissolved solids
WSN:	Wireless Sensor Network

ABSTRACT

Water is the most precious natural resource for all humans not only in living but also in manufacturing. However, water pollution and overexploitation have seriously affected the quality and availability of water, becoming a major problem globally. Water quality detection plays an important role in water pollution warning, water source pollution detection as well as water source diagnosis and treatment. The Internet and related technologies have created opportunities to improve water quality monitoring, while reducing the cost of measuring parameters such as temperature, turbidity, pH, etc. For the above reasons, in this thesis, we implement an Internet of Things (IoT) application system in water quality monitoring. The system aims to support proactive water management by detecting early signs of pollution or irregularities in water availability. The methodology involves the integration of multiple environmental sensors including temperature, turbidity, pH level, total dissolved solids (TDS), flow rate and GPS connected to a microcontroller. Indeed, data is collected from these sensors, processed and displayed on LCD and simultaneously transmits warnings to users when there is an abnormality as a message via mobile using 4G module (A7682S). Moreover, the system leverages the Blynk Internet of Things platform for real-time remote visualization and warning notification. The implemented system was tested under different conditions such as acidic, neutral, and alkaline environments. The results demonstrate that the system provides accurate sensors reading, timely alerts. In conclusion, the proposed IoT-based water resource monitoring system is a reliable, low-cost, and scalable solution that can support household water resource monitoring and management.

Keywords: Microcontroller, sensors, water quality monitoring, GSM Module, LTE Module

CHAPTER I.

INTRODUCTION

In this chapter, there are three main parts including theoretical background, goal and objectives, and structure of the senior report.

1. 1. Theoretical background

This section will be divided into 3 small parts including: (i) the importance of water resources and current challenges in Viet Nam, (ii) IoT applications in daily life and (iii) the reason for choosing the topic. These parts will be discussed in the following subsections.

1. 1. 1. The importance of water resources and current challenges in Viet Nam

Water covers approximately three-quarters of the Earth's surface and is a valuable resource for sustaining human life. In fact, around 70% of the planet's surface is water, but only 2.5% of it is freshwater, with the remaining 97.5% found in the oceans [1]. Of the available freshwater, just 0.3% is contained in rivers and lakes, about 30% exists as groundwater, and the majority is locked away in glaciers and ice caps [1]. Globally, water usage is divided among agriculture (70%), industry (22%), and domestic purposes (8%) [2].

The combined effects of industrialization, modernization, and climate change are exerting significant pressure on the quality and quantity of global water resources. Water depletion, rising demand for clean water, and deteriorating water quality are major challenges facing humanity. Currently, more than 2.6 million people worldwide lack access to basic sanitation, and nearly 1 billion people are without clean drinking water [2]. Every 20 seconds, a child dies from diseases linked to inadequate access to clean water and proper sanitation [2]. A recent World Bank report estimates that by 2030, global water demand will exceed supply by 40% [1].

Currently, many major cities — particularly Hanoi and Ho Chi Minh City — still lack adequate access to clean water for daily use. Groundwater resources are being exploited uncontrollably, with widespread drilling of wells to extract underground water. This not only leads to waste and depletion but also risks contaminating these water sources. Additionally, due to a lack of awareness about the importance of water resources, improper management of landfills, burial sites, and waste treatment facilities occur across the country. These sites often fail to comply with regulations and environmental protection procedures, allowing leachate to seep into groundwater sources and flow into saltwater areas.

With the growing scarcity and pollution of water resources, the need for effective monitoring and management of water quality has become more urgent than ever. These challenges call for advanced technological solutions to safeguard and manage precious water supplies. As a result, the application of water quality monitoring technology, particularly IoT systems equipped with smart sensors, not only ensures accurate measurements but also provides real-time data to support the timely detection and management of water pollution and depletion issues. This approach will be key to protecting water resources and ensuring the safety and quality of life for communities.

1. 1. 2. IoT applications in daily life

The development of the Internet of Things (IoT) has a significant impact on production, business, life and society across various sectors, including infrastructure management, healthcare, construction and automation monitoring [3]. IoT is a rapidly expanding technology trend that enables internet-connected objects or devices to collect, process, and share information [4]. It is recognized as a technology that has established itself as a network of machines or devices capable of communicating with one another [4].

In recent years, IoT has emerged as one of the most important technologies. It helps people live and work more efficiently while enabling them to be proactive in managing their daily lives. In the field of water quality monitoring, IoT plays a vital role by providing automatic and intelligent monitoring solutions. For example, a real-time drinking water quality monitoring system based on a wireless sensor network was introduced in [5]. This system sent users SMS alerts with water quality parameters — including temperature, turbidity, and pH — using a Zigbee module. A similar system in [6], monitored the same parameters, transmitting the data to users via an XBee wireless module and displaying it on an LCD screen. When the parameters reached dangerous levels, a buzzer would sound an alert. Additionally, a real-time mobile water temperature monitoring system, designed to help aquaculture farmers optimize their operations, was presented in [7]. In this system, a Raspberry Pi acted as the microcontroller and connected to a mobile device via the internet. Finally, a comprehensive survey on water quality monitoring using wireless sensor networks (WSN) was provided in [8], highlighting the system's heavy reliance on mobile networks.

1. 1. 3. The reason for choosing the topic: IOT-Based Applications for Water Resource Monitoring System

The International Organization for Standardization (ISO) defines water quality monitoring as the process of collecting, measuring, and documenting or indicating various water characteristics, with the objective of evaluating compliance with specified water quality objectives [4]. Water quality describes the overall biological, physical, and chemical composition of the water. Therefore, assessing drinking water quality requires monitoring a range of physical, chemical, and biological parameters. This is where the application of IoT in water quality monitoring becomes essential, enabling continuous, accurate, and efficient data collection and analysis, which provides a solid foundation for informed decision-making in water management.

In this thesis, an IoT system was developed to measure water quality indicators, including pH, temperature, turbidity, total dissolved solids (TDS), and flow rate, with greater accuracy and efficiency than existing instruments. The device integrates multiple environmental sensors connected to an Arduino microcontroller, an ESP8266 module, a GPS module and a 4G module, enabling real-time data transmission to mobile devices via the Blynk IoT platform and SMS. Users can easily monitor water quality on their smartphones and receive immediate alerts when abnormalities are detected. With the ability to continuously collect data and send real-time notifications, the system enhances the efficiency of water resource monitoring, reduces operational costs, and optimizes response processes when issues arise.

1. 2. Goals and objectives

1. 2. 1. Goal

In this thesis, we will design and development of an IoT-based system for monitoring water resources by measuring temperature, pH, turbidity, total dissolved solids (TDS), flow rate, and location. Sensor data is collected via a microcontroller and transmitted to a mobile app through Wi-Fi and 4G signals, with abnormal values triggering SMS alerts.

1. 2. 2. Objectives

1. Review the existing techniques that use IoT approaches to monitor water quality.
2. Design and implement an IoT-based system to monitor water resources by measuring temperature, pH, turbidity, total dissolved solids (TDS), flow rate and location. The data will then be sent to the user via the Blynk platform and SMS message.
3. Evaluate the system performance in different environments.

1. 3. The structure of the thesis

The content of this thesis is divided into seven chapters. The chapter I provides about theoretical background, and it also presents the goals and objectives of the senior. The second chapter is design specifications and standards. The third chapter provides a budget and cost management plan, a project management plan, tasks to be performed, and specific timelines for each task, all displayed in a Gantt chart. Next are the references related to our project, providing knowledge and solutions for developing the water quality monitoring system presented in Chapter IV. The fifth chapter provides the methodology for achieving the objectives. Chapter VI presents the results. Finally, chapter VII discusses conclusions, implications, strengths, weaknesses and effectiveness of the system and future development prospects. Finally chapter VIII discusses about business, social and ethical of the thesis.

CHAPTER II.

DESIGN SPECIFICATIONS AND ENGINEERING STANDARDS

This chapter provides a detailed description of the hardware and software design of the IoT-based water resource monitoring system. It establishes a clear framework for the system design, including the architectural structure, functional requirements, and engineering constraints to ensure reliable and efficient operation. The system utilizes microcontrollers and various sensors to collect data, connects to WiFi and 4G modules, and transmits information to users over the network..

2. 1. Design Specifications

2. 1. 1. System overview

The water quality monitoring system uses Arduino UNO and ESP8266 to connect temperature, pH, turbidity, total dissolved solids (TDS), flow rate, and geographic location sensors to WiFi and 4G module. The data will be transmitted to the Blynk application, where users can monitor the parameters in real time.

The index sensors include: DS18B20 sensor (temperature measurement), pH sensor, turbidity sensor, total dissolved solids (TDS), flow rate sensor and geographic location sensor.

The 4G module (A7628S) is used for communication via 4G network, ensuring monitoring capability in the absence of WiFi.

2. 1. 2. Functional requirements.

- Measure key water parameters: temperature, pH, turbidity, TDS, flow rate and location.
- Collect data using an Arduino-based microcontroller.
- Display real-time readings on a local LCD screen.
- Transmit sensor data to the Blynk mobile application via Wi-Fi (ESP8266)
- Send SMS alerts via the A7682S 4G LTE module when abnormal values are detected.

2. 1. 3. Wifi standard

The system uses the ESP8266 WiFi module, supporting the IEEE 802.11 b/g/n WiFi standard. This WiFi standard allows data transmission at speeds up to 150 Mbps in the 2.4 GHz band. This is a popular standard and is suitable for IoT applications thanks to its stable connection and good coverage in indoor and outdoor environments. In addition, this module supports security protocols such as WPA/WPA2, ensuring the safety of transmitted data.

2. 1. 4. Cellular Communication Standard (4G LTE)

The system uses the A7682S 4G LTE module for mobile communication, which complies with the 3GPP LTE standards. LTE (Long-Term Evolution) provides higher data rates, lower latency, and better coverage compared to traditional GSM based modules. The A7682S module supports a variety of frequency bands and operates on the 4G network infrastructure, allowing data to be transmitted efficiently and reliably, especially in areas without Wi-Fi connectivity. This standard ensures stable and secure data communication for sending SMS alerts and supporting remote monitoring in IoT applications.

2. 1. 5. Engineering Codes and Standards

Table 2. 1 Engineering Codes and Corresponding Standards

Element/Product/System	Engineering Standards	Comments
Electrical Safety	IEC 61140: Protection against electric shock	Ensure proper insulation and grounding in circuit design
Embedded Systems Design	IEEE 1474: Guidelines for microcontroller-based systems	Guides integration of Arduino, ESP8266, and A7682S module
Wireless Communication	IEEE 802.11 (Wi-Fi), 3GPP LTE (4G) standards	Governs ESP8266 Wi-Fi and A7682S 4G module communication
Sensor Calibration and Accuracy	ISO 15839: Water quality online sensors for water monitoring	Ensures proper setup and interpretation of pH, TDS, turbidity sensors

Environmental Data Handling	IEEE 1451: Smart sensor interface for transducers	Standardizes the way sensors communicate with the microcontroller

2. 2. Realistic constraints

Table 2. 2 Realistic Constraints

Area	Realistic Constraints
Economic	Low-cost components such as Arduino UNO, ESP8266, and basic sensors are used to reduce total cost.
Environment	The system is intended to be used in varied environmental conditions, requiring water-resistant casing and stable operation under temperature/humidity fluctuations.
Social	Provides access to water quality information for households and rural communities, improving awareness and safety.
Ethical	Accurate and reliable data collection is ensured to avoid misleading results that could affect health or environmental decisions.
Sustainability	Electrical safety measures, such as proper insulation and low-voltage design, are implemented to prevent shock or short circuits.
Health and Safety	The system consumes low power and is designed for long-term deployment with minimal maintenance.
Manufacturability	Designed with off-the-shelf, widely available components to support ease of assembly and prototyping.

CHAPTER III.

PROJECT MANAGEMENT

This chapter shows the project budget, cost management plan, project schedule and resource planning.

3. 1. Budget and Cost Management Plan.

Table 3.1 provides a description of how the project costs are managed. Provides detailed information on the costs of all components and equipment required for the project.

Table 3. 1 Table of estimated costs.

Numbers	Description	Quantity	Cost
1	Arduino UNO R3	1	99,000 VND
2	ESP8266 (Node MCU)	1	95,000 VND
3	LCD2004	1	82,000 VND
4	4G module	1	189,000 VND
6	GPS module	1	200,000 VND
7	Temperature sensor	1	20,000 VND
8	pH sensor	1	1,100,000 VND
9	Turbidity sensor	1	120,000 VND
10	Ultrasonic sensor	1	30,000 VND
11	TDS sensor	1	110,000 VND
12	Flow sensor	1	77,000 VND
13	Other component		500,000 VND
14	Other costs		1,000,000 VND
15	Total		3,622,000 VND

3. 2. Project schedule

The project progress and timeline to achieve the goals and objectives are shown in the Gantt chart below

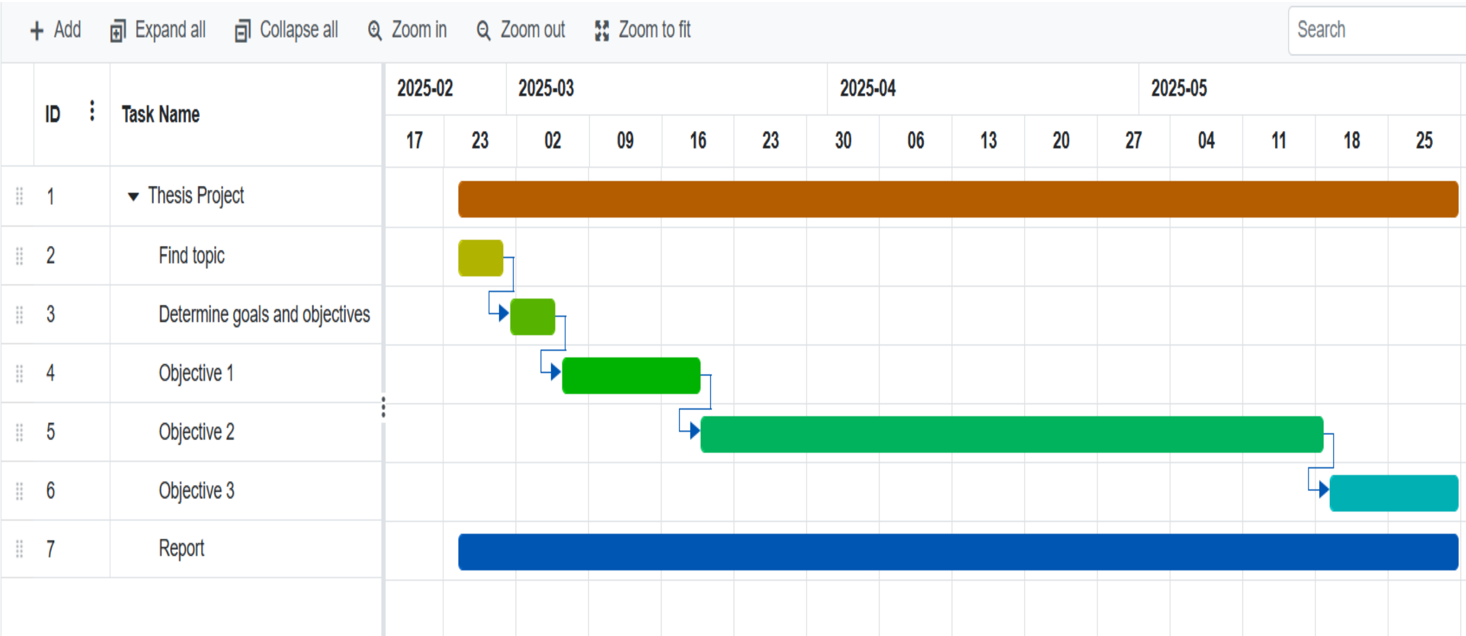

Figure 3. 1 Project schedule

3. 3. Resource Planning

Hardware resources: The system was built using low-cost components, including Arduino UNO, ESP8266, A7682S, various water quality sensors pH, turbidity, TDS, temperature, flow sensor, GPS module, and a 20x4 LCD.

Software tools: we will use the C programming language. All code will be developed on Arduino IDE software. There are main libraries we use: Wire.h, SoftwareSerial.h, OneWire.h, DallasTemperature.h, LiquidCrystal.h, ESP8266WiFi.h, TimerOne.h, BlynkSimpleEsp8266.h. Proteus was utilized for circuit simulation, and the Blynk platform was used for mobile-based monitoring

CHAPTER IV.

LITERATURE REVIEWS

Based on section **1.2.2**, the first objective is to study the existing techniques using IoT approaches to monitor water quality. To achieve this objective, we have divided the literature review into two main sections: **4.1** Existing IoT based water quality monitoring systems and **4.2** Proposed methodology to be applied in this senior project. Below are details of each part.

4. 1. Existing IoT based water quality monitoring systems.

Recently, with the advancement of IoT standard, several IoT based solutions have been introduced for water quality monitoring such as the following articles.

4. 1. 1. First article: Design & Implementation of Water Quality Monitoring & Notification System [9].

This paper presents a low-cost IoT-based solution for real-time water quality monitoring. The system uses sensors to measure pH, turbidity and temperature parameters, integrated with Arduino Mega microcontroller for data collection and processing. The results are displayed locally on the LCD screen and SMS notifications are sent via GSM module (SIM900A), helping users receive instant alerts when parameters are abnormal.

4. 1. 1. 1. Hardware.

The hardware devices used include:

- Turbidity Sensor
- Temperature sensor
- PH sensor
- Ultrasonic sensor
- Arduino Mega Board
- GSM shield module
- LCD display

4. 1. 1. 2. Block diagram and prototype of system.

Figure 4.1 shows the connection diagram of the components and Figure 4.2 is the prototype of the product.

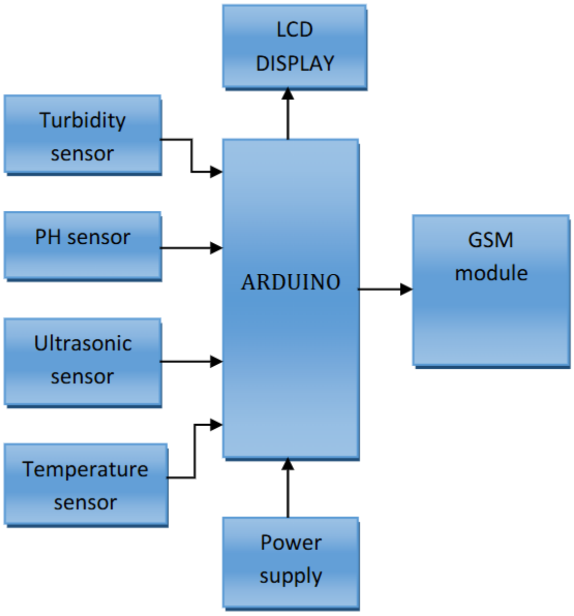

Figure 4. 1 Block diagram showing connections of all components [9]

Figure 4. 2 Prototype of water quality monitoring & notification system [9]

4. 1. 2. Second article: Design and Implementation of a Smart Water Monitoring System (IoT) Using Arduino Microcontroller [10].

This study presents a smart water monitoring system using IoT technology, focusing on real-time measurement of water quality and level. The system integrates multiple sensors, Arduino Mega microcontroller and Cayman IoT platform for data monitoring and visualization.

4. 1. 2. 1. Proposed methodology.

The overall design of the water monitoring system is shown in Figure 4.3[10].

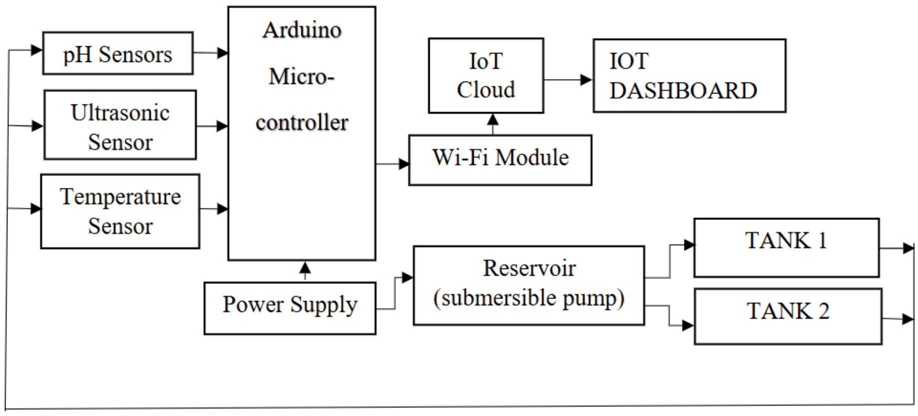

Figure 4. 3 Block diagram of the project [10]

The system consists of two tanks and a water reservoir connected, and a 5V DC pump system. Each tank is equipped with an ultrasonic sensor placed on top, which is responsible for monitoring the water level in the tank. When the water in the tank reaches the lowest level, the ultrasonic sensor will send a signal to the Arduino microcontroller to activate the pump, ensuring that water is pumped into the tank. Conversely, when the water reaches the highest level, the sensor will send a signal to turn off the pump, helping to prevent water overflow. The system operates fully automatically, ensuring effective management of the water level in the tanks.

A pH sensor is installed in the reservoir where water is pumped into the two tanks to assess safety for use. The pH value is displayed on the IoT dashboard, and if the pH is out of the neutral range (below 7 is acidic, above 7 is alkaline), the water will need to be filtered. The pH scale ranges from 0 to 14, with 7 being neutral, indicating a balance between acid and alkalinity [10]. Additionally, a temperature sensor is placed in the reservoir to measure the temperature of the water as it enters the tank, determining how hot or cold the water is.

The data collected from the sensor, including water level, pH, and temperature, is transmitted to the Cayenne myDevices IoT platform via a Wi-Fi module [10]. This platform allows for real-time analysis and visualization of values, helping users monitor and manage water quality effectively.

Figure 4.4 is a flow chart of the system's operation.

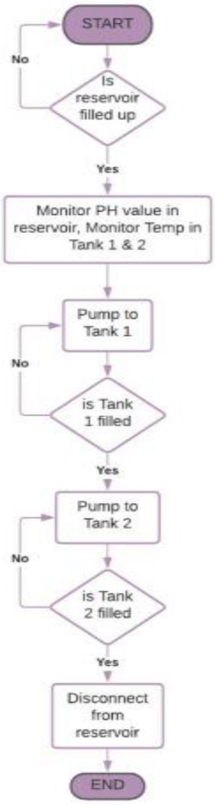

Figure 4. 4 Flow chart diagram of the project [10]

4. 1. 2. 2. Hardware.

These are the hardware devices as well as the final product developed in figure 4.5.

- Ph sensor
- Arduino mega
- Esp8266 wifi module

- Temperature sensor
- Ultrasonic sensor

Figure 4. 5 Image of the final project work [10]

4. 1. 3. Third article: Real-time Water Quality Monitoring and Notification System for Aquaculture [11]

This paper presents a water quality monitoring system that can automatically adjust four types of water quality parameters including temperature, potential hydrogen (pH) level, turbidity, and dissolved oxygen. The system uses Arduino Nano as the main controller, combined with NodeMCU (ESP8266) to transmit data via Firebase Realtime Database [11]. A mobile application is developed using React Native, supporting real-time value monitoring, receiving notifications when the indicators are out of standard, and providing appropriate action suggestions. The main purpose of the research is to develop a smart farm model using IoT to raise fish at high density in a closed system to be environmentally friendly and sustainable [11].

4. 1. 3. 1. Hardware design.

Key features include:

- Monitoring and reporting abnormal values.
- Customizing water quality thresholds.
- Displaying historical data in a visual graph.

Figure 4.6 below illustrates the conceptual framework and main components of the system and Figure 4.7 shows the main components of the hardware system.

Figure 4. 6 Conceptual Diagram of Water Quality Monitoring and Notification System [11].

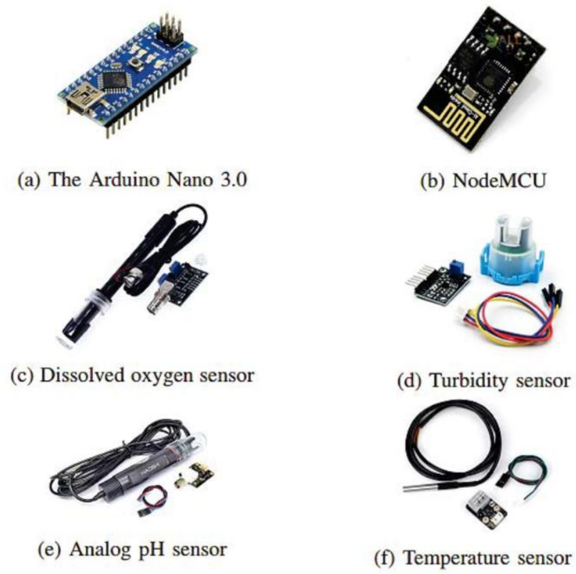

Figure 4. 7 The major components of the system ***[11]***

4. 2. Proposed methodology for this thesis

Through the studies of related documents in section **4.1**, it can be observed that many water quality monitoring systems have been developed based on IoT technology. Most of them use sensors to measure important parameters such as temperature, pH, dissolved oxygen and turbidity, combined with connection modules to transmit data in real time or over the network. The study by Katole and colleagues (section **4.1.1**) used Arduino Mega, temperature, pH, turbidity sensors, and GSM module to collect, analyze water quality data and send SMS notifications to users. This system allows real-time monitoring and alerts when parameters exceed safety thresholds. Similarly, Ogundele Joshua's research (section **4.1.2**) focused on monitoring water quality and water levels in tanks, combined with the Cayenne IoT platform to display data via an online dashboard. This research highlights the flexibility and integration of IoT in remote water monitoring, making it easy for users to check important indicators from anywhere. And Jomsuda Duangwongsa's research (section **4.1.3**) successfully implemented a system using Arduino Nano, NodeMCU (ESP8266) and Firebase Realtime Database to monitor water in aquaculture ponds, providing information directly via a mobile application. These studies are important references for developing the method in my project.

Based on the results and techniques from the above studies, this project applies pH, temperature, turbidity, total dissolved solids (TDS), flow and GPS sensors with an Arduino UNO microcontroller, displays parameters on LCD screen and transmitted via Wi-Fi using the ESP8266 module to the Blynk mobile application. Simultaneously, a 4G LTE communication module (A7682S) is employed to send SMS alerts to users when critical thresholds are exceeded. The difference is the flexible combination of two data transmission methods (WiFi and 4G), allowing the system to operate even without WiFi connection. This not only saves costs but also ensures providing real-time data and warnings when water parameters exceed thresholds.

CHAPTER V.

METHODOLOGY

Based on the goals and objectives in Chapter I and the analysis results from related studies in Chapter IV, the overall design of the water monitoring system is shown in Figure 5.1

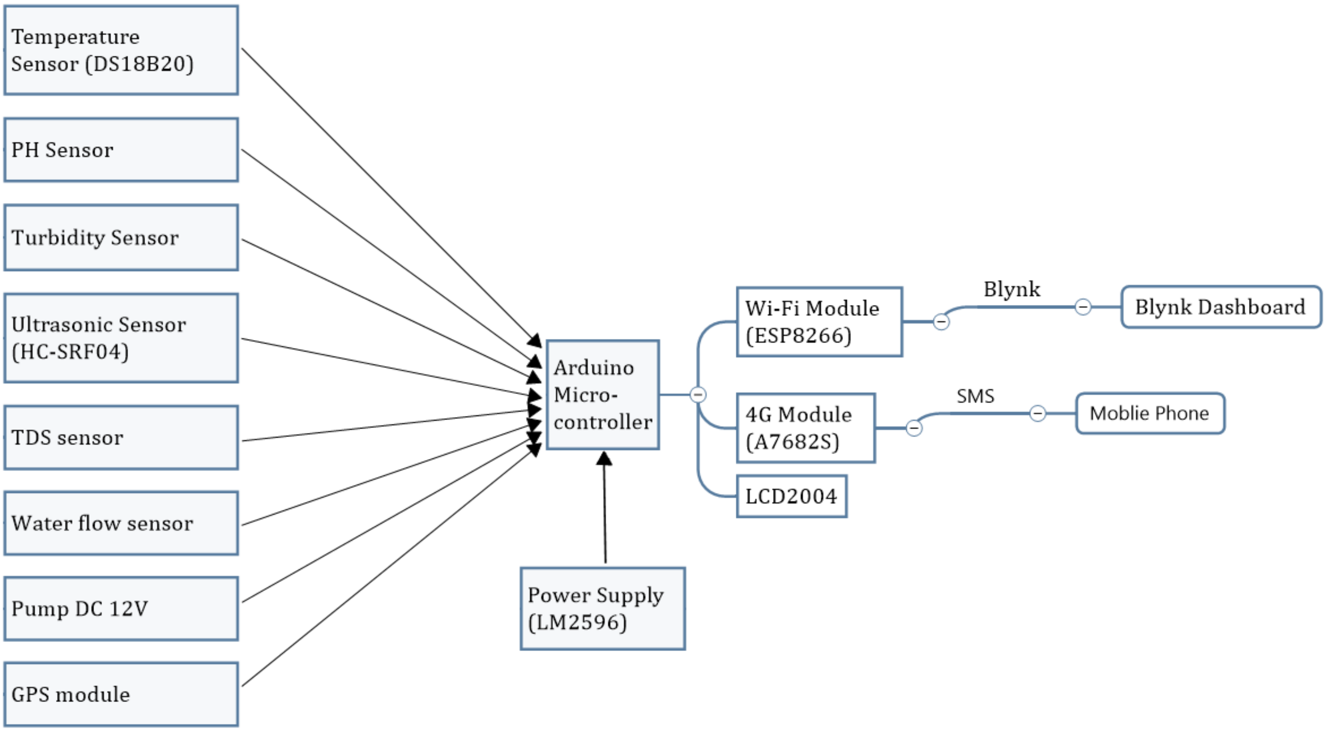

Figure 5. 1 Block diagram of the system.

The methods will be described in detail in this chapter. It is organized into four main sections:

1. Flow chart
2. Hardware design
3. Software design
4. Proposed model

5. 1. Flow chart

Figure 5.2 illustrates the flowchart of the IoT-based water resource monitoring system. The process begins with establishing connections between the Arduino UNO microcontroller, all environmental and location sensors, the ESP8266 Wi-Fi module, and the A7682S 4G LTE module via a hotspot or Wi-Fi connection. Once connections are successfully initialized, the system continuously reads water-related parameters from the following sensors:

- Temperature sensor (DS18B20): Measures the water temperature.
- pH sensor: Detects the acidity or alkalinity of the water.
- Turbidity sensor: Monitors water clarity.
- TDS sensor: Measures the total dissolved solids concentration.
- Flow sensor: Calculates the water flow rate during pumping.
- Ultrasonic sensor (SRF04): Estimates the water level inside the container.
- GPS module: Provides real-time geographical location of the monitoring unit.

The collected analog or digital signals are processed by the Arduino UNO. The sensor readings are then:

- Displayed on a 20x4 I2C LCD for local on-site observation.
- Transmitted to the ESP8266 module and forwarded to the Blynk Cloud for real-time monitoring via a mobile application.

If any measured parameter exceeds its predefined threshold, a warning is triggered in the Blynk interface by activating a red virtual LED. Simultaneously, an SMS alert is sent via the A7682S 4G LTE module to a predefined phone number to notify the user about the abnormal condition.

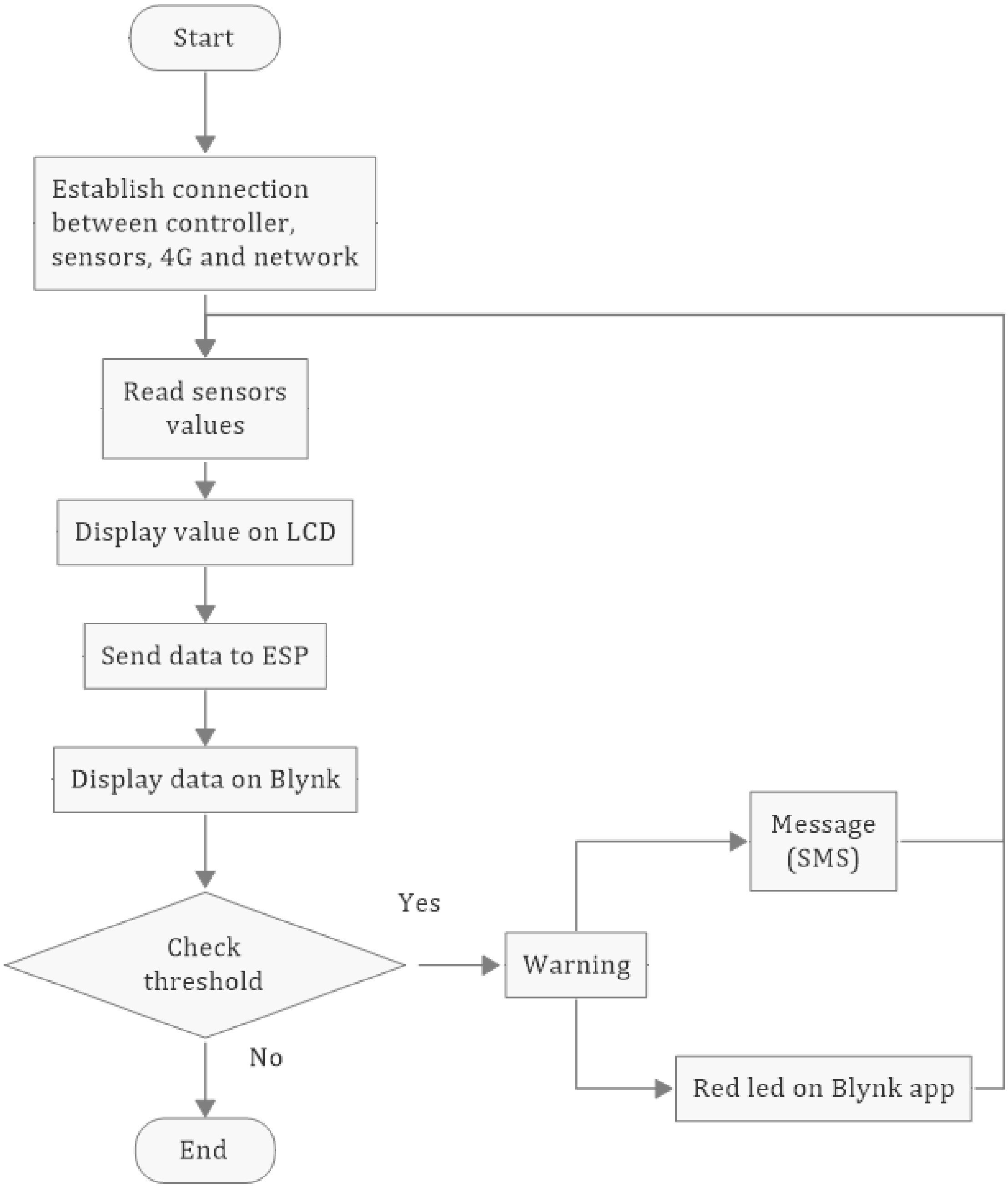

Figure 5. 2 System flowchart of the IoT-Based Water Resource Monitoring System

5. 2. Hardware design

The components used in this system are explained as follows.

5. 2. 1. Temperature sensor

The Dallas temperature sensor shown in Figure 5.3 is a 1-wire programmable temperature sensor and measures temperature in the range of -55°C to +125°C with an accuracy of ±0.5°C [9]. The sensor has a durable, waterproof design, suitable for harsh environments such as chemical fluids or soil. The DS18B20 only needs one data pin of the microcontroller, in the system connected to pin 12 of Arduino UNO via 1-Wire protocol, Arduino collects temperature data from DS18B20 using the **OneWire.h** and **DallasTemperature.h** libraries.

Figure 5. 3 Dallas temperature sensor (DS18B20)

5. 2. 2. pH sensor.

pH (potential Hydrogen) is the acidity or alkalinity of water. The pH sensor module in figure 5.4 consists of pH sensor also called as pH probe and a signal conditioning board which gives an output which is proportional to the pH value and can be interfaced directly to any microcontroller [11].

Figure 5. 4 Analog PH sensor

Technical parameters of pH sensor module E-201C is shown in Table 5.1.

Table 5. 1 Technical parameters of pH sensor [13]

Numbers	Parameters	Values
1	Power supply	5VDC
2	Working current	5 ~ 10mA
3	Power consumption	<0.5W
4	Return signal	Analog
5	PH measurement range	0 - 14 pH
6	Response time	≤ 5 seconds
7	Stabilization time	≤ 60 seconds
8	Accuracy	±0.1 pH (at 25°C)
9	Working temperature range	0°C – 60°C (best at 20°C)
10	Working humidity range	0% – 95% (best at 60%)
11	Response speed	< 1 minute
12	Weight	25g

The analog signal is connected to the **A0** pin of Arduino UNO. pH value ranges from 0-14, with 0 – 6 as acidic and 8 – 14 as alkaline. Acidic water tastes sour, while alkaline water tastes bitter or soap [12].

5. 2. 3. Turbidity Sensor

Turbidity is the darkness or opacity of water due to the presence of many microscopic particles in the water that are invisible to the naked eye, like smoke in the air [9]. The turbidity sensor in figure 5.5 can detect water quality by measuring the level of turbidity/opacity in the water. It can detect suspended particles in water by measuring the scattering rate and transmittance, which vary with the amount of total suspended solids in the water. As the total suspended solids increase, the turbidity of the liquid also increases. The scale used by this sensor is Nephelometric Turbidity Units (NTU). In this system, the turbidity sensor outputs an analog voltage that is proportional to the water's turbidity level. The analog signal is connected to the **A2** pin of Arduino UNO, where it is read and processed.

Figure 5. 5 Turbidity sensor.

5. 2. 4. TDS sensor (Total Dissolved Solids)

The TDS sensor shown in Figure 5.6 measures the concentration of total dissolved solids in water, with the unit expressed in parts per million (ppm). TDS represents the number of milligrams of dissolved solids present in one liter of water. The higher the TDS value, the greater the concentration of dissolved substances, corresponding to the lower purity of the water. The sensor connects to the Arduino's **A1** analog pin and is processed in real time along with other sensor data.

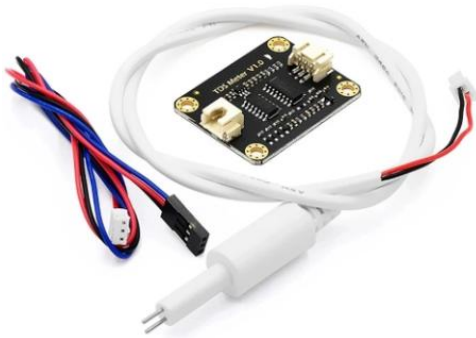

Figure 5. 6 TDS sensor

To better understand the implications of TDS levels on water quality, the figure 5.7 below provides a classification range:

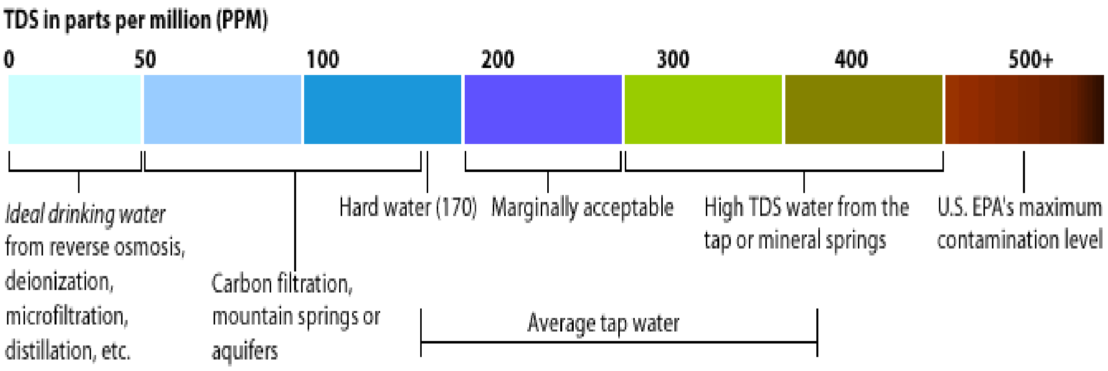

Figure 5. 7 Classification of TDS levels in water (ppm) [14]

- 0 – 100 ppm: ideal drinking water, water safe for human.
- 100 – 400 ppm: water for domestic use only
- Above 500 ppm: polluted water, absolutely do not use

5. 2. 5. Ultrasonic sensor.

The ultrasonic sensor, as shown in figure 5.8 measures distance by transmitting ultrasonic waves and receiving the reflected waves from the target surface. In this system, the sensor is used to monitor the water level in the tank, determining whether it is empty or full. The sensor works by calculating the time taken for the ultrasonic waves to travel to the water surface and return, which is then converted into distance using the speed of sound.

The ultrasonic sensor is connected to the Arduino UNO with two pins:

Trigger pin: Sends out the ultrasonic signal (Pin 4 of Arduino UNO)

Echo pin: Receives the reflected signal (Pin 5 of Arduino UNO)

Figure 5. 8 Ultrasonic sensor (HC-SRF04).

5. 2. 6. Flow Sensor and DC pump

In this system, the water flow sensor employed is a hall sensor type (Figure 5.9), widely used in both residential and industrial applications due to its durability and reliable measurement capability. The sensor typically consists of three main components: a water inlet valve, a turbine-style rotor, and a hall magnetic sensor positioned near the rotor.

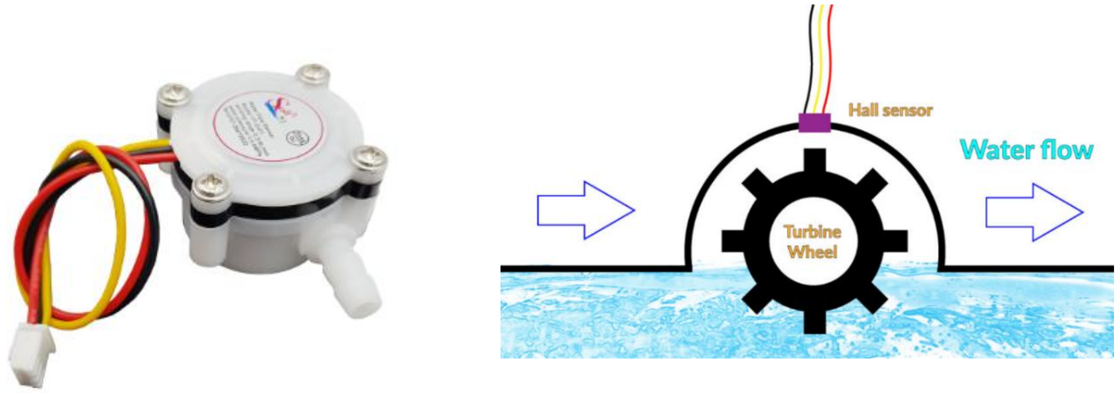

Figure 5. 9 YF-S401 sensor

When water passes through the valve, the water flow rotates the rotor, generating electrical pulses through the change in magnetic field at the Hall sensor location. The higher the flow rate, the higher the frequency of the pulses. These electrical pulses are sent to pin 2 of the Arduino.

In addition to the flow sensor, the system also integrates a pump motor with a pumping capacity of 1.5 liters to 2 liters of water per minute operating with a voltage of 12V DC (Figure 5.10), which is connected to digital pin 9 on the Arduino. The pump can be remotely switched on or off via the Blynk application by sending control commands over the serial interface from ESP8266 to the Arduino. Specifically:

Sending the character '1' turns the pump on.

Sending the character '2' turns the pump off.

Figure 5. 10 Pump motor 385 12V DC

5. 2. 7. Wifi module.

The ESP8266 Wi-Fi Module, as shown in figure 5.11, is a self-contained system-on-chip (SoC) with an integrated TCP/IP protocol stack, enabling any microcontroller to connect to a Wi-Fi network. In this system, the ESP8266 is connected to the Arduino UNO via serial communication (TX/RX pins). Once the Internet connection is established, the module transmits data, including temperature, pH, and turbidity values, to the Blynk Cloud platform for remote monitoring.

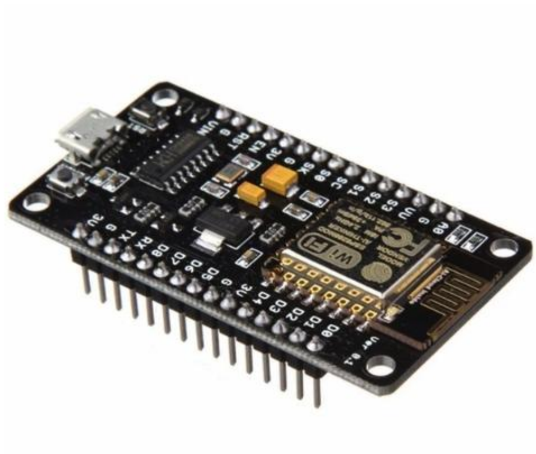

Figure 5. 11 The ESP8266 Wi-Fi module.

5. 2. 8. 4G module.

The 4G module, as shown in figure 5.12, is used to provide cellular communication capabilities for the system. It allows Arduino UNO to send and receive SMS alerts using the 4G network. In this system, A7682S is used to connect to Arduino UNO via serial communication (TX/RX pin).

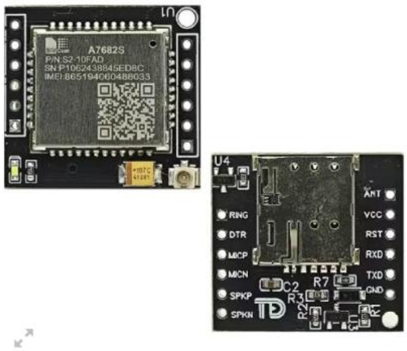

Figure 5. 12 A7682S module.

When the measured parameters such as temperature, pH, turbidity, distance and TDS exceed the pre-defined threshold value, the module will send an SMS alert to a designated phone number, ensuring that the user receives timely warnings about abnormal water quality conditions.

The A7682S 4G LTE module used in this system is compatible with all major mobile network providers in Vietnam, including Viettel, Vinaphone, and Mobifone. The module requires a stable power supply of 3.8V to 4.2V for normal operation, which is achieved through the DC-DC converter in the circuit.

5. 2. 9. GPS module

The GPS module in figure 5.13 provides the real-time location of the monitoring station. It communicates with the ESP8266 via UART and is used to display longitude and latitude on the Blynk dashboard.

Figure 5. 13. GPS Module

5. 2. 10. Power Supply.

The power supply module provides the necessary voltage and current to operate the entire system. In this system, a DC-DC converter (LM2596) in Figure 5.14 is used to step down the voltage from a 12V power source to 5V, ensuring compatibility with the components.

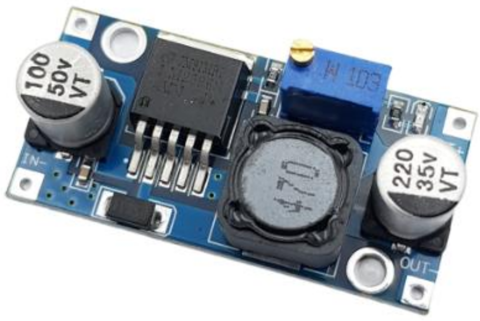

Figure 5. 14 DC Voltage Reduction Circuit LM2596.

5. 3. Software design.

5. 3. 1. Drawing the schematic.

From the components in section 5.2, figure 5.15 is the circuit diagram of the system drawn on proteus software.

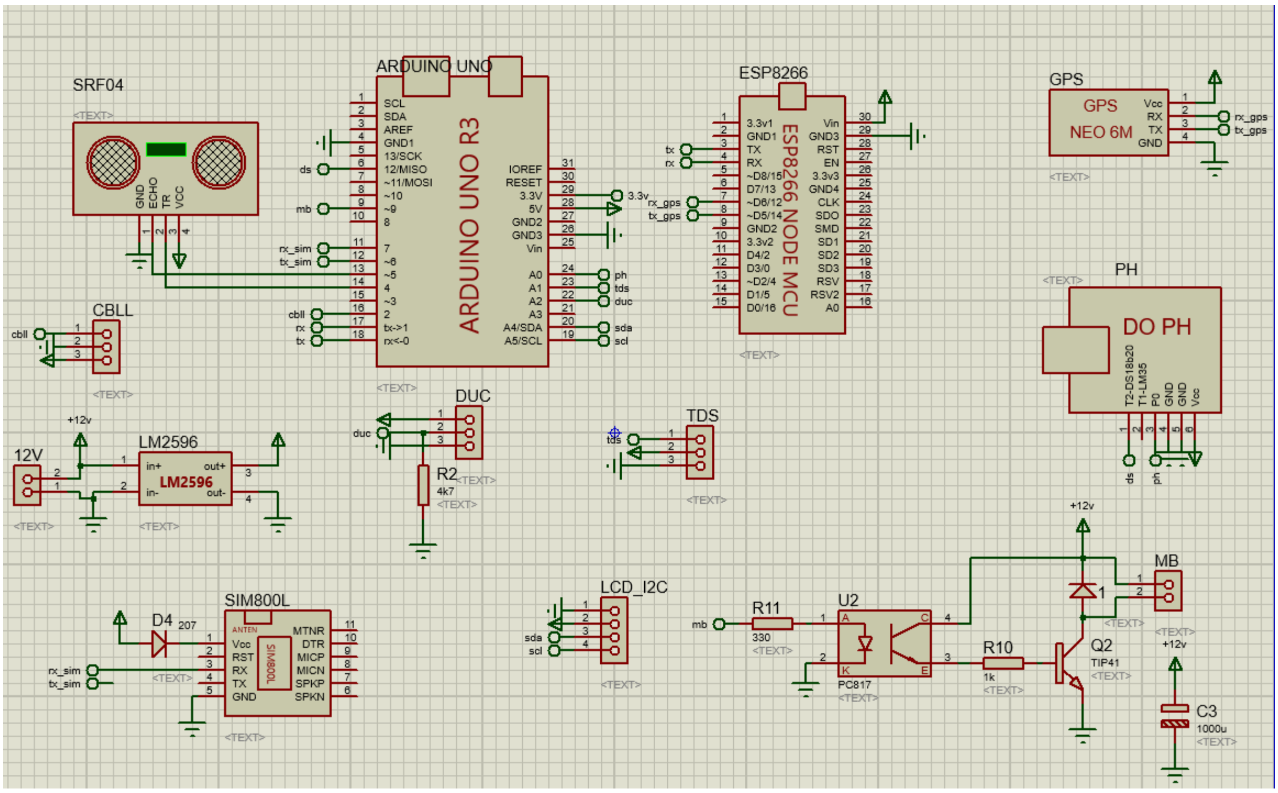

Figure 5. 15 Schematic of the system on Proteus software.

5. 3. 2. Blynk.

Blynk is an IoT platform that enables users to create custom mobile dashboards for monitoring and controlling hardware systems via IOS and Android devices. After downloading the Blynk application, users can design a virtual interface using various widgets such as buttons, sliders, and gauges. These widgets interact with the hardware through virtual pins, allowing for real time data display and control. In this project, the Blynk app is used to display real time sensor data collected from the water monitoring system. The following parameters are visualized:

- Temperature, measured by the DS18B20 sensor.
- pH level, measured by the analog pH sensor.
- Turbidity, indicating water clarity, measured by the turbidity sensor.
- Water level measured using the ultrasonic sensor (SRF04).
- Total dissolved solids (TDS), indicating water quality in ppm.
- Flow rate, calculated from the pulse-based flow sensor.
- Geographic location, obtained from the GPS module.

These values are sent from the ESP8266 Wi-Fi module to the Blynk cloud and then retrieved by the app for live display.

CHAPTER VI.

EXPECTED RESULTS

In this chapter, we will show the results of this project.

6. 1. Results

6. 1. 1. Hardware design.

Figure 6.1 is the complete hardware design for an IoT-based applications for water resource monitoring system, including main components such as sensors and the placement of components detailed on the circuit board below.

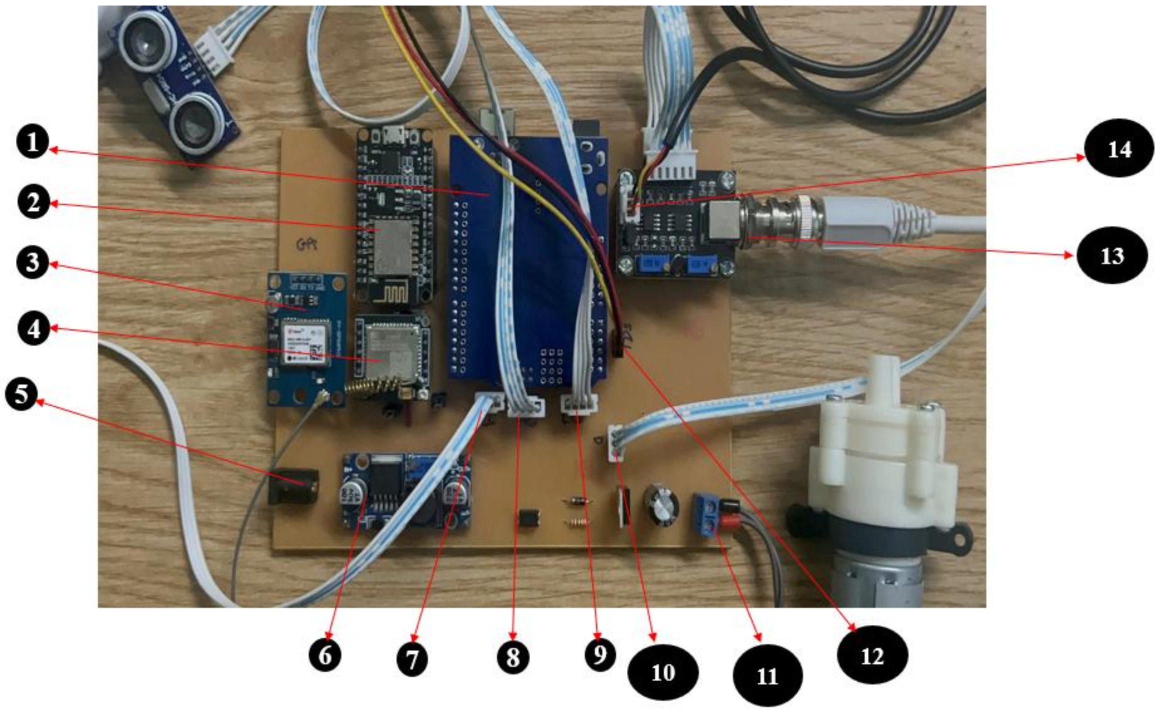

Figure 6. 1. Hardware system.

1. Arduino UNO R3
2. Wifi module (ESP8266)
3. GPS module
4. 4G module (A7862S)
5. Power jack
6. DC-DC converter (LM2596)

7. Flow sensor

8. Ultrasonic sensor (HC-SRF04)

9. LCD display

10. Turbidity sensor

11. Pump

12. TDS sensor

13. pH sensor

14. Temperature sensor (DS18B20)

6. 1. 2. Software design.

6. 1. 2. 1. Blynk app.

Figure 6.2 shows the Blynk interface on a smartphone, displaying the measured parameters such as pH, temperature, water level turbidity, TDS and water flow. The longitude and latitude are read from the GPS module and a pump control switch. These values are updated in real time via a Wi-Fi connection. In addition, an alarm is also triggered when the parameters exceed the safety threshold, indicated by a red LED on the control panel.

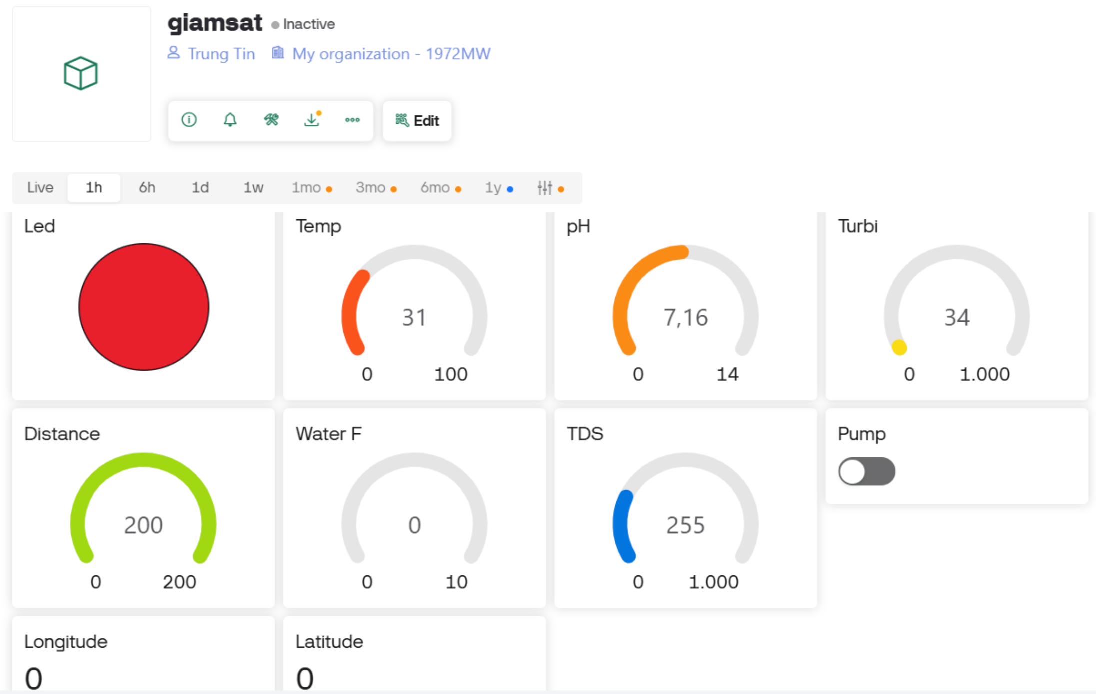

Figure 6. 2 Blynk application interface on smartphone.

6. 1. 2. 2. System boot.

When the system starts, the LCD screen will display the message "INIT SIM... PLEASE WAIT..." (Figure 6.3) to signal that the system is checking and initializing the connection with the 4G module.

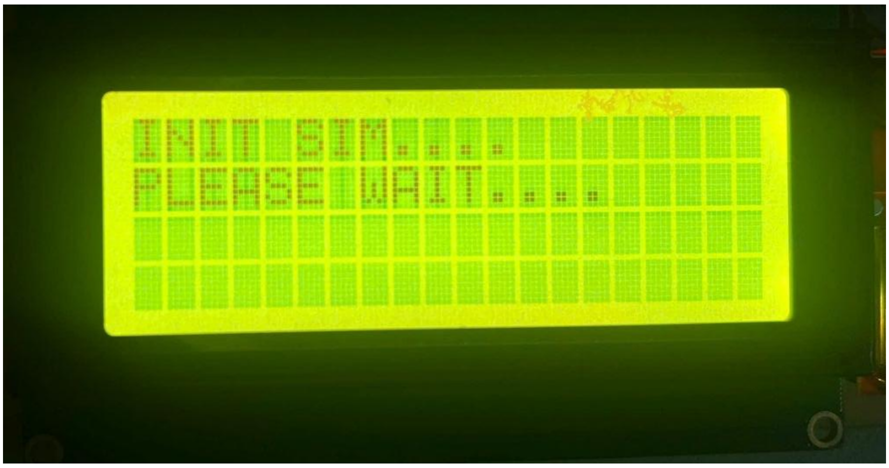

Figure 6. 3 LCD display

If the connection is successful, the flashlight on the 4G module will blink as shown in Figure 6.4.

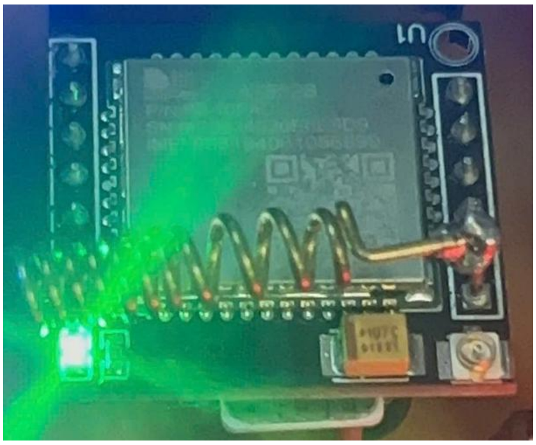

Figure 6. 4 4G module in operating state.

And a message “START SUCCESSFUL” will be sent to the predetermined phone number, along with the parameters measured from the sensors at that time as in Figure 6.5.

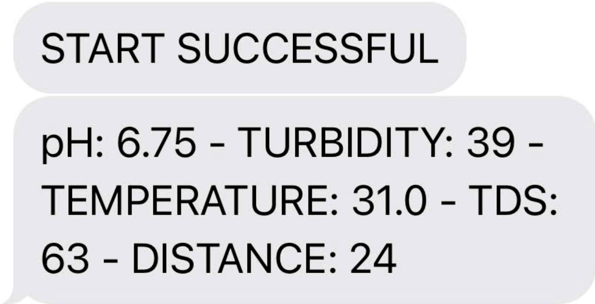

Figure 6. 5 SIM connection success notification and sensor data.

For Wi-Fi network connection, the ESP8266 module plays a role in ensuring the connection between the system and the Blynk application. When the ESP8266 module successfully connects to the Wi-Fi network and the Blynk application on the phone, the light on the module will light up, indicating the operating status as in Figure 6.6.

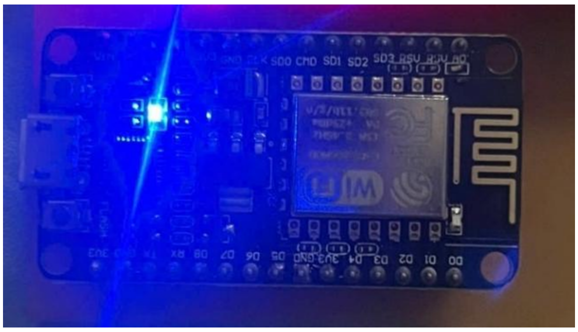

Figure 6. 6 ESP8266 module successfully connects to the Wi-Fi network.

For the 4G module, when the antenna captures the coordinates, the flash light on the module will blink as shown in Figure 6.7.

Figure 6. 7 GPS module connected successfully

At the same time, the latitude and longitude are also sent to the blink app and a google link is displayed on the terminal as shown in Figure 6.8.

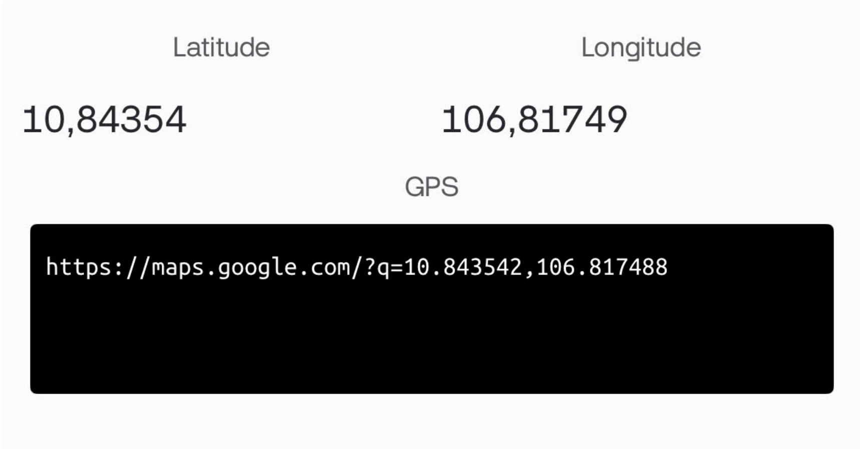

Figure 6. 8 Real time GPS coordinates and location link displayed on Blynk app

When clicking on the link and selecting show on map, it will automatically switch to google map and show the location where the system is located. This is illustrated in Figure 6.9

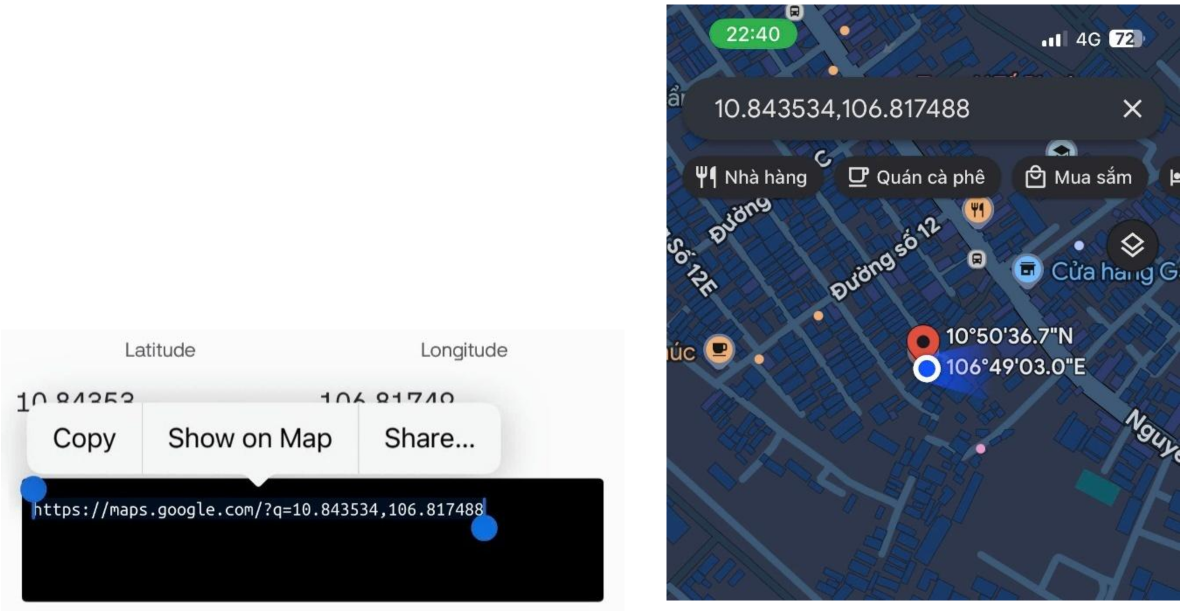

Figure 6. 9 GPS link from blynk app and location on google maps

At that time, the Blynk application will start receiving and directly displaying parameters from the sensors, including pH, temperature, turbidity, TDS, water level and water flow (Figure 6.10).

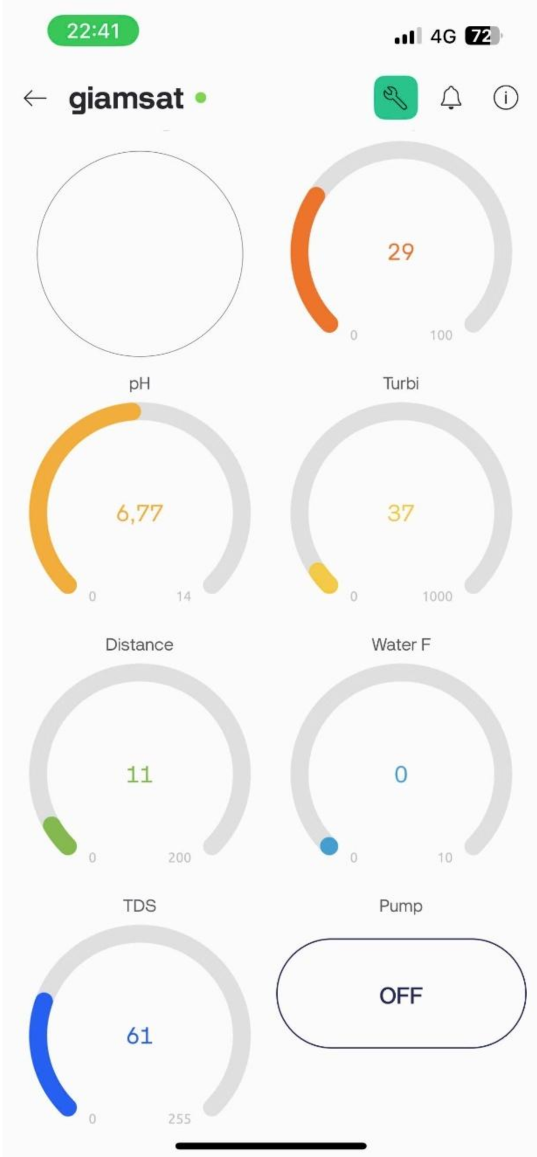

Figure 6. 10 Blynk application interface displaying sensor parameters.

6. 1. 3. Evaluate the system performance in different environments.

The water quality monitoring system was tested in different environments to evaluate the accuracy of the sensors measuring pH, temperature, turbidity and water level. Among the measured parameters, pH is the most important, to create a neutral, acidic, basic water environment. I used a pH correcting powder, as shown in Figure 6.11.

Figure 6. 11 pH correction package.

With pH parameters provided by the manufacturer as shown in table 6.1

Table 6. 1 pH correction package specifications

°C	pH4.01	pH6.86	pH9.18
10	4.00	6.92	9.33
15	4.00	6.90	9.28
20	4.00	6.88	9.23
25	4.01	6.86	9.18
30	4.01	6.85	9.14
35	4.02	6.84	9.10
40	4.03	6.84	9.07
45	4.04	6.83	9.04
50	4.06	6.83	9.02

To check the accuracy of the system after calibration, I conducted tests in three specific cases, corresponding to three different environments:

- Acidic environment: pH about 4.
- Neutral environment: pH about 6.
- Basic environment: pH about 9.

6. 1. 3. 1. Case 1: Acidic environment: pH about 4.

In the first scenario, water with a low pH (around 4) was tested. The system measured a value of 4.02, which matched the results from the litmus test, confirming the accuracy of the sensor, as shown in the figures below.

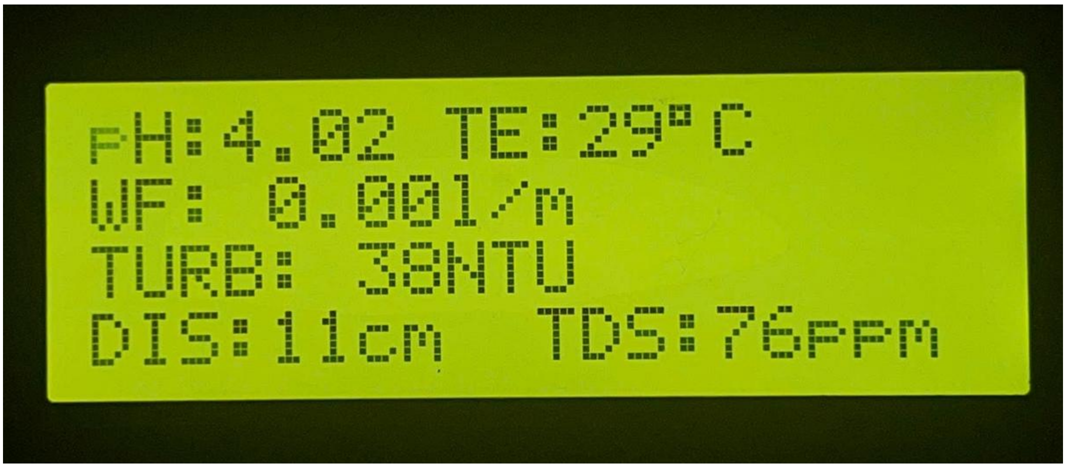

Figure 6. 12 Hardware system when operating with low pH water samples.

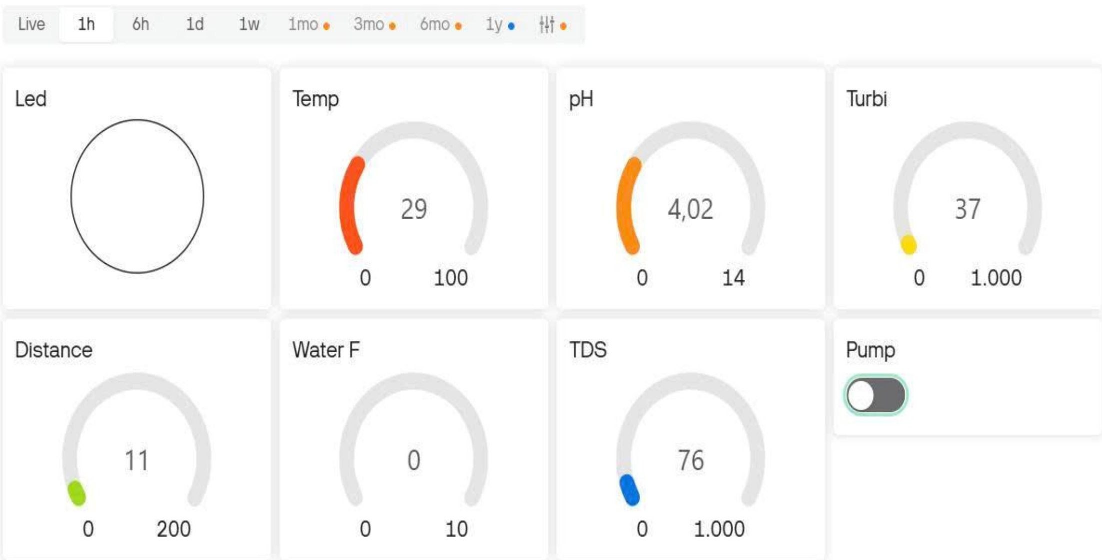

Figure 6. 13 Blynk interface shows pH measurement result is 4.02 with other indicators

Figure 6. 14 The litmus test results showed that the pH was at 4.

6. 1. 3. 2. Case 2: Neutral environment: pH about 6.

In the second case, water with a neutral pH (around 6.) was measured and the value returned from the system was 6.96, which is close to the litmus test result, confirming the accuracy of the sensor as:

Figure 6. 15 Hardware system when operating with pH = 6.96 water samples.

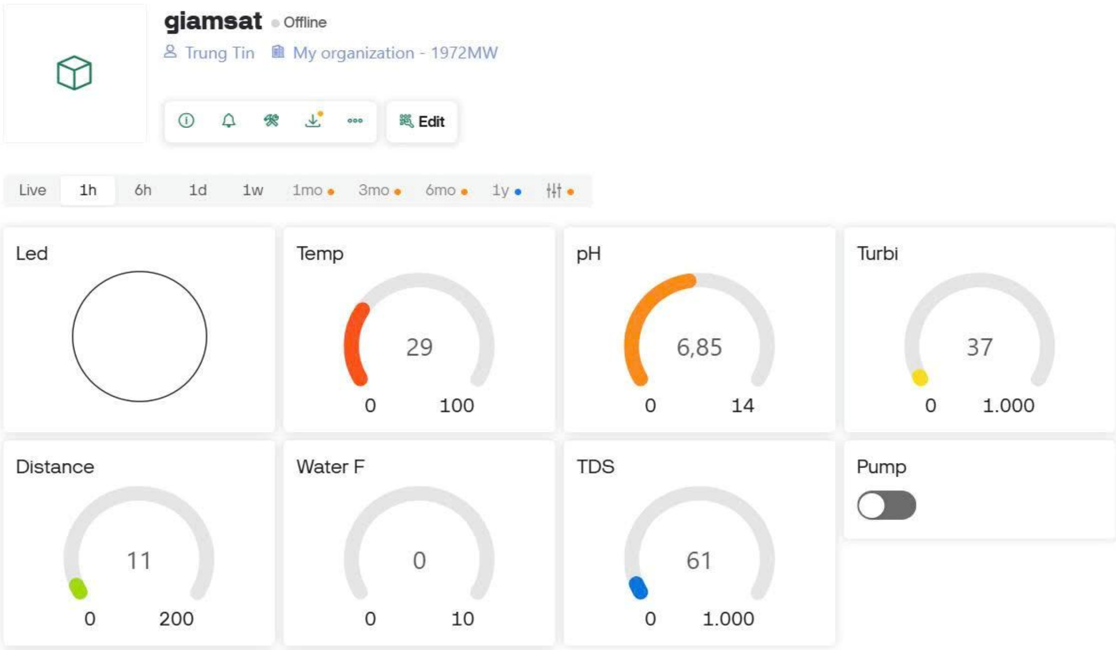

Figure 6. 16 Blynk interface shows pH measurement result is 6.85 with other indicators

Figure 6. 17 The litmus test results showed that the pH was at 6

6. 1. 3. 3. Case 3: Basic environment: pH about 9.

In the third test, water with a high pH (above 9) was measured and the value returned from the system was, which is close to the litmus test result. Illustrative image of the test:

Figure 6. 18 Hardware system when operating with high pH water samples

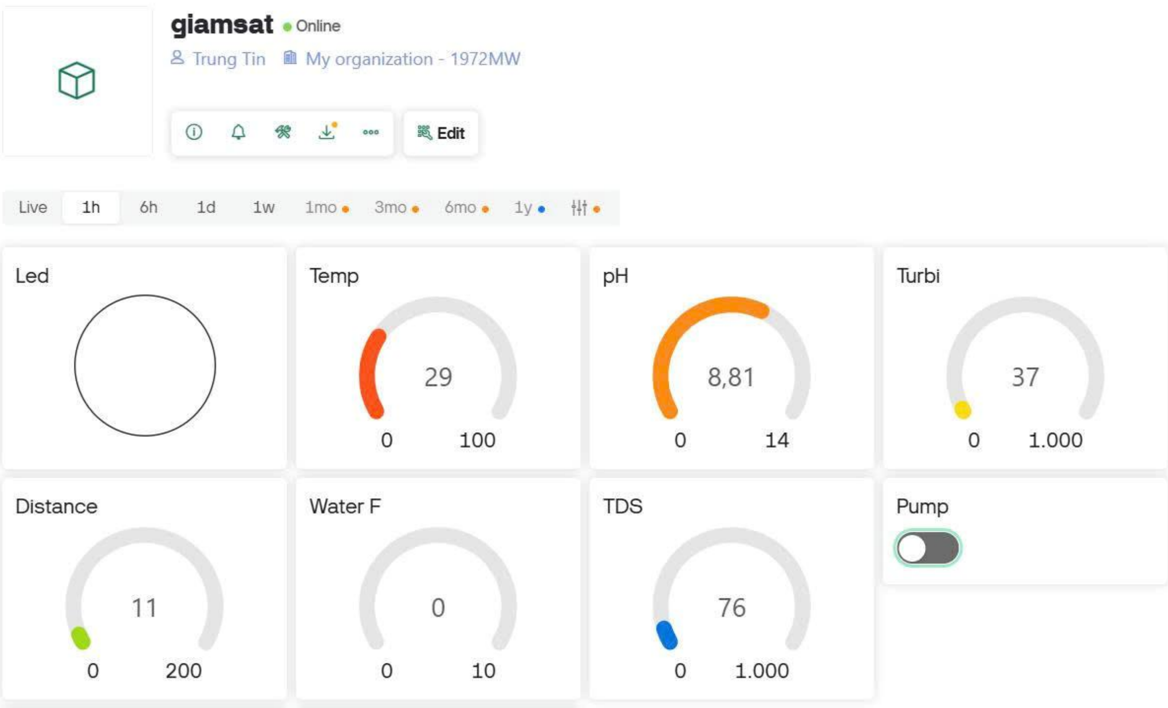

Figure 6. 19 Blynk interface shows pH measurement result is 8.81 with other indicators

Figure 6. 20 The litmus test results showed that the pH was at 10

6. 1. 4. Flow rate measurement results

To calculate the water flow in liters per minute (l/m), the formula used in the program is as follows

$$\text{water flow} = \frac{\text{x} \times 60}{\text{encoder}}$$

where

- Water flow is the water flow in liters/minute (l/m)
- x is the number of pulses measured in 1 second
- 60 is the conversion factor from seconds to minutes (1 minute = 60 seconds)
- Encoder is the number of pulses corresponding to 1 liter of water

The encoder coefficient is calculated according to the following process. The system uses a 385 12VDC pump motor and a YF-S401 sensor as in section **5.2.6**, using an additional 8mm water pipe and a 1-liter water measuring bottle. Count the pulses for 1 liter of water: let the pump operate and the flow sensor will start counting pulses until the bottle has enough 1 liter of water, then stop. Doing this 10 times in a row, we ontain the results in Table 6.2.

Table 6. 2 Number of pulses measured per liter in 10 calibration runs

Number of measurements	Pulses/liter results
1	2418
2	2299
3	2398
4	2340
5	2420
6	2425
7	2433
8	2361
9	2381
10	2345

Encoder average value = 2382 pulses/l

Using the encoder coefficient in the actual water quality monitoring system, the system pumps water for 1 minute and the result on the LCD display is 1.86 l/m in figure 6.21 That means in 1 minute the system has pumped 1.86 liters of water. The result is almost exactly the same as the capacity of the 385 pump motor.

Figure 6. 21 LCD display with WF = 1.86 l/m

6. 1. 5. Warning system test results.

About SMS alert system and red LED alert on blynk app illustrated in two cases below are turbidity and distance

6. 1. 5. 1. Turbidity warning exceeds 500 NTU

When the turbidity value exceeds the warning threshold exceeds 500 NTU (689 NTU), the warning LED turns red (figure 6.22) to attract attention.

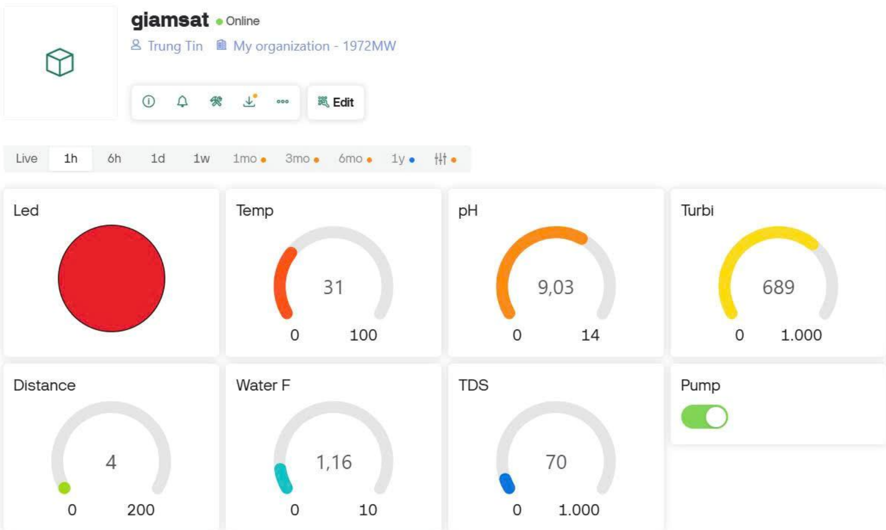

Figure 6. 22 Turbidity alert on Blynk

Warning sent via SMS using 4G module with turbidity value: 619 NTU in Figure 6.23

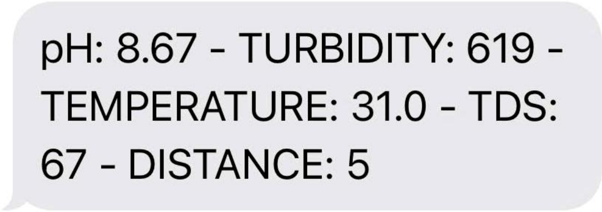

Figure 6. 23 SMS alert with turbidity: 619 NTU

6. 1. 5. 2. Distance warning exceeds 60

When the distance value exceeds the warning threshold exceeds 60 (200), the warning LED turns red (figure 6.24) to attract attention.

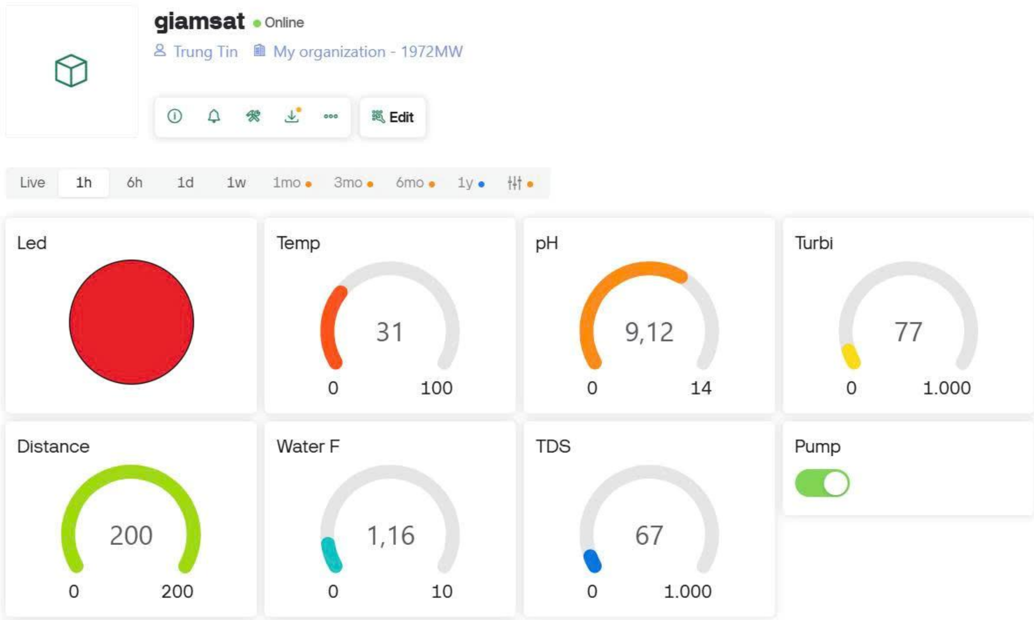

Figure 6. 24 Distance alert on Blynk

Warning sent via sms using 4G module with distance value: 200 in figure 6.2.

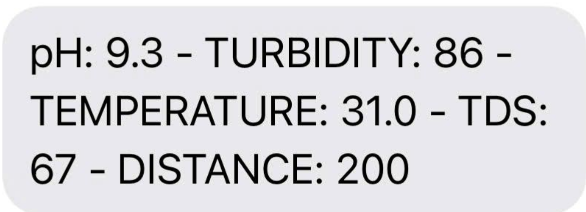

Figure 6. 25 SMS alert with distance: 200.

6. 2. QR code for test data archive

Figure 6.26 shows the QR code leading to the Google Drive folder containing images and videos of the entire testing process in Chapter VI.

Figure 6. 26 QR Code leading to thesis results folder

6. 3. Discussions

The above results demonstrate the stability of the system. The measured parameters including temperature, pH, turbidity, TDS, water level, flow rate and GPS location are continuously transmitted and displayed in real time on the Blynk application. For example, the pH measured for the environment is approximately the same as the pH calibration package. The TDS values range from 50 to 600 ppm, indicating the water hardness in each environment, supported by the classification in Figure 5.7. The temperature reading, recorded at 29 to 33 °C, is typical for ambient water under normal conditions. The system also effectively triggered alerts through the Blynk virtual LED and SMS messages when thresholds were exceeded. For instance, when turbidity surpassed 100 NTU, the dashboard displayed a red LED and a message was sent via the A7682S 4G LTE module, showing that the warning mechanism was functional and responsive.

Compared to the previous studies referenced in Chapter IV, this system offers several improvements: integration of more sensors (including GPS and TDS), dual communication methods (Wi-Fi and 4G) and integrated real time control via mobile application. Particularly the replacement with 4G module when the system of Kavita Katole, Yashoj Narnaware [9] section 4.1.1 uses 2G sim module which is completely cut off in Vietnam. The ability to monitor flow through pulse-based sensors has added an additional layer of understanding to detect abnormal water usage.

CHAPTER VII.

CONCLUSIONS AND FUTURE WORK

7. 1. Conclusions.

During this senior project, I have gained extensive knowledge and practical experience in developing an IoT-based water quality monitoring system. This includes learning about integrating sensors such as DS18B20 (temperature sensor), pH sensor, turbidity sensor, and ultrasonic sensor with Arduino UNO microcontroller. We also developed skills in using ESP8266 and GSM module for wireless communication and data transmission.

Furthermore, this project also provided me with practical experience in circuit design, as well as practical techniques in assembling and testing hardware systems. I have also improved my skills in working with Blynk IoT platform to create a user-friendly interface for remote monitoring and management.

Although the current system is stable, there are still parts that need to be optimized and improved. In the future, I will improve the efficiency of the system, expand the monitoring capabilities by adding more sensors, and improve the reliability of communication channels to ensure seamless operation in various environments.

7. 2. Future work.

An IoT-based water quality monitoring system has been successfully developed to measure parameters such as temperature, pH, turbidity, and water level. While the current system meets the main goals of real-time monitoring and remote access, there are still limitations that need to be addressed. For example, the system's reliance on Wi-Fi to transmit data to the cloud can be problematic in areas with unstable Internet connections. The accuracy of some sensors could be further optimized to be able to identify clean, polluted, or highly polluted water.

In the future, to expand the system for broader applications such as aquaculture monitoring and household water safety, I would like to see some improvements. First, improving the accuracy and stability of the main sensors, especially for pH, turbidity and TDS, would allow the system to better classify water conditions as clean, polluted or highly polluted. Second, integrating additional sensors such as dissolved oxygen and salinity sensors, to provide a more comprehensive assessment of water quality. This classification is essential for both aquatic health and public safety. Finally, another potential improvement involves applying AI-based analytics to predict water quality and provide proactive alerts, ensuring timely intervention.

CHAPTER VIII.

BUSINESS, SOCIAL AND ETHICAL CONSIDERATIONS

8. 1. Business considerations

The proposed IoT-based water quality monitoring system demonstrates strong potential for real-world application in various business sectors, particularly in environmental services, agriculture, aquaculture, and rural infrastructure development. Its relatively low cost, modular design, and ability to provide real-time data make it feasible for commercialization, especially in markets that require scalable and affordable monitoring solutions.

8. 2. Social considerations

This system is useful in daily life, especially in rural or low-income areas where people rely on wells, rainwater or rivers for their daily water use. The system helps detect unsafe water sources early and alerts users when water quality is poor, helping to protect health and prevent diseases. In fish or shrimp farming, the system can monitor water conditions such as pH, turbidity and temperature, and alert farmers when the values are out of range, increasing productivity. Because it uses simple components and works with mobile phones, the system is easy to use, low cost and suitable for many different places. The system supports access to clean water and helps people take good care of their water resources and the environment.

8. 3. Ethical considerations

This project did not involve any people or animals in testing, and no personal information was collected. The hardware and software used are open-source and safe for learning and development. In the future, if the system is used in communities or public areas, it is important to use the data carefully. People should know how the data is used, and alerts must be clear and correct to avoid confusion. The system should always be used to help imp

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APPENDICES