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IoT Based Smart Tank for Water Monitoring and Management

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In Front of the Juries

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DEDICATION

We dedicate this work :

To our dear parents, whose encouragement, sacrifices and support have fueled our aspirations and instilled in us an unyielding determination to pursue knowledge, and we are eternally grateful for the countless opportunities they have provided for us.

To our family members for always being here for muse and for always supporting us.

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Fadlaoui Takieddine
Abdeddaim Adib
Chicha Ayoub

ACRONYMS

IoT: Internet of Things

MCU: Micro-controller Unit

PCB: Printed circuit board

TCP: Transmission control protocol

UDP: User data-gram protocol

IP: Internet Protocol

PC: Personal Computer

IDE: Integrated Development Environment

API: Application programming interface

LAN: Local area network

WAN: Wide area network

WLAN: Wireless local area network

CPU: Central processing unit

RAM: Random access memory

IaaS: Infrastructure as a Service

PaaS: Platform as a Service

SaaS: Software as a Service

GPIO: General purpose Input/Output

RF: Radio frequency

RFID: Radio frequency identification

UI: User interface

SPI: Serial Peripheral Interface

IC: Integrated circuit

I2C: Inter-Integrated Circuit

UART: Universal Asynchronous Receiver-Transmitter

ML: Machine learning

GUI: Graphical user interface

AC: Alternating current

DC: Direct current

ADC: Analog to digital converter

DAC: Digital to analog converter

PWM: Pulse width modulation

HVAC: Heating, Ventilation, Air-conditioning

UML: Unified modeling language

DEFINITIONS

Sensor: a device or component that detects and responds to physical inputs from the surrounding environment. It is used to measure various physical quantities such as temperature, pressure, light, sound, motion, proximity, and many others.
Sensors convert these physical inputs into electrical signals that can be processed and analyzed by electronic systems or computer programs.

Cloud: a network of remote servers hosted on the internet that are used to store, manage, and process data and applications. The cloud provides various computing resources and services, such as storage, computing power, databases, software applications, and networking capabilities.
Cloud computing allows users to access and utilize these resources on-demand, without the need for local infrastructure or hardware. Instead of running software or storing data on local computers or servers, users can leverage the cloud infrastructure to access and manage their applications and data remotely.

Network: a collection of interconnected devices (computers, servers, routers, etc.) also knows as nodes, that can communicate and share resources with each other. These devices are connected through physical or wireless connections, forming a network infrastructure.

Edge Devices: a set of computing devices that are located at or near the edge of a network or system. These devices are typically situated close to the source of data generation or where data is consumed, rather than in a centralized or cloud-based infrastructure.

Internet: a global network of interconnected computers and other devices that allows communication and the exchange of information across vast distances. It is a decentralized network that connects millions of devices worldwide, enabling them to share data, resources, and services.

Hardware: Hardware refers to the physical components of a computer system or electronic device. It includes all the tangible and visible parts that you can touch and interact with.

Software: Software refers to the programs, data, and instructions that tell the computer what to do. It is a collection of electronic instructions and data that can be executed by the hardware.

Toolkit: a set of software libraries, tools, and resources that developers use to build applications or software systems. Tool-kits provide pre-built components, functions, and APIs (Application Programming Interfaces) that simplify the development process and help programmers accomplish common tasks more efficiently.

Actuator: a mechanical or electrical device that is used to control or manipulate a physical system. It is responsible for converting energy, typically in the form of electrical, hydraulic, or pneumatic power, into mechanical motion or force to perform a specific action.

Micro-controller a small integrated circuit (IC) that contains a processor core, memory, and input/output peripherals, all on a single chip. It is designed to perform specific tasks and control functions in embedded systems.

Micro-processor an integrated circuit (IC) that serves as the central processing unit (CPU) of a computer or electronic device. It is responsible for executing instructions, performing calculations, and controlling the overall operation of the system.

WiFi short for "Wireless Fidelity," is a technology that allows devices to wirelessly connect to a local area network (LAN) or the internet. It provides a means of wireless communication between devices such as computers, smartphones, tablets, and other network-enabled devices.

Bluetooth a wireless communication technology that allows devices to connect and exchange data over short distances. It is commonly used for connecting devices such as smartphones, tablets, laptops, headphones, speakers, and other peripherals.

TCP/IP: a suite of protocols that form the basis of communication in the Internet and most computer networks. It provides a standardized set of rules and specifications for transmitting data between devices connected to a network.

Framework: a framework is a reusable and pre-designed software structure that provides a foundation for developing applications. It offers a set of tools, libraries, and components that developers can use to build applications more efficiently by abstracting common functionalities and providing a structure for organizing and implementing code.

Front-end: The front-end refers to the client-side of an application, which is responsible for presenting the user interface and interacting with users. It typically involves the use of HTML, CSS, and JavaScript to create the visual elements, layout, and interactivity of a website or application.

Back-end: The back-end refers to the server-side of an application, which handles the processing, storage, and retrieval of data, as well as business logic and server-side operations. It involves the use of programming languages, frameworks, and databases to build the server-side components of an application.

Machine Learning: a sub-field of artificial intelligence (AI) that focuses on the development of algorithms and models that enable computers and systems to learn and make predictions or decisions without being explicitly programmed. It involves the study and construction of algorithms that can learn from and make predictions or take actions based on data.

Abstract

Water scarcity, caused by climate change, population growth, and unsustainable practices, necessitates efficient water resource management. Water tanks are essential for storing and conserving water, reducing reliance on external sources. However, challenges such as lack of monitoring and water wastage persist. To address these issues, we propose an IoT smart tank monitoring system that remotely monitors water levels and controls valves. This solution eliminates manual monitoring, providing real-time data and alerts through a mobile app. The system comprises a micro-controller, ultrasonic sensors, and a WiFi module, collecting data for a cloud-based database. Benefits include water wastage reduction, damage prevention, and energy savings. Our practical solution offers efficient water resource management in a water-scarce world, facilitating remote monitoring and control. A case study demonstrates the system's effectiveness, highlighting its potential for widespread adoption and impact. Overall, our smart technology solution contributes to sustainable water management, reducing wastage and increasing efficiency

Key-words:

- Internet of Things
- Smart Home
- Water Management
- Monitoring
- Sensors
- Micro-controller
- Smart Water Tank

Introduction

Water scarcity is a global challenge that demands efficient and sustainable water resource management. According to the World Wildlife Fund, around 1.1 billion people worldwide lack access to freshwater [1].This research focuses on developing an IoT smart water tank monitoring system as a solution to address these challenges. In this research we explore the intersection of computer science and environmental sustainability. The domain of water resource management traditionally relied on manual processes, leading to inefficiencies and errors. The integration of IoT technology presents new opportunities for real-time monitoring, data collection, and remote control of water systems. Our goal is to develop an intelligent system that enables efficient monitoring and control of water tanks using micro-controllers, sensors, wireless communication, and cloud-based databases. By implementing the IoT smart tank monitoring system, we address challenges such as accurate water level monitoring, event handling, and valve control. The system empowers users to monitor their water tanks, receive alerts, and make informed decisions about water usage. This enhances water conservation efforts, reduces costs, and improves overall management efficiency. Throughout our research, we explore the theoretical foundations, practical implementation, and validation of the proposed smart tank monitoring system. The research findings contribute to the field of IoT-based water resource management and provide insights for future researches. The outcomes have the potential to positively impact water conservation, sustainability, and environmental well-being.

Content Overview:

- **Chapter 1 - Introduction:** Introduces the research topic and the objective of developing an IoT smart water tank monitoring and management system.
- **Chapter 2 - Background:** Provides an overview of the system's architecture, components, and design specifications.
- **Chapter 3 - System Design and Implementation:** Discusses the detailed design and implementation process of the IoT smart water tank monitoring and management system, including the selection of components, integration of sensors, and development of the software.
- **Chapter 4 - Validation and Testing:** Presents the validation process and results of the developed system, evaluating its performance, reliability, and accuracy through hardware and software testing.
- **Chapter 5 - Discussion and Future Work:** Examines the research findings, discusses their implications, and explores potential areas for improvement and future enhancements to the system.

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Chapter 1 - Introduction

1 Introduction

1.1 Overview

Water scarcity is a critical issue that affects millions of people worldwide, and it requires immediate and effective solutions [2]. One of the most promising solutions is the smart water tank, an automated system designed to control the water tank in homes automatically. This system allows users to monitor their water usage and behavior through a mobile application that displays data such as the amount of water, water temperature, and the state of water valves if they are opened or closed. By using this data, users can better control their water tank and make adjustments according to their habits and needs.

The smart water tank system also includes various features to optimize water usage, such as automatically closing the tank's output valve when water is close to running out, This helps prevent wastage and ensures that there is always enough water available for daily needs. Additionally, the system measures the water temperature and when the temperature is close to a freezing point the tank will shut off and close the valves so when water freezes it does not burst or damage the water pipes or valves, since a frozen valve most of the time cannot be closed therefore it causes an issue, especially during winter.

This chapter will provide a comprehensive overview of the smart water tank system, including its components, working principles, and benefits. It will also discuss the significance of this technology in addressing water scarcity and promoting sustainable water use practices.

1.2 Motivation and Importance

The motivation for developing the smart water tank system is to address the various issues that can arise in water tanks, many of which can go undetected until significant damage occurs. Homeowners may not be aware of these problems until it is too late, resulting in costly repairs or replacements of valves or floats. Additionally, for water tanks located in tall buildings, manual inspections can be difficult and dangerous for individuals tasked with monitoring the water quantity and quality. In such cases, the smart water tank system can provide a safer and more efficient solution for monitoring and controlling the water supply.

Moreover, the importance of the smart water tank system lies in its ability to promote sustainable water management practices by reducing water wastage, increasing efficiency, and providing real-time insights into water levels. With the ability to remotely monitor water consumption and detect anomalies, the smart water tank system can help homeowners conserve water, reduce their water bills, and contribute to environmental conservation efforts. Furthermore, the system can also help individuals with disabilities or even the elderly and those with underlying health conditions.

1.3 Smart Water Tanks

1.3.1 Definition

Smart water tanks are water storage tanks that use advanced sensors, controllers, and communication technologies to collect and transmit data about water usage, quality, and other parameters [3]. These tanks are equipped with internet of things (IoT) devices that enable remote monitoring and control of the tank's water valves, pumps, and other components. This technology allows users to monitor the water level and quality in real-time, and remotely control the water supply to minimize waste and optimize water usage [4].

Figure 1: Smart Water Tank Level Sensor with WiFi Connectivity

1.3.2 Features

Smart water tanks have several features that make them ideal for managing water resources efficiently. One of the key features is remote monitoring, which allows users to monitor the water level in the tank from anywhere in the world. This feature is particularly useful for those who own multiple properties or travel frequently or if they have a disability, as it enables them to keep track of their water usage and ensures that they never run out of water. Additionally, smart water tanks have a water level indicator that provides real-time data about water levels in the tank, sending alerts when the water levels reach a critical point. Some smart water tanks also have the ability to monitor water quality, which is useful for those who rely on rainwater harvesting for their water supply or those who store their drinking water in water tanks [5].

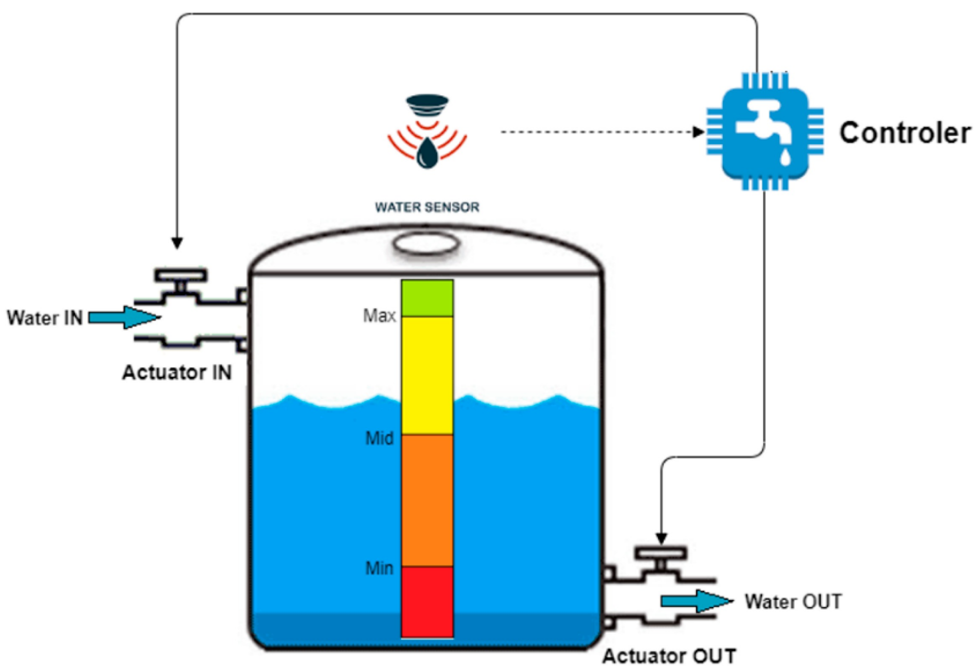

Figure 2: Smart water tank schema with sensors to monitor and control water valves

1.3.3 Benefits

Smart water tanks offer several benefits that make them an excellent choice for managing water resources. One of the most significant benefits is their ability to reduce water wastage, smart water tanks can help conserve water and reduce the demand for external water sources. Additionally, they can help prevent water damage by detecting leaks and sending alerts to the user's device. Smart water tanks also saves energy and time by reducing the need for manual monitoring and control and by also removing the need to travel to different locations to monitor different tanks [6].

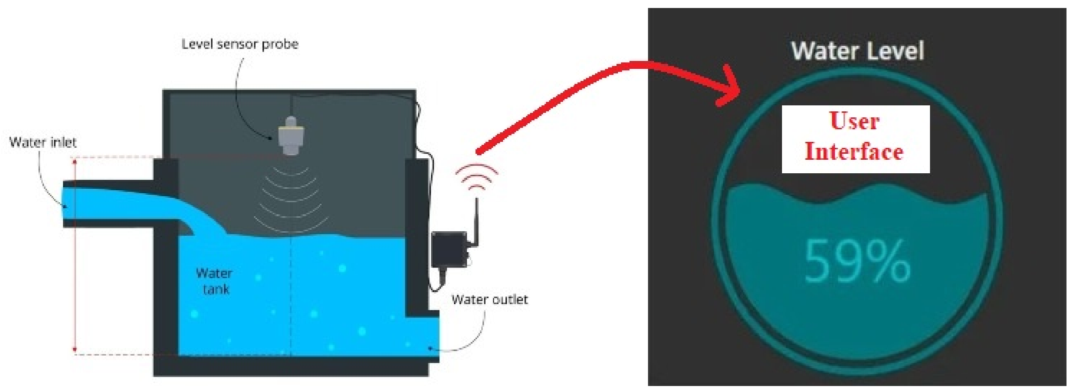

Figure 3: The Functionality of the smart water level monitoring system

1.3.4 Challenges

Despite their numerous benefits, smart water tanks face several challenges that need to be addressed. One of the most significant challenges is the lack of awareness about their existence and benefits. Many people are not aware of the advantages of smart water tanks and continue to rely on traditional water management practices. Additionally, smart water tanks can be expensive, making them inaccessible to low-income households. There is also a need for proper maintenance and monitoring to ensure that the system functions correctly, which can be a challenge for those who are not technically inclined.

1.4 Internet of Things

1.4.1 Introduction

The Internet of Things (IoT) is a term used to describe a network of physical objects, devices, and machines that are embedded with sensors, software, and connectivity, enabling them to collect and exchange data over the internet. This technology has revolutionized the way we interact with our surroundings and has the potential to transform industries such as healthcare, transportation, and manufacturing [7].

IoT enables devices to communicate with each other and share data, creating a seamless and connected ecosystem. This allows for more efficient monitoring and control of various systems,leading to improved decision-making, reduced costs, and increased productivity [8].

The concept of IoT has been around for several years, but it was not until the early 2000s that it began to gain significant attention. Today, the IoT market is rapidly growing, and it is estimated that by 2025, there will be over 75 billion connected devices worldwide [9].

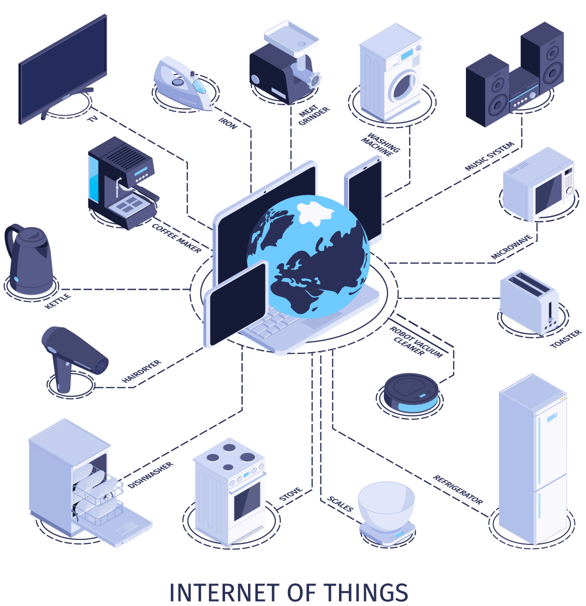

Figure 4: IoT devices connected.

1.4.2 Definition

The Internet of Things (IoT) is a revolutionary concept that has transformed the way we interact with our physical surroundings. It is essentially a network of interconnected physical objects, vehicles, buildings, and devices that are embedded with sensors, software, and network connectivity. These devices can collect and exchange data without the need for human intervention, allowing for real-time monitoring and control [10].

The IoT has enabled a range of new services and business models, providing unprecedented levels of insight and control over physical environments. From smart homes and cities to industrial automation and healthcare, the IoT is driving innovation and changing the way we live and work [11].

One of the key benefits of the IoT is its ability to improve efficiency and productivity. By automating tasks and collecting data in real-time, the IoT can optimize processes and reduce waste. This can lead to significant cost savings and environmental benefits [10].

Despite these challenges, the IoT is an exciting and rapidly evolving field with enormous potential. As more devices become connected, the possibilities for innovation and new services will continue to expand, making the IoT an area of great interest for research and development [12].

1.4.3 IoT Layers and architecture

The internet of things has many types of architectures and layers, where they range from three layers all the way up to sever layer architecture, in our case we will use the four layer architecture that has the following layers:

Perception Layer: This layer includes devices, sensors, and gateways that collect data and transmit it to the next layer. It is the layer where the physical objects are connected to the internet.

Network Layer: This layer is responsible for transmitting data from the perception layer to the cloud or other systems. It includes protocols such as WiFi, Zigbee, and cellular networks.

Platform Layer: This layer processes the data received from the network layer and provides storage, analysis, and other services to enable decision-making. It includes cloud computing platforms and data analytics tools.

Application Layer: This layer includes the applications that interact with the data and systems provided by the platform layer. It includes dashboards, mobile applications, and other software applications that allow users to monitor and control connected devices [13].

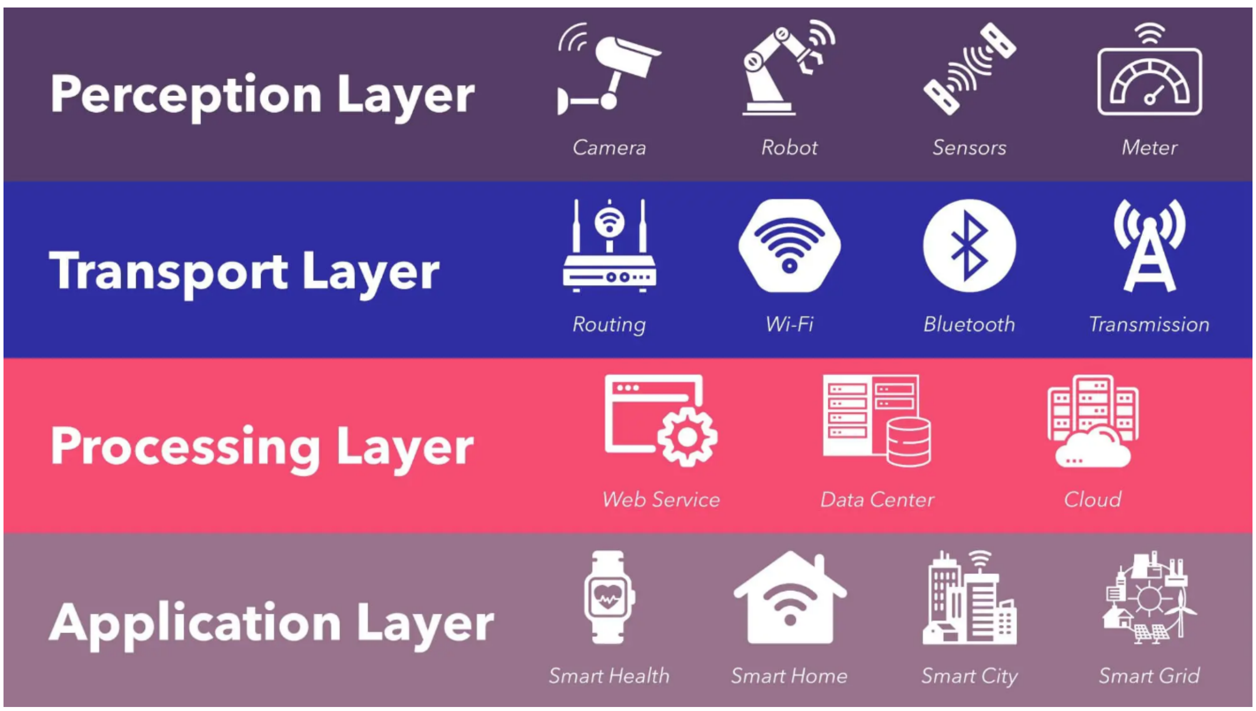

Figure 5: Internet of Things Layers

1.5 Internet of Things based solutions

IoT based solutions refers to technological solutions that utilize devices or sensors equipped with internet connectivity to collect, transmit and analyze data in order to automate, optimize or improve various aspects of daily life, business, and industry. These solutions typically involve the integration of hardware, software, and cloud-based services to enable the seamless communication and exchange of data between different devices or systems. IoT-based solutions can be applied to a wide range of fields, including smart homes, healthcare, transportation, manufacturing, and agriculture, among others [**14**].

1.6 Sensors and components

There are various types of IoT sensors and components that can be used to monitor and control water levels and water valves in smart water tanks, some of the common ones are:

1.6.1 Water Level Sensors

These sensors are used to measure the water level in the tank. There are different types of water level sensors, including ultrasonic sensors, float sensors, and pressure sensors.

Float Sensor: A water float sensor is a simple and reliable device used to measure the level of liquid in a tank or container. It consists of a buoyant object connected to a switch or sensor. When the liquid level rises, the buoyant object floats up and activates the switch, triggering an alarm or other action. Float sensors have no moving parts and can be used in a wide range of liquids, making them versatile and easy to use. However, they may become stuck or jammed and are not suitable for use in very small or large tanks, and they may not be as precise as other types of level sensors such as ultrasonic or pressure sensors. The precision of a float sensor can also be affected by external factors such as temperature changes, vibrations, or debris in the tank. Overall, while float sensors may not be the most precise type of level sensor, they are often reliable and cost-effective for many applications [14].

Figure 6: Water float sensor

Pressure Sensor: A water pressure sensor measures the pressure of water in a system using a sensing element and transducer. Benefits include high accuracy, versatility, and ability to detect changes in pressure over time. Inconveniences include sensitivity to external factors and need for calibration and maintenance. Precision depends on quality and calibration of the sensor, and can be affected by external factors. Overall, water pressure sensors are popular due to their accuracy and versatility [15].

Figure 7: Water pressure sensor

Depth Sensor: A water level depth sensor is a device that measures the depth of water in tanks or wells. It consists of at least two metallic probes that are submerged in water, and when the water level reaches a certain height, the probes are electrically connected, triggering an action which is sent to an MCU. Benefits include affordability and ease of use, but they may require frequent maintenance and may not be precise enough for advanced applications, and since it's most of the time submerged, bad water quality might deteriorate the sensor's functionality [16].

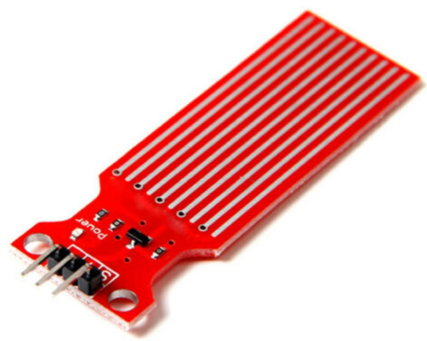

Figure 8: Water depth sensor

Ultrasonic Sensor: Ultrasonic sound sensors use sound waves to measure distances and detect objects, providing high accuracy and non-contact measurement. They are widely used in various applications, including automotive, robotics, and industrial automation. They are efficient and reliable devices, providing accurate measurements over a certain range. One of the key advantages of ultrasonic sound sensors is their versatility. They can be used in various applications, such as obstacle detection in robotics or measuring fluid levels in tanks. Additionally, they provide non-contact measurement, making them ideal for applications where contact is not possible or desired. While there are some limitations to their use, such as susceptibility to external factors and interference, ultrasonic sound sensors remain a popular choice for many industrial and automotive applications. Overall, they are efficient, reliable, and provide precise measurements,making them a valuable tool in a wide range of applications, and since they are not submerged they are less prone to water damage [17].

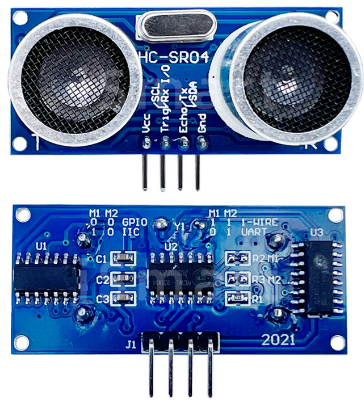

Figure 9: Ultrasonic sensor (HC SR-04)

1.6.2 Flow Meters

Water flow sensors, also known as flow meters, are devices that measure the volume, velocity, or flow rate of a liquid flowing through a pipe or channel. They are commonly used in a variety of applications, including industrial process control, water management systems, and HVAC systems [18].

Turbine flow meters: These flow meters use a rotor with blades to measure the flow of water. As water passes through the blades, the rotor rotates, and the frequency of the rotations is used to determine the flow rate [19].

Figure 10: Turbine flow meter

Magnetic flow meters: These flow meters use a magnetic field and electrodes to measure the flow of water. As water passes through the meter's magnetic field, it induces a voltage, and the electrodes measure the voltage, which is proportional to the flow rate [20].

Figure 11: Magnetic flow meter

Ultrasonic flow meters: These flow meters use ultrasonic waves to measure the flow of water.They emit ultrasonic waves into the water and measure the time it takes for the waves to travel upstream and downstream. The difference in time is used to calculate the flow rate [21].

Figure 12: Ultrasonic flow meter

Vortex flow meters: These flow meters use a bluff body placed in the water flow to create vortices, which are detected and measured to determine the flow rate [22].

Figure 13: Vortex flow meter

1.6.3 Electric Water Valves

These are used to control the flow of water into or out of the tank or different pipes. There are different types of valves, including solenoid valves and ball valves.

Solenoid valves: These are electrically operated valves that use an electromagnetic solenoid to control the flow of water. They can be controlled remotely and are commonly used in automated irrigation systems [23].

Figure 14: Electric Solenoid valve

Ball valves: These are quarter-turn valves that use a ball to control the flow of water. They can be manually or electrically operated and are commonly used in plumbing systems [24].

Figure 15: Electric Ball valve

Gate valves: These valves use a gate or wedge-shaped disk to control the flow of water. They are typically used in large diameter pipes and are not recommended for frequent use [24].

Figure 16: Electric Gate valve

1.6.4 Micro-controllers

They are used to process the data from sensors and control the valves and pumps. There are many types of micro-controllers but here are one of the most used ones in IoT projects:

Arduino: An open-source micro controller board designed for simple electronics projects.

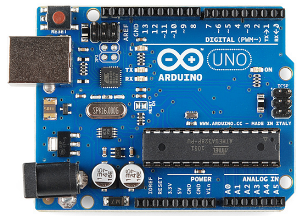

Figure 17: Arduino Uno Board

Raspberry Pi: A single-board micro computer that runs on Linux and can be used for a variety of projects, some raspberry's count as micro computers and other count as micro processors.

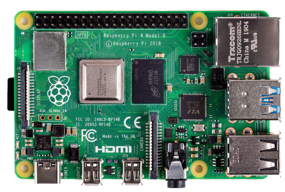

Figure 18: Raspberry Pi Board

Node-MCU: A low-cost WiFi microchip with a micro-controller capabilities

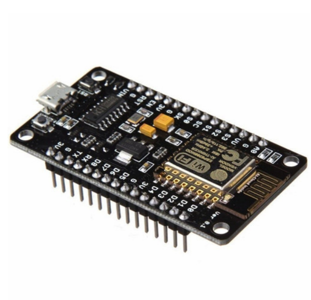

Figure 19: NodeMCU ESP-8266 board

1.6.5 Communication Modules

These modules are used to connect the micro-controller to the internet and allow remote control or communication between devices.

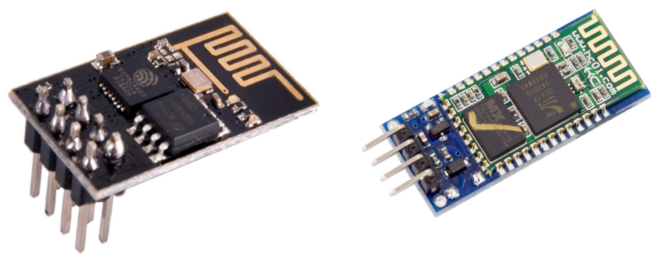

Figure 20: ESP-01 WiFi module to the left, HC-05 Bluetooth module to the right

1.6.6 Power Supplies

A power supply is a unit that provides power to a set of devices, modules and sensors. The power supplies can range from Li-ion batteries to voltage adapters and power bricks.

Figure 21: Li-ion battery to the left, 12v power brick to the right

1.6.7 Solar Panels

A solar panel is a device it usually comes in a thin rectangular shape with the purpose of converting solar rays into electricity, the converted electricity can be stored in a lithium ion battery or it can be sent directly to a device.

Figure 22: A mini solar panel user to power small devices

1.6.8 GSM Module

A board with an antenna and a sim card place holder with the main objective of providing cellular services such as SMS and calls to specific systems.

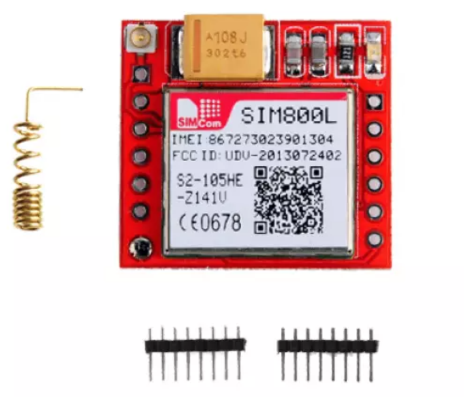

Figure 23: SIM-800L GSM Module

1.7 Related works

1.7.1 Related Work 1

Title: Smart water quality monitoring system with cost-effective using IoT [25]

Authors: Sathish Pasika, Sai Teja Gandla.

DOI: https://doi.org/10.1016/j.heliyon.2020.e04096

Summary: The article "Smart water quality monitoring system with cost-effective using IoT" discusses the need for an efficient and cost-effective system to monitor the quality of drinking water, which is a basic necessity for human survival. Contaminated water is responsible for a significant number of deaths globally, with around 40% of these fatalities attributed to polluted water. Therefore, ensuring a supply of purified drinking water to people, both in cities and villages, is of utmost importance.

The proposed solution to this problem involves the use of Internet of Things (IoT) technology, which enables connections between various devices to exchange and gather data. The system consists of several sensors that measure various parameters, including pH value, turbidity in the water, level of water in the tank, temperature, and humidity of the surrounding atmosphere.

These sensors are integrated with a Micro-controller Unit (MCU), which facilitates data processing. The data collected by the sensors is processed at a Personal Computer (PC) and sent to the cloud using an IoT-based Thing Speak application. The cloud-based monitoring system provides real-time information about the quality of the water, enabling timely action to be taken in case of any contamination. The system is cost-effective and efficient, making it an ideal solution for monitoring the quality of drinking water.

In summary, the research question or problem addressed in the abstract is how to monitor the quality of drinking water using a cost-effective and efficient system designed with Internet of Things (IoT) technology. The proposed system can help ensure a supply of purified drinking water to people in cities and villages, where contaminated water is responsible for a significant number of deaths. The system consists of several sensors, an MCU, and a cloud-based monitoring system, providing real-time information about the quality of the water.

1.7.2 Related Work 2

Title: Internet of Things (IoT) Based Water Level Monitoring System for Smart Village [26]

Authors: Timothy Malche, Priti Maheshwary

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Summary: The article "Internet of Things (IoT) Based Water Level Monitoring System for Smart Village" highlights the importance of water sources in agricultural and farm production, as well as for maintaining the quality of life. Monitoring the water level of a water source, such as a water tank or bore well, is crucial for ensuring that the water supply is sufficient for its intended purpose. In agricultural settings, water is necessary for irrigation, and in order to ensure that crops receive the necessary amount of water, it is important to monitor the water level and take appropriate action to maintain it.

One common issue that can arise if the water level drops below the threshold level for pumping in a bore well is that the pump motor may get damaged due to dry running. This can result in significant costs for repairing or replacing the pump motor, as well as a disruption in the water supply. In such cases, monitoring the water level and controlling the water pump accordingly becomes a necessary task to prevent damage and ensure that the water supply remains stable. Beyond preventing damage to pump motors, there are many other situations where water level monitoring is an important task. For instance, it may be used to preserve water by controlling its usage, or to study the water usage of a water source in order to develop more effective strategies for conservation.

In this context, the paper proposes a prototype system design, implementation, and description of the required tools and technologies to develop an Internet of Things (IoT) based water level monitoring system. The system would be specifically designed for agricultural and farm production, and would be applicable for smart villages in India. The ultimate goal is to improve the quality of life and preserve water resources in agricultural areas by effectively monitoring and controlling water levels.

1.8 Overall comparison

Both works focus on the application of Internet of Things (IoT) technology in the field of water monitoring, but they address different aspects of the problem. Work 1 discusses the need for a cost-effective and efficient system for monitoring the quality of drinking water, while Work 2 focuses on the importance of monitoring water levels in agricultural settings to ensure a stable water supply for irrigation.

Work 1: proposes a system that consists of several sensors and a Micro-controller Unit (MCU) integrated with a cloud-based monitoring system to provide real-time information about the quality of water. The system uses IoT technology to exchange and gather data between devices, and it is cost-effective and efficient.

Work 2: In contrast, proposes a prototype system design for an IoT-based water level monitoring system, specifically designed for agricultural and farm production in smart villages in India. The system aims to improve the quality of life and preserve water resources in agricultural areas by effectively monitoring and controlling water levels.

Overall Both works demonstrate the potential of IoT technology in addressing various water-related issues, such as water quality and water level monitoring. They also highlight the importance of efficient and cost-effective solutions to these problems, as well as the need to apply these technologies in a targeted manner to specific industries and regions.

Conclusion	
Work 1	**Work 2**
Smart water quality monitoring system with cost-effective using IoT	Internet of Thing (IoT) Bases water level monitoring system for smart villages
Main sensors use in prototype	
Micro-controller (Arduino Mega) + NodeMCU + PH sensor + Turpidity Sensor	Micro-controller (Arduino Uno) + water depth sensor

Table 1: Comparison between the hardware of the related works

1.9 Chapter 1 Conclusion:

In conclusion, this chapter provides a comprehensive overview of the background, context, and objectives of the smart water tank system. It highlights the global issue of water scarcity, discusses the limitations of traditional water tank management, and introduces the need for an automated solution. The chapter sets the stage for the subsequent chapters, where we will delve into the technical implementation and explore the system in detail. Overall, Chapter 1 establishes the significance of our research and the potential impact it can have on water resource management.

Chapter 2 - Background

2 Background

2.1 Overview

In this chapter, we delve into the hardware and software components of the smart water tank system, which enables automated control of the water tank. We begin by discussing the problem of traditional water tank management and the objective of our proposed solution. Next, we provide a high-level overview of the general architecture of the system, followed by a detailed breakdown of the system's environment, users, sensors, and other components. We also include diagrams to illustrate the various components of the system. Finally, we conclude with a summary of the key design specifications and necessary information to understand the system.

2.2 Problem

The problem with traditional water tank systems is that they often lack the necessary automation and real-time monitoring capabilities required to effectively manage and monitor water level and temperature. This can lead to inefficiencies and potential safety hazards, especially in tall buildings where manual checks can be difficult and dangerous to perform. Furthermore, traditional systems can result in unexpected maintenance costs, such as valve or float damage, which can be both time consuming and expensive to repair. Therefore, the need for a reliable and efficient smart water tank system that can monitor and control water levels and temperatures in real-time has become increasingly important in recent years. The use of IoT sensors and actuators allows for automation of the monitoring and control process, providing users with real-time updates and enabling remote access and control through a mobile application.

2.3 Objective

The smart water tank system aims to achieve the following objectives:

- To automatically monitor the water level in the tank and alert users when it reaches a low level, preventing water shortage and ensuring continuous water supply.
- To automatically monitor the temperature of the water in the tank and notify the user if the level exceeds a certain threshold to prevent freezing or overheating, especially during extreme weather conditions.
- To provide real-time notifications to users through a mobile application that shows the status of the system, including the amount of water in the tank, water temperature.
- To periodically monitor the rate of water consumption and provide statistical data to users through the mobile application, enabling them to manage their water usage efficiently.

2.4 Short Description of The System

The smart water tank system is designed to provide real-time monitoring and control of water levels, temperature, and consumption, allowing users to remotely access and manage their water tanks through a mobile application. The system utilizes sensors to collect data on the amount of water in the tank, the rate of water consumption, and the temperature of the water. These sensors are connected to a micro-controller, which processes the data and sends it to the user's mobile device through the Internet. The system also includes a feature that detects when the water level is running low and automatically closes the tank. In addition, the system measures the temperature of the water inside the tank to prevent problems during cold weather. This is achieved by opening the valves slightly to prevent water pipes from bursting.

Overall, the smart water tank system provides users with a convenient and reliable way to monitor and manage their water tanks, ensuring that they always have access to a safe and sufficient supply of water.

2.5 Technologies Used in The Project

Arduino programming language: Is an open-source computer programming language based on the wiring development platform, the Arduino IDE is based upon the Processing IDE, and it is available in several operating systems, which give us a programming editor with integrated libraries support and a way to easily compile and load our Arduino programs to a board connected to the computer [27]. This language is a framework built on top of C++, the main difference from c/c++ is that you wrap all your code into two main functions, any Arduino program must provide at least two main functions [28].

Flutter: Flutter is Google's portable UI toolkit for crafting beautiful, native compiled applications for mobile, web, and desktop from a single code base. Flutter works with existing code, is used by developers and organizations around the world, and is free and open source [29]. We use this technology to build a mobile application to display the data that comes from the ESP32 micro-controller to the user, and this app allows the user to control valves by sending a signal from the app to the micro-controller

Firebase: is a mobile and web application development platform owned by Google that provides developers with a suite of tools and services for building and managing scale-able, real-time, and cloud-hosted applications. Firebase offers a wide range of features, including database management, authentication, storage, cloud messaging, analytic, and crash reporting. It allows developers to build apps quickly without the need for managing servers, infrastructure, or back-end code. Firebase is designed to work with a variety of client-side frameworks, including Android, iOS, and web frameworks like React and Angular. It is often used for developing mobile apps, web apps, and games, as well as for hosting server-less web applications. (Firebase Official Website: https://firebase.google.com/) [30].

2.6 Hardware and Components of The System

NodeMCU ESP-32: The ESP32 is a dual-core 160MHz to 240MHz CPU, whereas the ESP8266 is a single-core processor that runs at 80MHz. These modules come with GPIOs that support various protocols like SPI, I2C, UART, ADC, DAC, and PWM.
The best part is that these boards come with wireless networking included, which makes them apart from other micro-controllers like the Arduino.
This means that you can easily control and monitor devices remotely via WiFi or Bluetooth for a very low price. We will program this controller to deal with the data coming from the connected sensors and send it to the application for display to the user [31].

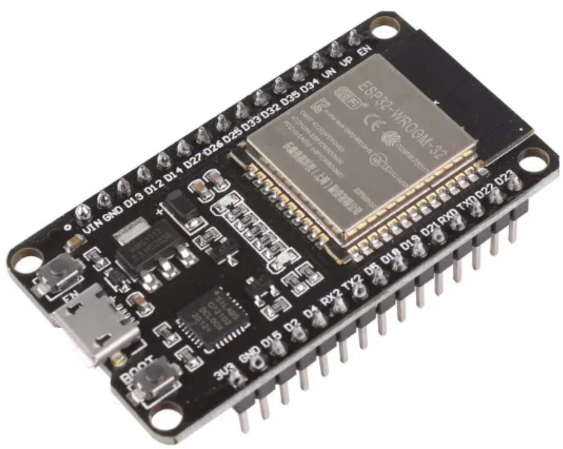

Figure 24: NodeMCU ESP-32

Ultrasonic Sensor: The ultrasonic sensor measures distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected from the target. Ultrasonic sensors measure the distance to the target by measuring the time between the emission and reception [32]. We will use this sensor in this project to calculate the amount of water in the tank, as we will place it at a point at the top of the tank and it will measure the distance between it and the level of water in the tank. This sensor sends the data obtained to the ESP32, where it will be connected to it.

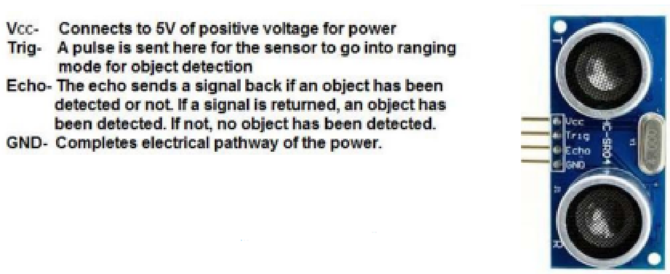

Figure 25: Ultrasonic Sensor HC SR-04

Solenoid Valve: Solenoids are very commonly used actuators in many process automation systems. Solenoid valves are used wherever fluid flow has to be controlled automatically. These valves are control units that, when electrically energized or de-energized, either shut off or allow fluid flow [33].

We use these valves to open or close tank pipelines. We will put two of these valves in the tank. We will place the first one at the point of entry of the water into the tank, where we will control the process of entering the water coming from the source to the tank through it. We will place the second valve at the point of exit of the water from the tank to control the process of exit of water from the tank to the consumer through it.

Figure 26: Solenoid valve

Relay Module: 2-Channel Relay Module is a relay interface board, it can be controlled directly by a wide range of micro-controllers. It uses a low-level triggered control signal to control the relay. Triggering the relay operates the normally open or normally closed contacts. It is frequently used in an automatic control circuit [34]. To put it simply, A relay is an electro-mechanical device that allows you to control one electrical circuit with another circuit. It works by using an electromagnetic coil to open or close a switch [35].

Figure 27: 2-Channel 5v Relay module

Other components and modules: Our system might also include other components such as solar panels and Li-ion batteries, our main prototype will be powered by a power brick, but we intend to make a second prototype powered by a solar panel, where the solar panel will provide the system with enough energy and charge the Li-ion battery so the system can still be powered at night times, the figure below displays the main components needed for a solar powered system.

Figure 28: Solar Charging System

2.7 Design Alternatives

This sub-section explains the alternative for NodeMCU ESP-32 and why we did not use them

Raspberry Pi Raspberry Pi is a single-board computer. It is a credit-card-sized computer with low cost, which plugs into a computer monitor or TV and to operate it, a user can use a standard keyboard and mouse to operate it. The single-board consists of a fully functional computers with its dedicated memory, processor and it runs an operating system [36].

This table shows the main difference in specifications for ESP32 and Raspberry Pi3

Feature	Raspberry Pi	ESP-32
Processor	Broad-com BCM2837	Xtensa LX6
Clock Frequency	1.2 GHz	240MHz
RAM	1 GB	520Kb - 4 Gb
Storage	4 Mb	4Mb - 16Mb
Operating Voltage	5v	3.6v - 5v
Power Consumption	260-300ma	50ma - 100ma
WiFi	Yes	Yes
Bluetooth	Yes	Depends
Ethernet	Yes	No
Price	10−75	3−5

Table 2: Raspberry Pi 3 VS ESP-32 Comparison

There are several reasons why we want to use ESP32 over Raspberry Pi 3:

1. The ESP32 is significantly cheaper than the Raspberry Pi 3, which makes it an excellent choice for projects where cost is a major consideration.

2. The ESP32is a low-power micro-controller, which means it consumes less power than the Raspberry Pi 3. This makes it an ideal choice for projects that run on batteries or require low power consumption.

3. The ESP32 is much smaller than the Raspberry Pi 3, which makes it ideal for projects where space is a constraint.

4. The ESP32 has built-in WiFi connectivity, which makes it ideal for projects that require wireless communication. The Raspberry Pi 3 also has WiFi connectivity, but it also has Ethernet connectivity, which may not be necessary for certain projects.

5. The ESP32 is a micro-controller, which means it is better suited for real-time requirements compared to the Raspberry Pi 3, which is a full-fledged computer.

Arduino Mega Arduino Mega 2560 is a micro-controller board based on the AT-mega2560, it is designed for projects that require more I/O lines, more sketch memory, and more RAM. Connect the board to the computer using the USB cable to load the program and power it up [**36.**]
This table shows the main difference in specifications for Arduino Mega 2560 and ESP32 NodeMCU.

Feature	Arduino Mega	ESP-32
Processor	At-mega 2560	Xtensa LX6
Clock Speed	16 MHz	240MHz
Storage	4MB flash	4MB - 16MB
Operating Voltage	5v	3.6v - 5v
Power Consumption	50ma - 200ma	50ma - 100ma
WiFi	No	Yes
Bluetooth	No	Depends
Price	10−20	3−5

Table 3: Arduino Mega 2560 Vs ESP-32 comparison

There are several reasons why we want to use ESP32 over Arduino Mega 2560:

1. The ESP-32 has built-in WiFi connectivity, which makes it easier to connect to the internet or other wireless devices. In contrast, the Arduino Mega does not have built-in WiFi, so you would an additional shield or module to add WiFi connectivity.

2. The ESP-32 has a faster clock speed and more RAM than the Arduino Mega, which makes it better suited for the project.

3. The ESP-32 is significantly cheaper than the Arduino Mega, which makes it a good choice for projects where cost is a major consideration.

4. The ESP-32 is smaller than the Arduino Mega, which makes it a good choice in projects where space is a constraint.

2.8 Design Constraints

1. The system requires a reliable internet connection to function properly, as it relies on sending and receiving data through the internet.

2. The system requires a continuous supply of electricity to operate, as it uses sensors, actuators, and a micro-controller that need power to function.

3. The height of the water tank should not exceed 4 meters, as the ultrasonic sensor used to measure the water level has a limited range and accuracy beyond that distance.

2.9 Chapter 2 Conclusion:

Chapter 2 has provided an overview of the hardware and software components of the smart water tank system. We have discussed the challenges of traditional water tank management and introduced our proposed solution for automated control and monitoring. The chapter has covered the system's architecture, environment, users, and sensors, setting the stage for further exploration in the following chapters. This foundational knowledge will guide our analysis of the system's implementation, testing, and performance, bringing us closer to our objectives in water resource management.

Chapter 3 - System Design

3 System Design

3.1 Overview

This chapter delves into the design and implementation of the smart water tank system, which addresses key challenges in water management. It begins by discussing the problematic aspects, including inefficient water usage, limited visibility and control, and the need for manual intervention. The objective is to develop an IoT-based solution that enables remote monitoring and control while improving water management efficiency. The chapter provides a comprehensive overview of the system's functionality, detailing the hardware and software components used. Visual representations of system diagrams illustrate the architecture, highlighting the interconnection of the various components.

3.2 Problematic

The smart water tank system aims to address several key issues related to water management.

1. **Inefficient water usage:** Traditional water tank management often relies on manual monitoring and control, leading to potential water wastage and inefficient usage. The system aims to optimize water usage by providing automated control mechanisms.

2. **Limited visibility and control:** Without a smart monitoring system, users have limited visibility into the water level, temperature, and overall status of the tank. This lack of information can lead to unexpected water shortages or overflow. The system aims to provide real-time visibility and control to users.

3. **Manual intervention and inconvenience:** Manual management of water tanks requires regular physical monitoring and manual adjustment of valves. This can be time consuming and inconvenient. The system aims to automate these processes to save time and effort.

3.3 Objective

The objectives outlined for the system's design and implementation

1. **Develop an IoT-based monitoring system:** The objective is to design and implement an IoT-based monitoring system that utilizes sensors, micro-controllers, and wireless communication to collect and transmit data from the water tank to a mobile application.

2. **Enable remote monitoring and control:** The system aims to allow users to remotely monitor the water level, temperature, and other relevant parameters through a mobile application or web interface. Additionally, it enables users to control valves remotely.

3. **Improve water management efficiency:** The objective is to enhance water management efficiency by optimizing water usage, preventing wastage, and ensuring optimal water levels in the tank. This is achieved through automated control mechanisms and real-time alerts and notifications.

4. **Enhance user experience and convenience:** The system aims to provide a user-friendly interface and intuitive controls, making it easy for users to interact with the system.

3.4 Detailed description of the system

Main components of the system

- Ultrasonic sensor: Measures the distance between the water surface and the sensor, providing data to the micro-controller.

- Temperature sensor: Measures the water temperature inside the tank.

- ESP-32 micro-controller: Receives sensor data, processes it, and communicates with the mobile application.

- Mobile application: Provides real-time updates and control options to the user

Water level monitoring

- Micro-controller determines water level based on ultrasonic sensor data.
- if water level is nearing completion, the micro-controller closes the valve to prevent overflow and sends a status notification to the mobile app.

Temperature control

- Micro-controller monitors water temperature using the temperature sensor.
- If temperature is close to freezing, the micro-controller opens the valve slightly to prevent pipe damage from freezing.

Data processing and communication

- Micro-controller processes sensor data and sends it to the application through WiFi.

Mobile application features

- Real-time updates on water level, temperature, and system status.
- Remote control of the valve and system monitoring from anywhere.
- The ability to control and monitor multiple water tanks simultaneously

Reliability, efficiency, and ease of use

- The system is designed to be reliable and efficient in monitoring and controlling the water tank.
- The mobile application provides a user-friendly interface for convenient system management.
- Ensures sufficient water supply for daily use and enhances user convenience.

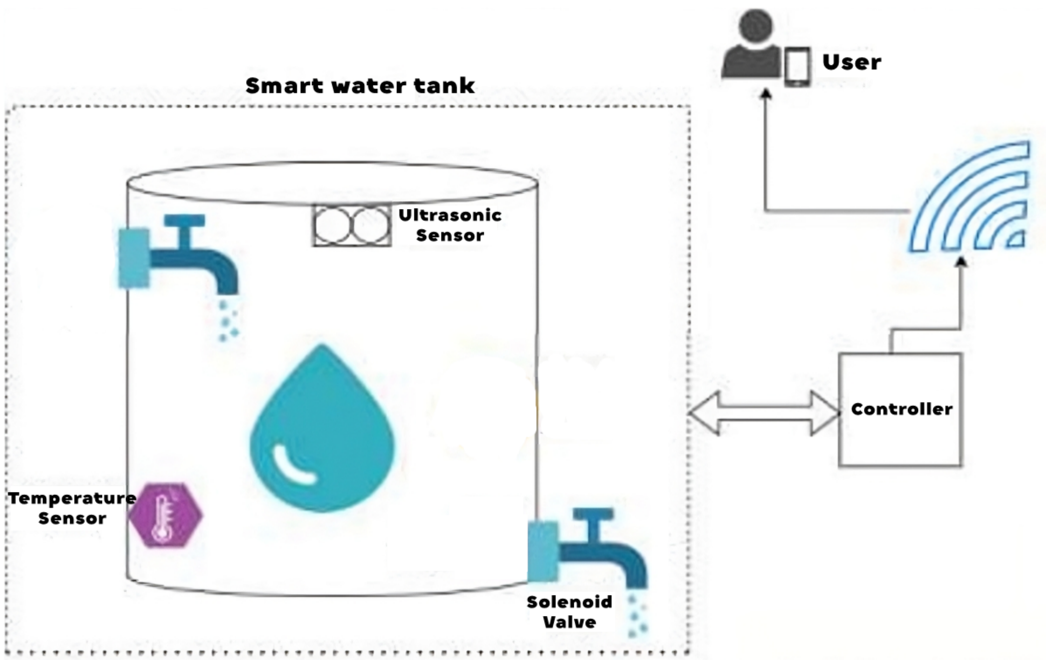

Figure 29: Visual illustration of Smart Water Tank

3.5 System diagrams

In this subsection, we will utilize diagrams to provide a visual representation of the system's functionalities. These diagrams serve to enhance our understanding of the project's concept and design, allowing for clearer comprehension and analysis.

System Block: The system block diagram provides a comprehensive visual representation of the project's architecture and highlights the flow of information and control within the system. This diagram illustrates the key components and their interactions, allowing for a better understanding of the overall system functionality.

The system block diagram illustrates the project's architecture. Sensors collect data and send it to the ESP32 micro-controller. The micro-controller processes and sends the data to the database for storage and analysis. The data from ultrasonic and flow sensors is used to make decisions about valve control and pump operation

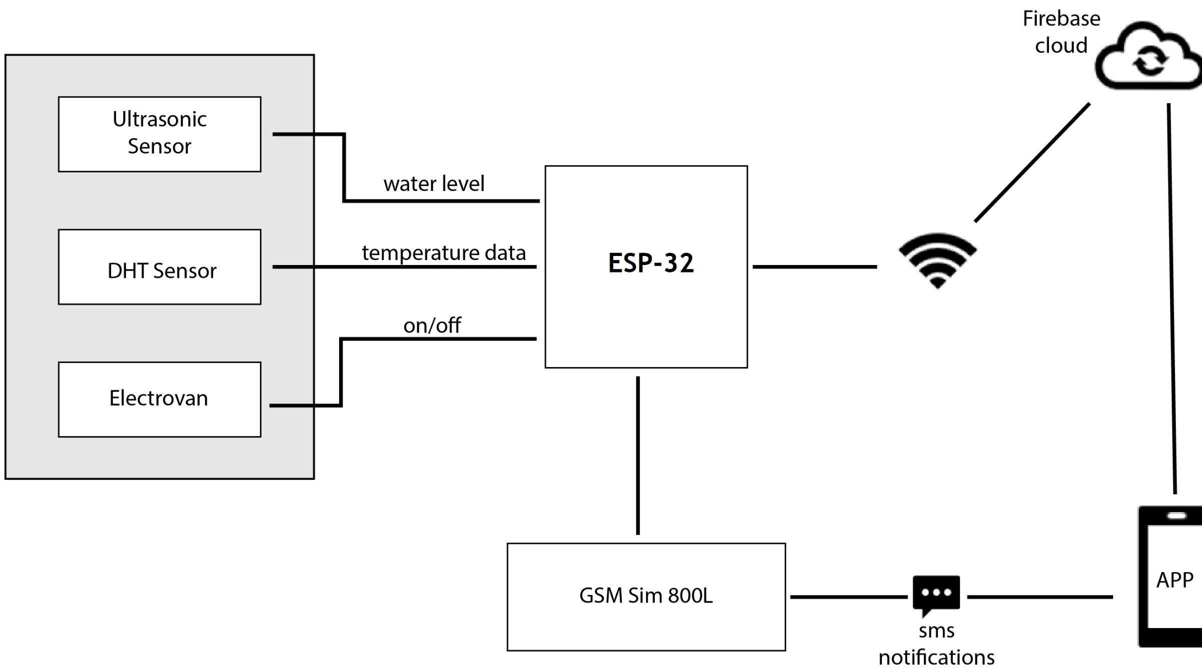

Figure 30: System Block Diagram

Schematic Diagram: The schematic diagram provides a detailed visual representation of the electrical connections and circuitry within the system. It showcases the arrangement and interconnections of various components, such as sensors, micro-controllers, valves, pumps, and other electronic elements. By illustrating the complete circuitry, including power supply connections, signal paths, and data flow, the schematic diagram offers a comprehensive overview of how the system's hardware components are interconnected and work together to achieve the desired functionality. It serves as a valuable reference for understanding the system's electrical design, aiding in troubleshooting, maintenance, and future modifications or expansions.

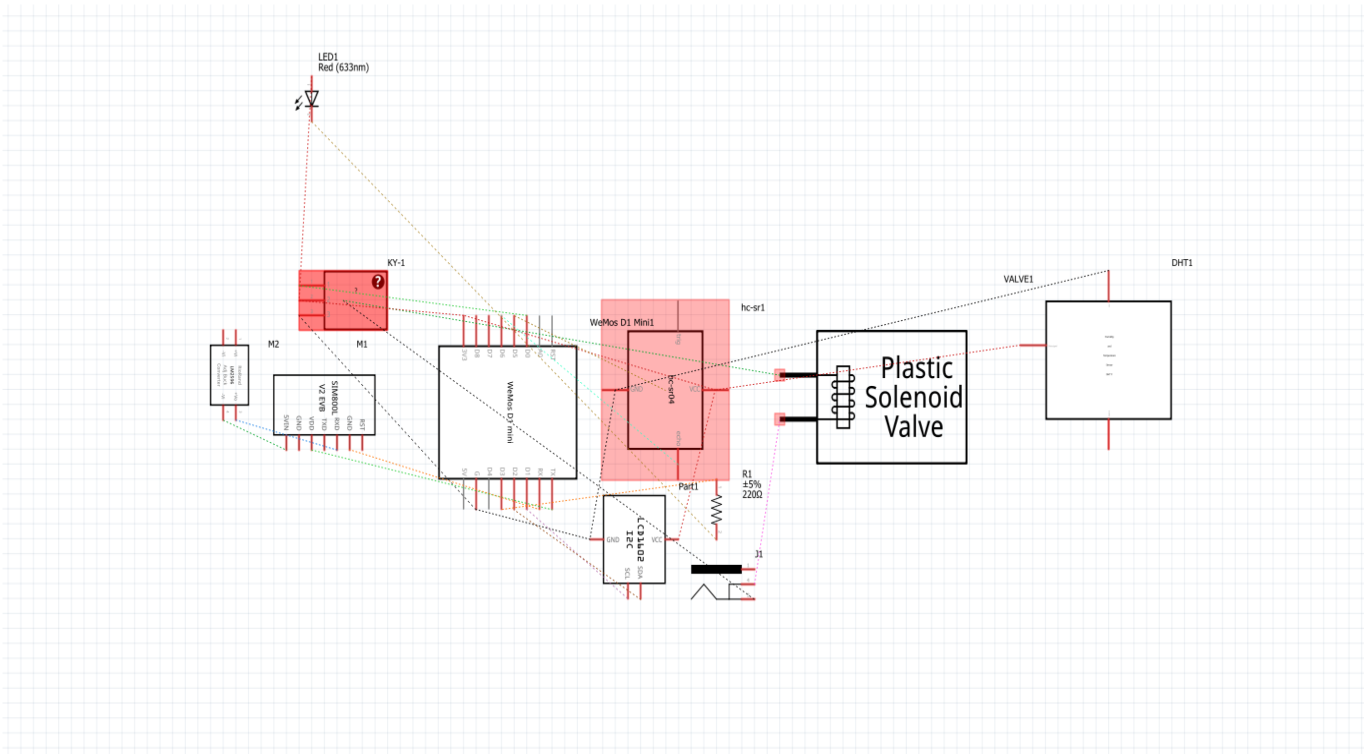

Figure 31: Schematic Diagram

Unified Modeling Language

Unified modeling language (UML) is a modeling language used by developers and programmers to describe their software systems, UML has many sets and types of diagrams each one represents a specific aspect of the system [37].

1. **Use Case Diagram** The use case diagram illustrates the different interactions and functionalities of the system from a user's perspective.

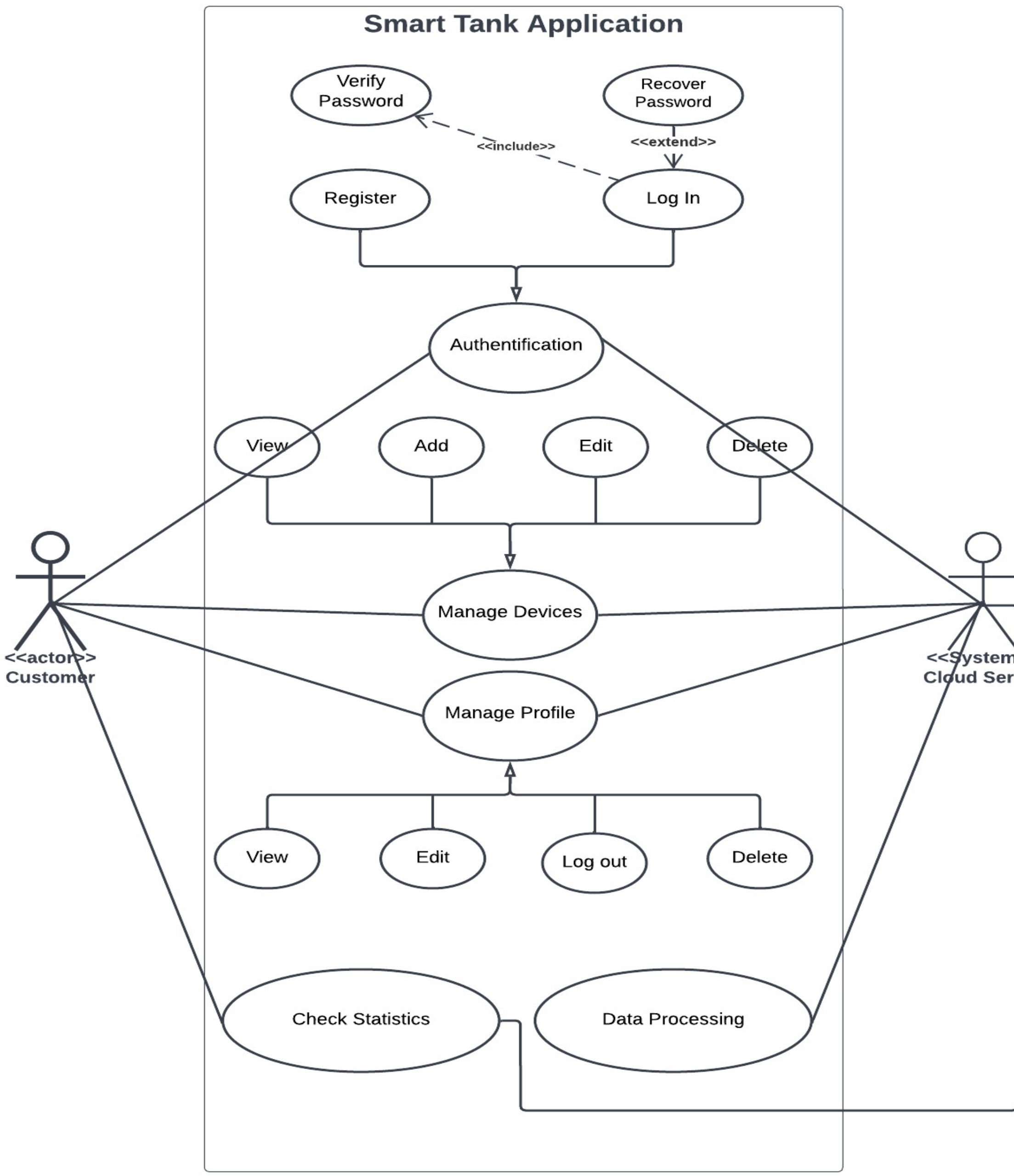

Figure 32: Use Case Diagram

2. **Sequence Diagram** The sequence diagrams provide a visual representation of the chronological order of interactions and message exchanges between system components or actors.

   - **Authentication** This diagram illustrates the authentication process between the user and the system

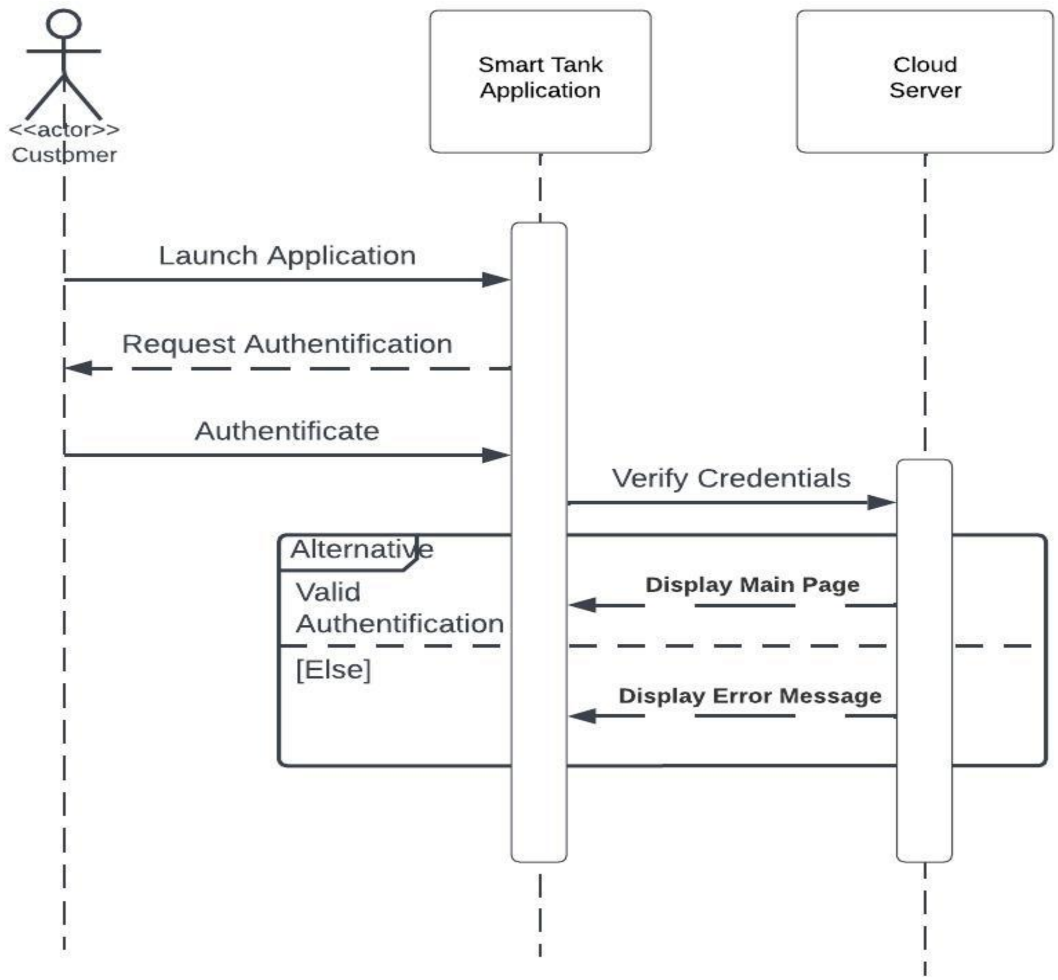

Figure 33: Sequence diagram of the Authentication

- **Configuration:** This diagram illustrates the device configuration process of the system

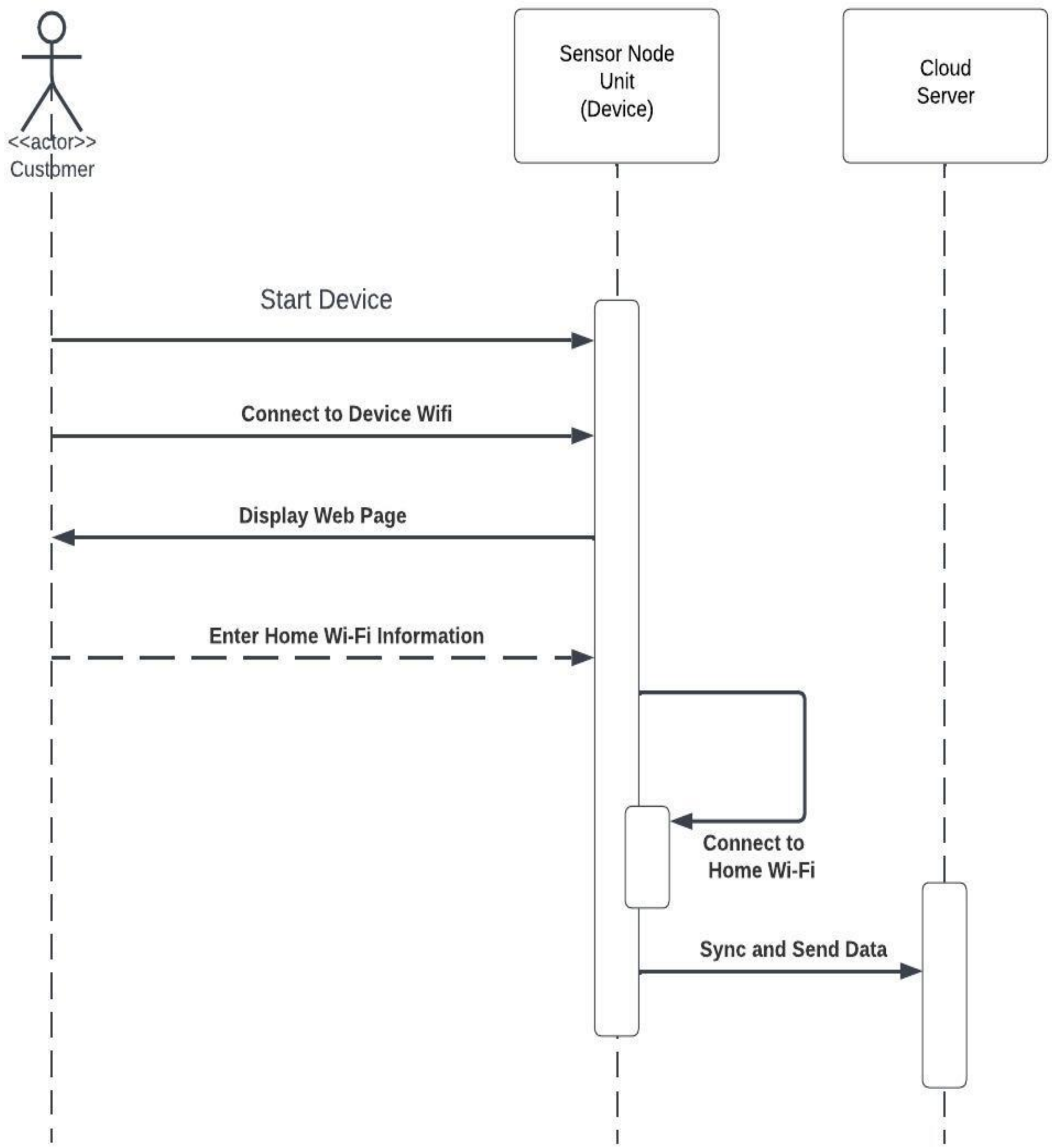

Figure 34: Sequence diagram of the configuration

- **General Diagram:** This diagram illustrates the general process of the system

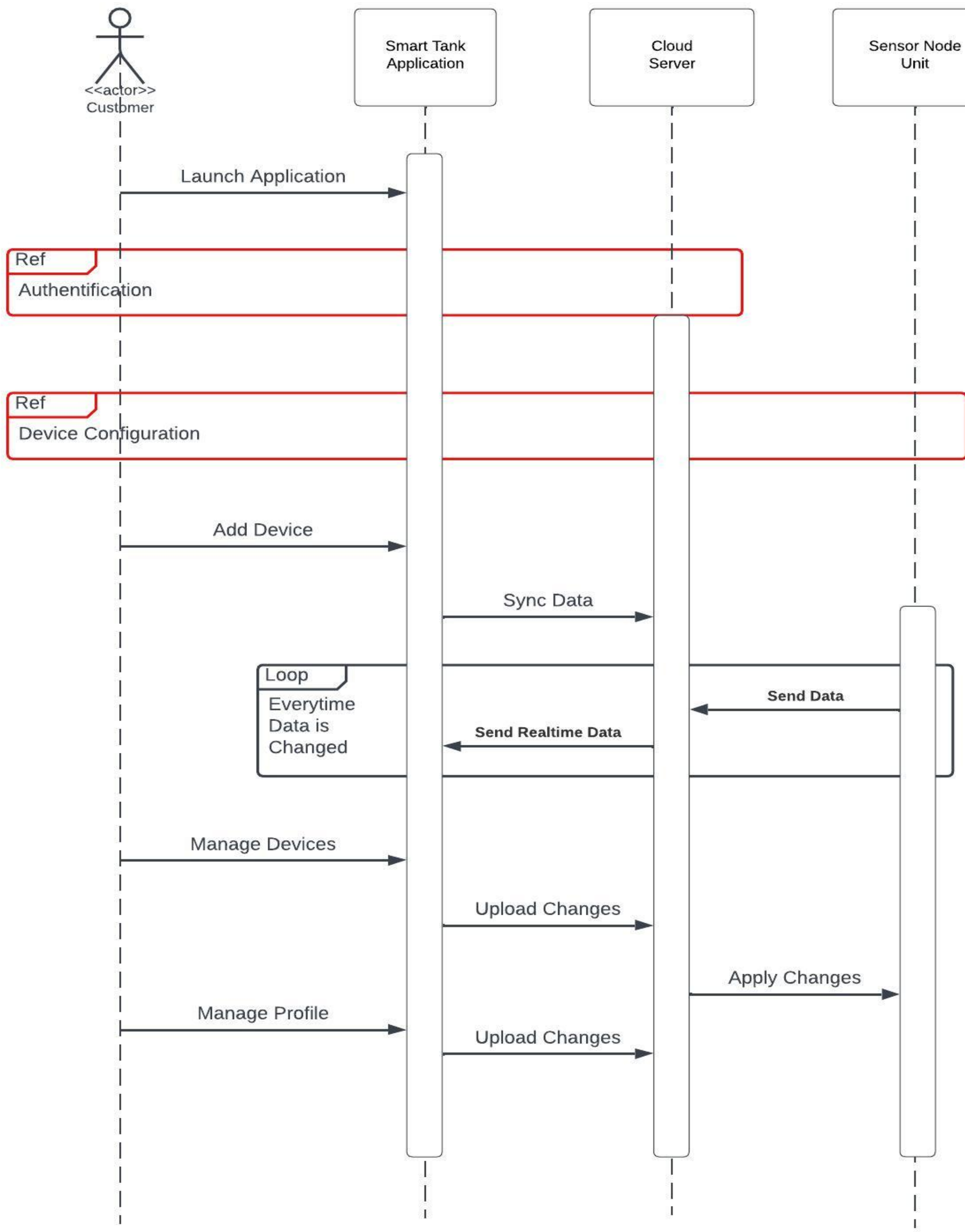

Figure 35: Sequence diagram of the app

3. **Flowchart** This diagram illustrates the flowchart of the system.

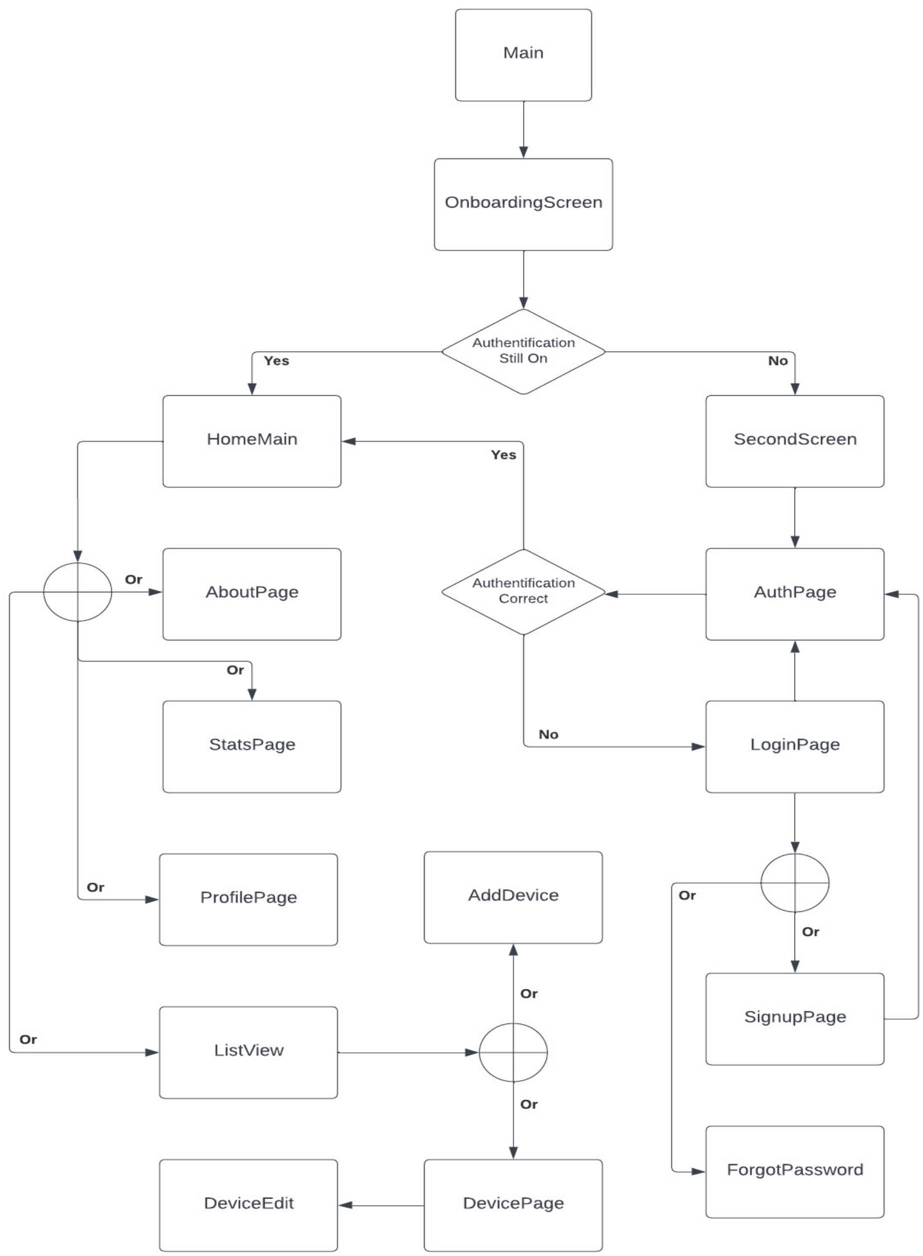

Figure 36: Flowchart of the mobile application

3.6 Chapter 3 Conclusion:

In this chapter, we delved into the intricacies of the smart water tank system, providing a comprehensive overview of its design and functionality. We began by presenting a detailed description of the system, highlighting its key features and capabilities. The system's functionality was carefully examined, considering aspects such as water level monitoring, temperature control, valve automation, and remote accessibility through a mobile application or web interface.

To enhance clarity and understanding, we supplemented the description with well-crafted system diagrams that visually illustrated the architecture and interconnections of the various system components. These diagrams served as valuable aids in comprehending the system's overall structure and operation.

By presenting a detailed description of the system and providing visual representations through system diagrams, we have established a solid foundation for the subsequent chapters. The information presented in this chapter serves as a road map for the implementation phase, guiding the development and realization of the smart water tank system's functionalities

Chapter 4 - System Implementation

4 System Implementation

4.1 Overview

In this chapter, we provide a detailed overview of the implementation of the smart water tank monitoring and control system. We discuss the key components of the system, including the sensors, micro-controller, and mobile application. We also examine the challenges and issues encountered during the implementation process and how they were addressed. The pseudo-code provides an algorithmic description of the system's logic. We describe the method used to validate the system, including hardware testing and software testing. We present the results of our validation efforts and provide an analysis and discussion of the findings. Finally, we conclude with recommendations based on the results to further improve the system's performance and reliability.

4.2 Description of the implementation

1. **Hardware components** The system consists of several hardware components, including an ultrasonic sensor, a temperature sensor, a Node-MCU ESP-32 micro-controller, a relay module, and a solenoid valve. These components are connected together through a breadboard and jumper wires.

2. **Power supply** The system is powered by a 5V DC power supply connected to the Node-MCU ESP-32 micro-controller, or it can be power by a solar panel and Li-ion battery combination.

3. **Sensor Calibration** Before using the sensors, they were calibrated to ensure accurate readings. The ultrasonic sensor was calibrated to measure the distance between the water surface and the sensor accurately, while the temperature sensor was calibrated to measure the temperature of the water inside the tank.

4. **Sensor data collection** The ultrasonic sensor measures the distance between the water surface and the sensor, while the temperature sensor measures the temperature of the water inside the tank. The data collected by the sensors is sent to the Node-MCU ESP-32 micro-controller.

5. **Data processing** The NodeMCU ESP-32 micro-controller processes the data collected by the sensors and calculates the amount of water in the tank based on the ultrasonic sensor readings.

6. **Valve control** The system uses a relay module to control the solenoid valve, which controls the flow of water into and out of the tank. The Node-MCU ESP32 micro-controller sends signals to the relay module to control the opening and closing of the valve based on the water level and temperature readings

7. **Mobile application** The system is connected to a mobile application that provides real-time updates on the water level, temperature, and other status information of the system. The application also allows the user to remotely control the valve and monitor the system from anywhere.

8. **WiFi application** The Node-MCU ESP32 micro-controller is connected to the internet through WiFi, allowing it to send data to the mobile application and receive control signals from the application.

9. **Enclosure** The system is enclosed in a waterproof enclosure to protect it from water damage and to ensure its longevity.

10. **Testing and validation** The system was extensively tested and validated to ensure its reliability and accuracy. Testing was done on both the hardware and software components of the system. The results of the testing are discussed in detail in the next section of this chapter

4.3 Mechanisms behind the system's operation

1. **Data collection** The system collects data from two sensors, the ultrasonic sensor, and temperature sensor. The ultrasonic sensor measures the water level in the tank, while the temperature sensor measures the temperature of the water.

2. **Data processing** The data collected by the sensors is processed by the NodeMCU ESP-32 micro-controller. The micro-controller calculates the amount of water in the tank based on the ultrasonic sensor readings, and checks for temperature levels.

3. **Status checks** The micro-controller checks the status of the system based on the data collected from the sensors. If the water level is low or nearing completion, the micro-controller closes the valve of the water tank to prevent water from overflowing or running out and sends a status notification to the user's mobile app. If the temperature is close to freezing, the micro-controller opens the valve to allow small amounts of water to escape from the tank, preventing the water inside the pipes from freezing and damaging the pipes.

4. **Communication with mobile application** The NodeMCU ESP-32 micro-controller sends the data collected from the sensors to the user's mobile app through WiFi. The mobile app provides real-time updates on the water level, temperature, and other status information of the system. The user can remotely control the valve and monitor the system from anywhere.

5. **Monitoring** The system continuously monitors the water level and temperature of the water in the tank. If the water level exceeds a certain threshold (low or high), the system closes both the input and output valves and sends a status notification to the user's mobile app. If the temperature is below 1 degree Celsius, the system opens the valve to allow small amounts of water to escape, preventing the water inside the pipes from freezing and damaging the pipes.

6. **Updating Data** The system regularly updates data stores data in the database

Overall, the system is designed to be reliable, efficient, and easy to use. It provides a convenient way for users to monitor and control their water tank system in real-time, ensuring that they always have sufficient water for daily use

4.4 Implementation issues and challenges

During the implementation of the system, we encountered several challenges that required us to find suitable solutions. These challenges include:

- **Power consumption** One of the main challenges we faced was finding a micro-controller that can operate efficiently while consuming low power. After considering several options, we settled on the ESP-32 micro-controller due to its low power consumption.

- **Cloud storage and analysis** Another challenge was finding a reliable and efficient way to store and analyze data collected by the system. We opted to use the Firebase Real-time Database, which offers an easy-to-use cloud-based solution for storing and retrieving data in real-time

- **Sensor calibration** Accurate sensor readings are crucial for the system to function properly. However, we faced difficulties in calibrating the sensors, particularly the ultrasonic sensor. To solve this challenge, we had to experiment with different calibration techniques until we achieved accurate and consistent readings.

- **Connectivity issues** The system relies heavily on a stable internet connection to communicate with the cloud database and the user's mobile app. However, we encountered connectivity issues, particularly in areas with weak or unstable network signals. To address this, we added a mechanism to buffer data in case of a connection loss, allowing the system to continue operating normally and update the cloud database once the connection is restored.

Despite the challenges we faced, we were able to successfully implement the system and ensure it operates efficiently and reliably.

4.5 Pseudo-code of the system

the following subsections provides a breakdown of the pseudo-code used in the system.

```
//Connect to the Internet and Database
connectToInternet()
connectToDatabase()

// Main loop for data collection and processing while true:
// Collect data from sensors
waterLevel = getWaterLevel()
temperature = getTemperature()
// Calculate water amount in the tank based on the ultrasonic sensor readings
amount = calculateWaterAmount(waterLevel)
// Check for low temperature
if temperature ¡ 1:
closeOutputValve()
openExternalValve() // to drain pipes and prevent freezing
alertUser("Water is close to freezing!")
// Check for low water level
if waterLevel is close to low point threshold:
closeOutputValve() // to ensure water availability
alertUser("Water is running low!")
// Check for high water level
if waterLevel is close to high point threshold:
closeInputValve() // to prevent water overflow
alertUser("Tank is full!")
// Update data
sendDataToDatabase()
end while loop
// Wait for next loop iteration
delay();
```

4.6 Validation Result

4.6.1 Hardware Testing

During hardware testing, the ESP32 micro-controller and sensors were evaluated for functionality and compatibility. The project setup in the lab is visually represented in the following images, showing the arrangement of components of the different devices:

1. **Size comparison between the Devices**

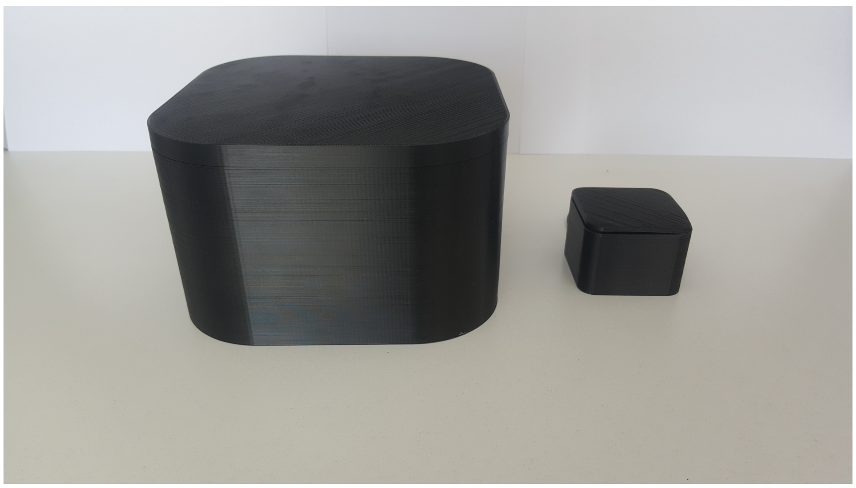

Figure 37: Size Comparison between different prototypes

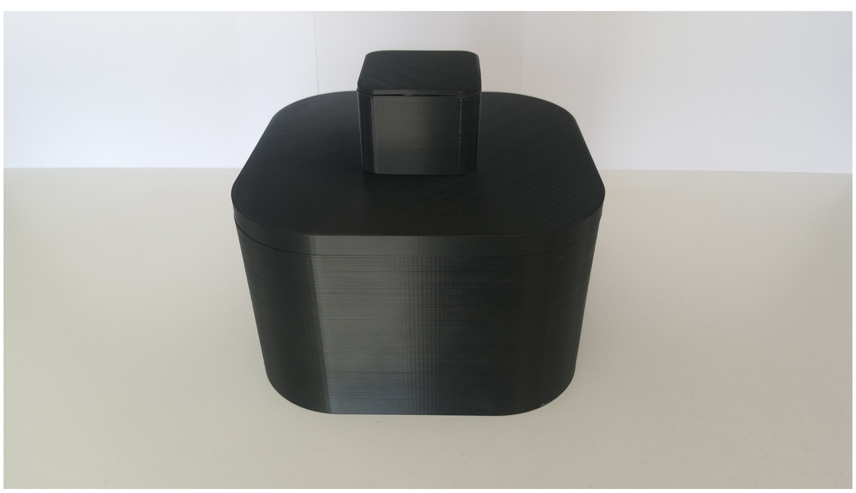

Figure 38: Size Comparison between different prototypes

2. **Main Device:** it contains the micro-controller, ultrasonic sensor, temperature sensor, relay modules to control water valves, LCD screen and a GSM module
this device works as a primary unit that is responsible of fulfilling the major roles and also to control secondary units (Auxiliary Devices)

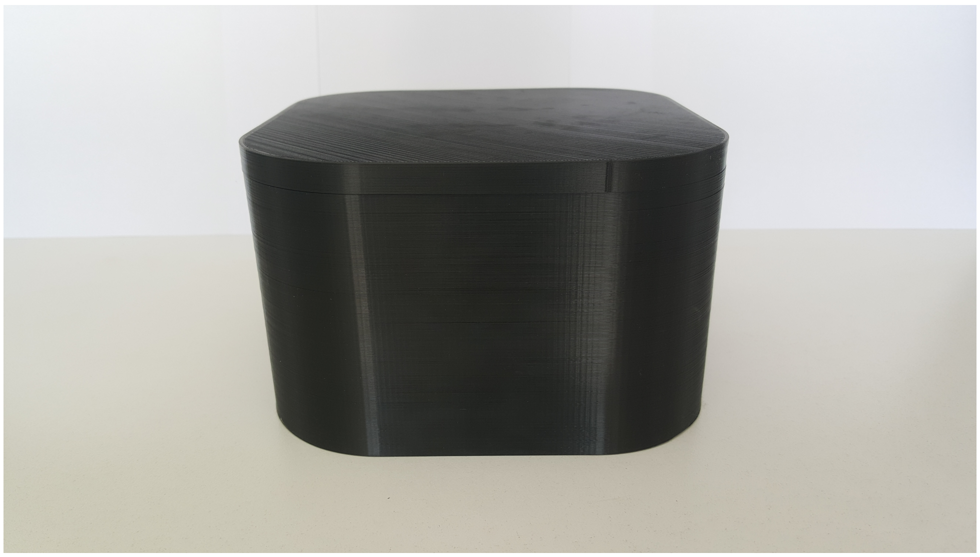

Figure 39: Main Device from the back

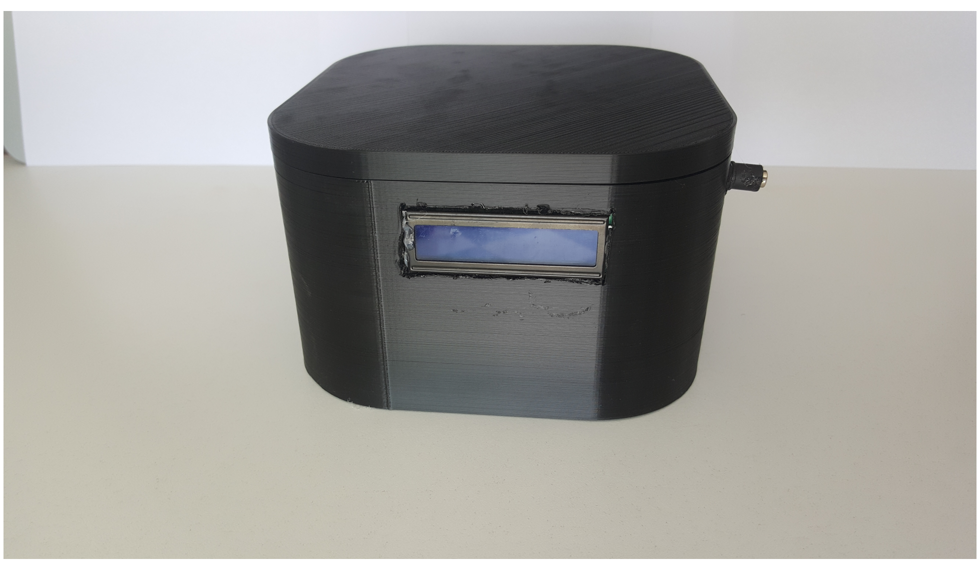

Figure 40: Main Device from the front

Figure 41: Main Device with the open cover where the fan is located

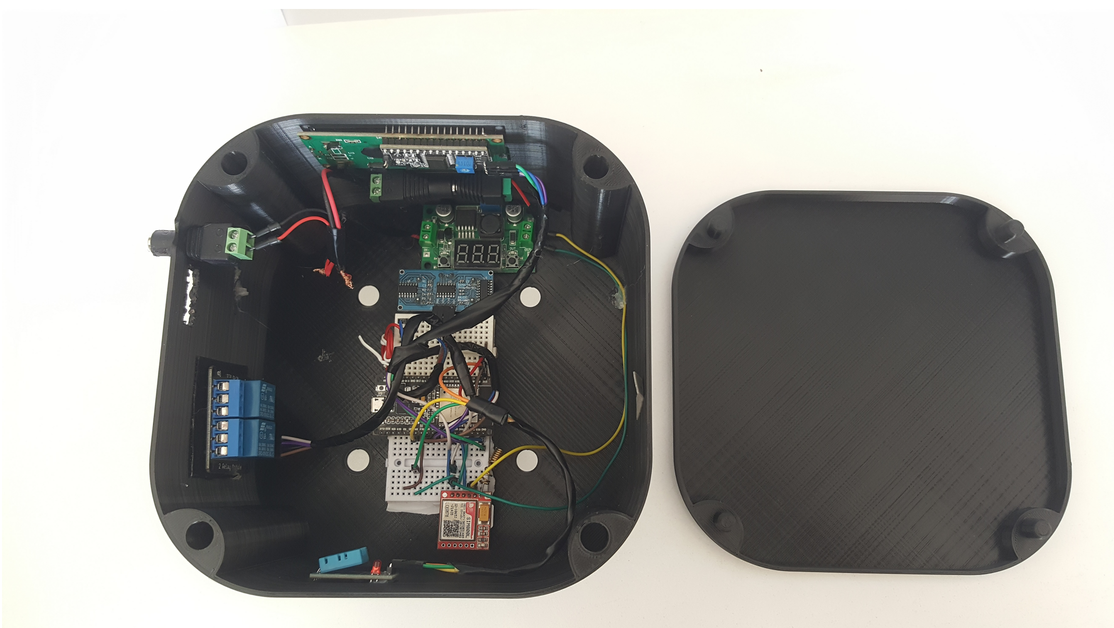

Figure 42: Main Device from the inside

3. **Auxiliary Device:** it can contain an ultrasonic sensor, temperature sensor, relay modules
   this device works as a secondary unit that is responsible of measuring, sensing and sending the data and to be controlled by a primary unit (Main devices)

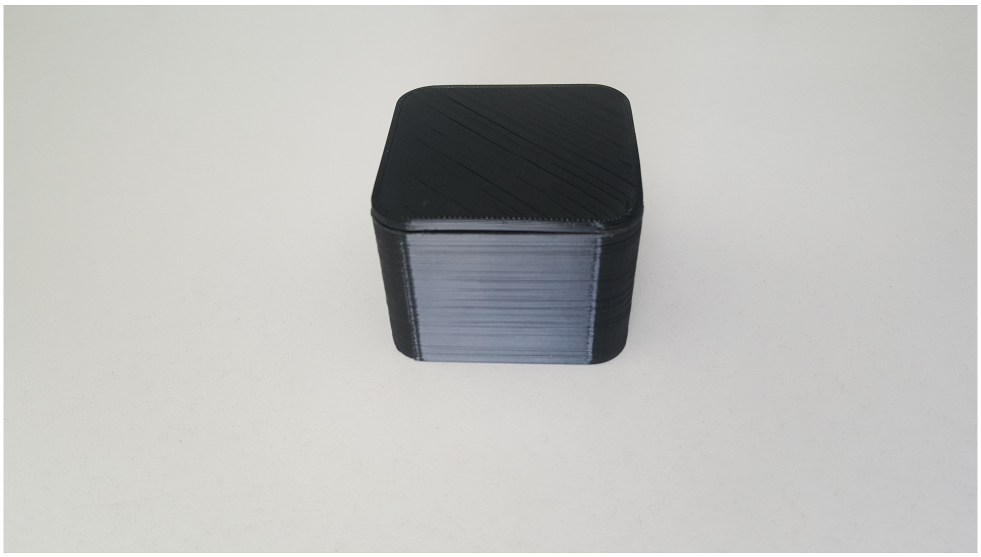

Figure 43: Auxiliary Device from front

Figure 44: Auxiliary Device from the side

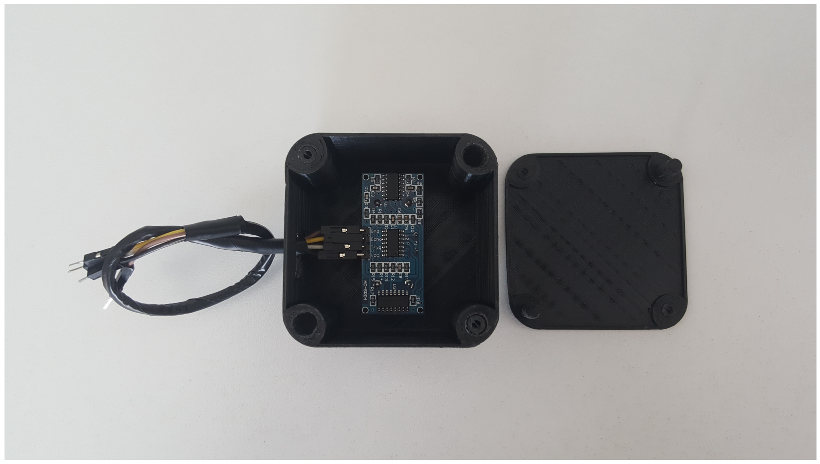

Figure 45: Auxiliary Device from the inside

4. **Maine Device Usage Example**

Figure 46: Example of Main Device installed on a water tank

The figure above shows how the device will be installed on top of any type of storage tank that has an opening on top

- The assembly of wires on the breadboard and ESP-32 controller was captured:

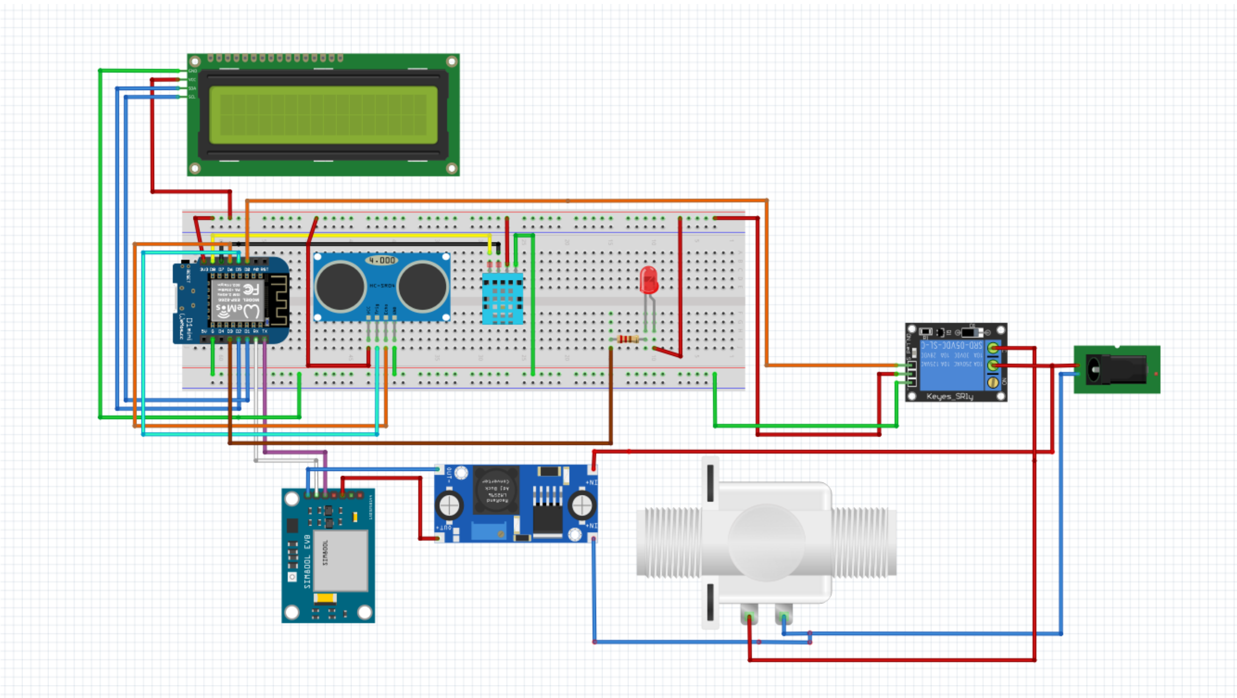

Figure 47: Hardware components connected and assembled on breadboard

- Data was successfully stored in Firebase Real-time Database:

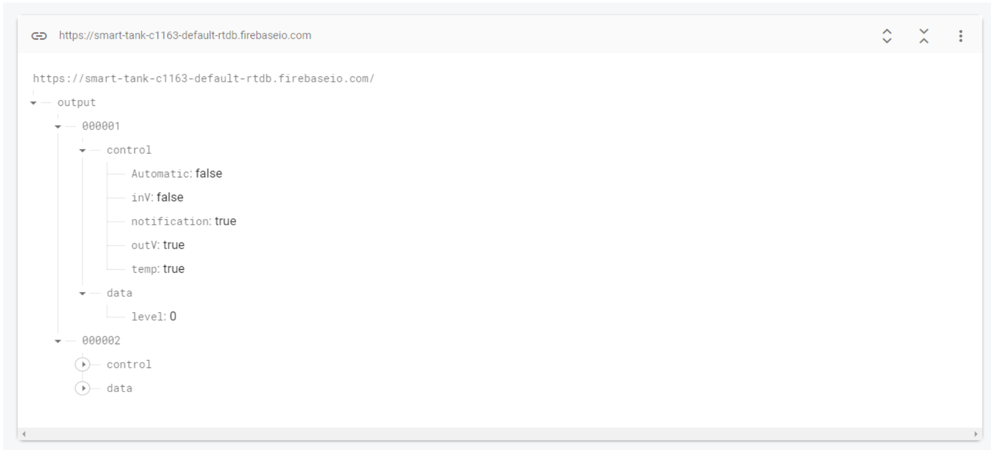

Figure 48: Fire-base Real-time database

These tests ensured the hardware components performed as intended, collecting and managing data effectively.

4.6.2 Software Testing

The tables below provide a detailed overview of the specific tests that were conducted to ensure the system's functionality and reliability.

#	Case	Expected Results	Obtained Results	Verdict
1	Internet	Connect to the Internet	Connected successfully	Pass
2	Database	Get Data from Database	Data collection successful	Pass
3	Sensors	Get sensors Data	Data collection successful	Pass
4	Send Data to Database	Send Data to Database	Data sent successfully	Pass

Table 4: Connection Test

#	Case	Expected Results	Obtained Results	Verdict
1	Tank is Full	Close input valve	Closed successfully	Pass
2	Tank is Empty	Close output valve	Closed Successfully	Pass
3	Low Temperature	Open output valve	Opened Successfully	Pass

Table 5: Automation Behavior Test

#	Case	Expected Results	Obtained Results	Verdict
1	API Connection	Display Data in User Interface	Data Displayed Successfully	Pass
2	Status Data	Show Current Tank Status Data	Data Displayed Successfully	Pass
3	Error Handling	Show Error Warning	Data Displayed Successfully	Pass

Table 6: Application data visualisation

#	Case	Expected Results	Obtained Results	Verdict
1	Check status of valves	show status of valves in use interface	Display data successful	Pass
2	Change status of valves (automatic)	change status in user interface and database	Change status successful	Pass
3	Control status of valves (manual)	control valves status in user interface	Control valves status successful	Pass

Table 7: Application valves control test

The mobile application was developed using Flutter, a cross-platform framework, making it compatible with both Android and iOS devices. It is integrated with Firebase real-time databases, enabling seamless data exchange with the cloud. Upon launching the app, users are directed to the home page, where they can view water levels, temperature readings, valve status, receive warnings if any issues arise, and they can switch between the different available functionalities.

The key features and functionalities of the mobile application include:

- **Real-time Monitoring:** The application displays real-time data of water level, and temperature collected from the sensors
- **Alert Notifications:** The application sends instant notifications to users when certain events occur, such as low water level, or freezing temperature
- **Control and Automation:** Users can remotely control the valves through the application and adjust the settings based on their needs.
- **Data Visualization:** The application provides visual representations of the collected data, such as graphs or charts, allowing users to analyze trends and patterns over time. This helps in making informed decisions regarding water management.
- **User Profiles and Settings:** The application supports multiple user profiles and devices, allowing different users to access the system with personalized settings. Users can configure settings and preferences according to their needs.

The following following section will showcase the app's functionalities.

1. **The registration process:** Upon opening the app, the user is greeted with a welcome page that contains information about the company and a slide in button, after the user slides the button he is sent to a sign in page where they need to enter their account details in order to login to their account. In the case of a new user, the option to sign up is available. Once signed in the users will be directed to the home dashboard where they can see connected devices and navigate the app. Additionally, users have the ability to edit their account details later.

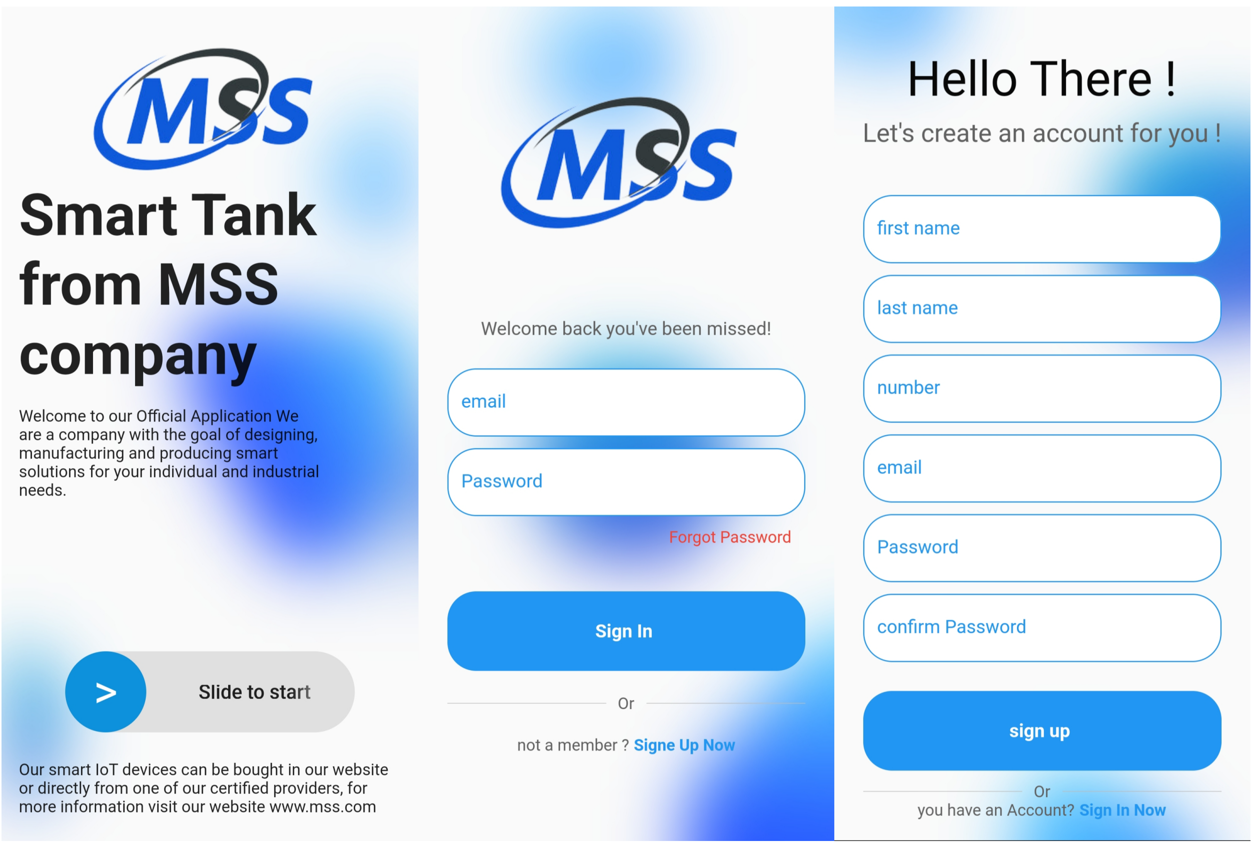

Figure 49: App launch and Registration

The figure above shows the following: welcome page to the left, sign-in page in the middle, sign-up page to the right

2. **Main Application pages:** The main application pages are, dashboard, statistics page, profile page.

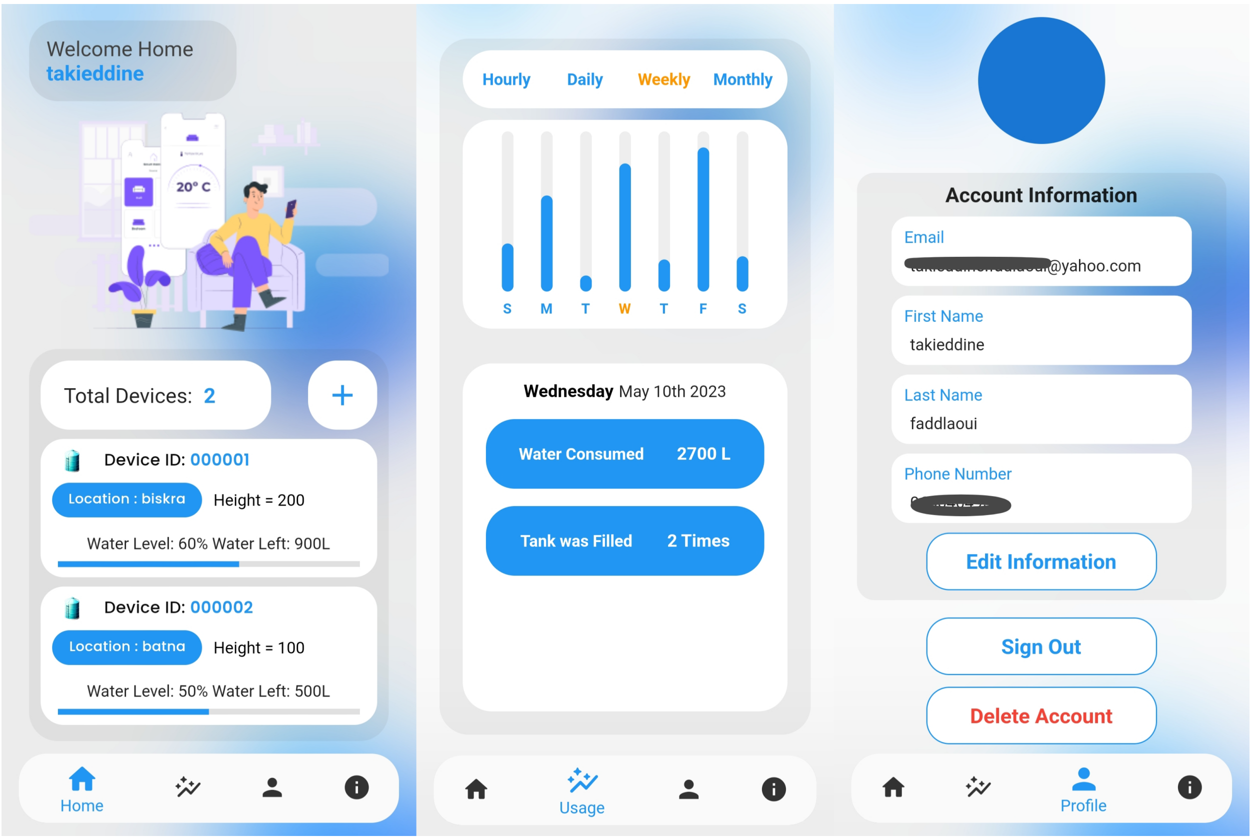

Figure 50: Main Application Pages

The figure above shows the following:

- Dashboard to the left, where the user can see a list of his devices, and he can either add a new device or click an already existing one to view it, he also gets an overview about the state of each device
- Statistics page in the middle, where the user can see his average water consumption by choosing the time stamps
- Profile page to the right, where the user can check hiss account information and take further actions listed in the Figure 39 below

3. **Account management process:** This section showcases how the user can manage his account either by editing his information, Signing-out or by deleting his account

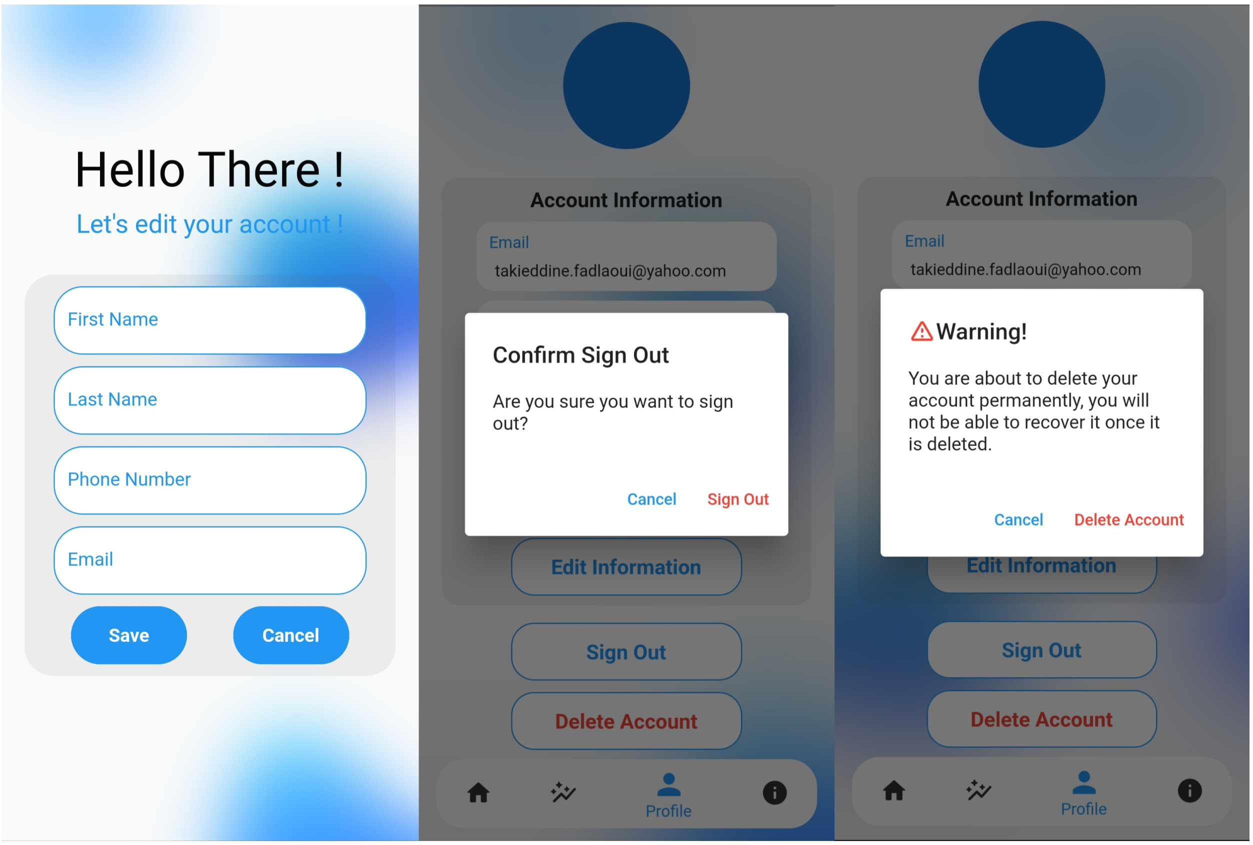

Figure 51: Account Management Process

The Figure above shows the following:

- Edit account page to the left, where the user can edit and change his information.
- Sign-out Page in the middle, where the user logs-out of the app
- Delete account page to the left, where the user can delete his account and all of his information

4. **Device management process:** This section showcases how the user can manage his device either by adding a new one, or editing the settings of an already existing device,

or by controlling the device.

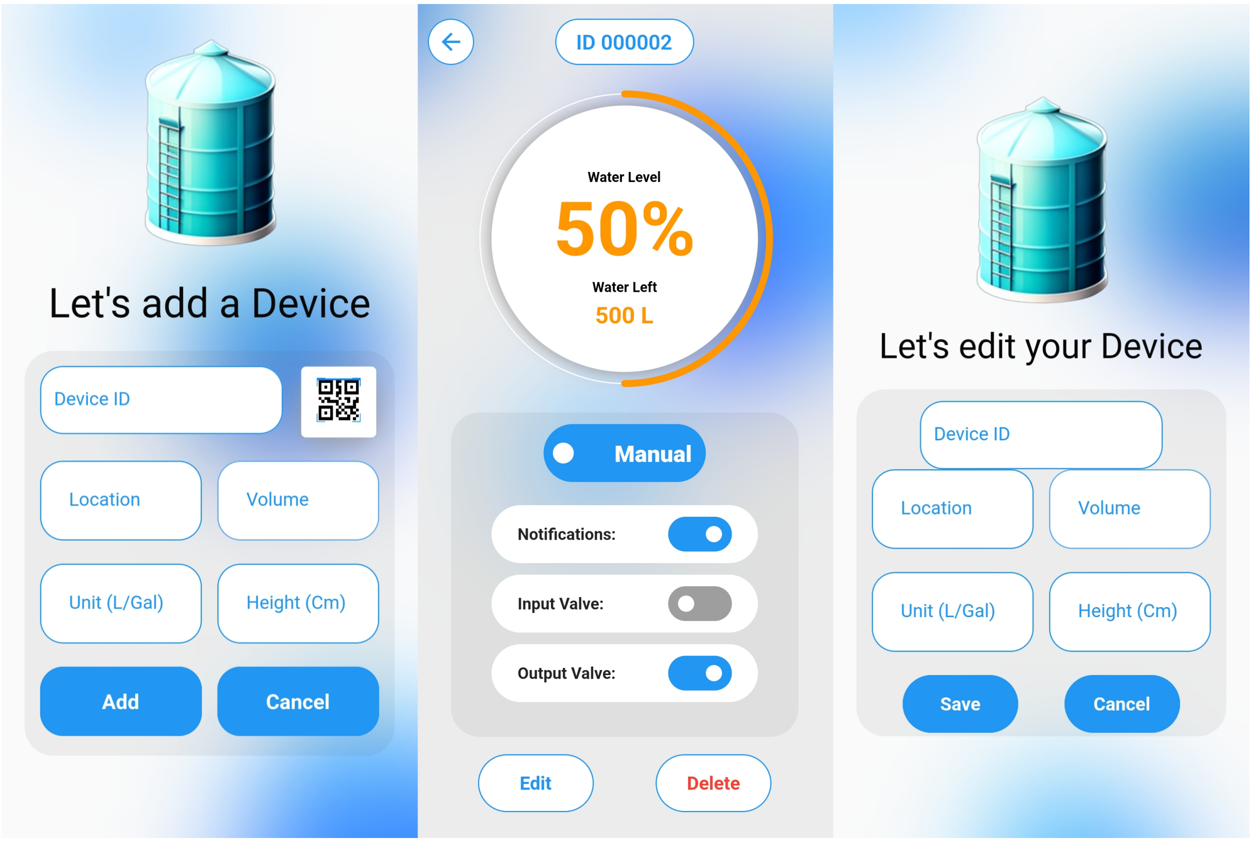

Figure 52: Device Management Process

The Figure above shows the following:

- Add device page to the left, where the user can add new devices by entering the characteristics of his tank or by scanning the QR-Code of the device.
- Device control Page in the middle, where the user can control different characteristics of his device, opening or closing water valves, enabling or disabling notifications, as well as selecting device mode (automatic or manual), the user can also delete devices.
- Edit device page to the left, where the user can edit or change the characteristics of a device in case the user changed the device to a new bigger or smaller tank.

5. **Water Level process:** This section showcases how the application displays the different states of the user interface and the water level and amount status

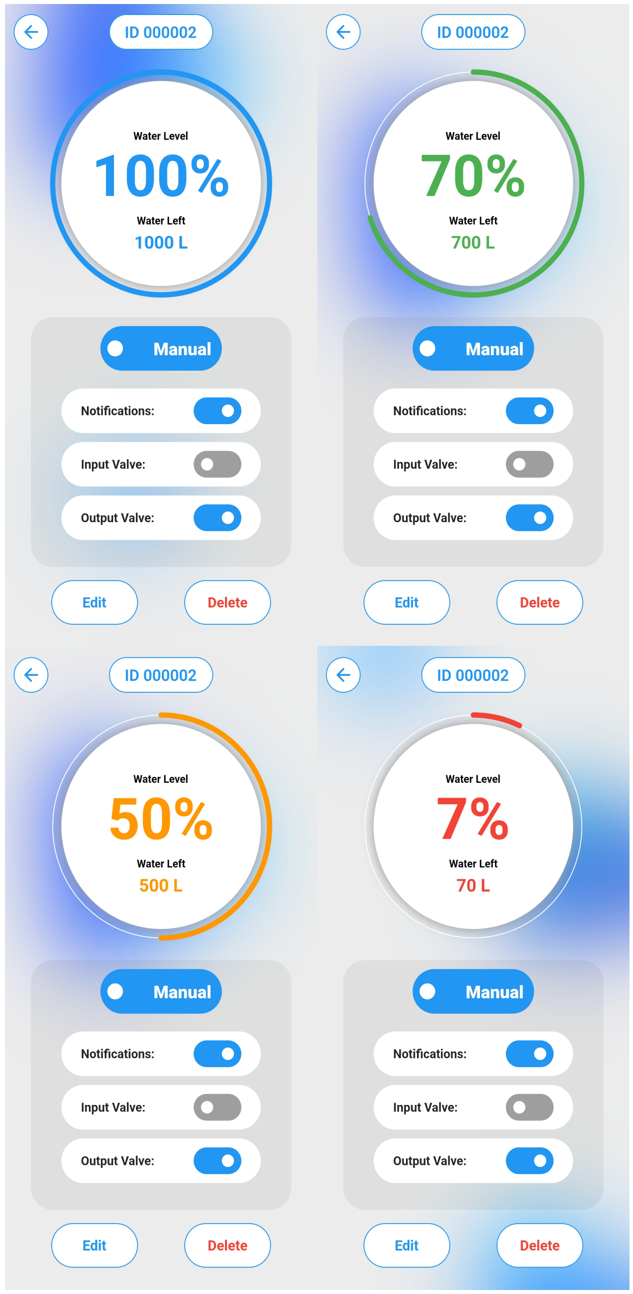

Figure 53: Water Level Process

The Figure above shows the following:

- If the water level is between 76 and 100% the interface will be displayed in the color Blue
- If the water level is between 51 and 75% the interface will be displayed in the color Green
- If the water level is between 26 and 50% the interface will be displayed in the color Orange
- If the water level is between 0 and 25% the interface will be displayed in the color Red

6. **Device Alerting process:** When water levels reach a critical level the user is alerted by an SMS message or by a notification, depending on the settings of the device.

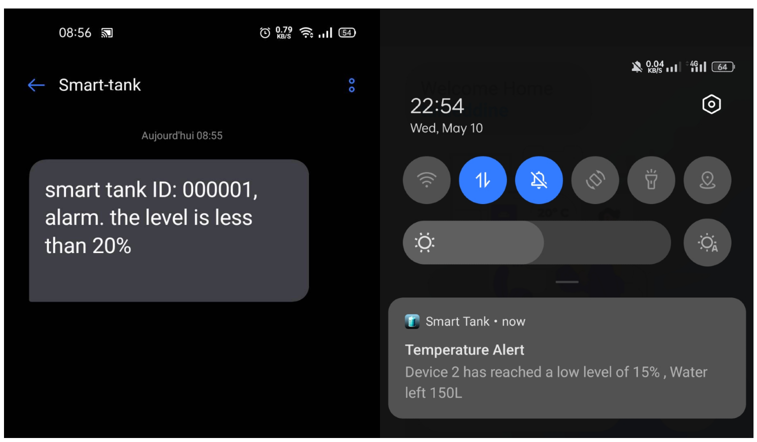

Figure 54: Device Alerting Process

The Figure above shows the following:

- Alerting by an SMS Message to the left, if the water level reaches a critical level the user will receive an SMS message alerting him of the situation
- Alerting by a notification to the right, if the water level reaches a critical level the user will receive a notification alerting him of the situation

4.7 Discussion

Throughout the implementation of the system, we have worked towards achieving the goals and objectives that were set for the project. We have successfully connected and programmed the components of the system, ensuring that they work together seamlessly. Several tests were performed to ensure that the system is functioning properly, meeting all the required specifications.

One of the most significant achievements was the successful collection of data from the sensors. The controller was able to store, process, analyze, and perform calculations on the obtained data, and control the valves accordingly.

We encountered several challenges during the implementation of the system, such as selecting the appropriate micro-controller and storing data in the cloud. However, we were able to overcome these issues by selecting the ESP32 as the appropriate micro-controller for the system and using Firebase database to store data.

Overall, the system was able to perform all its intended functions, including the process of sending and receiving data from the database, which was done correctly. The mobile application was able to display the required messages and perform the necessary controls as needed. Based on the results obtained, we are confident that the system is a significant step forward towards providing a reliable and efficient solution for monitoring and controlling water in tanks.

4.8 Chapter 4 Conclusion:

Chapter 4 provided an in-depth overview of the practical implementation and validation of the smart water tank system. The chapter presented the detailed process of implementing the system, including the integration of hardware and software components. Throughout the implementation, several challenges and issues were encountered, highlighting the complexity of translating the system design into a functional prototype.

The chapter further discussed the validation process, which involved rigorous hardware testing and software testing. The validation results demonstrated the effectiveness and reliability of the system in monitoring and controlling the water tank. The system successfully collected data from sensors, processed it through the micro-controller, and communicated with the mobile application. The validation process also shed light on potential areas for improvement, such as enhancing sensor accuracy and optimizing system responsiveness.

Overall, the implementation and validation phase proved the feasibility and functionality of the smart water tank system. It provided valuable insights into the system's performance, limitations, and possibilities for further enhancements. The findings from this chapter serve as a foundation for the subsequent chapters, where the implications and recommendations based on the validation results will be explored in more detail.

Chapter 5 - Conclusion and Future Works

5 Conclusion

This project aimed to develop a smart water tank monitoring system that enables efficient water usage by automatically controlling the water flow based on real-time environmental data. The system was successfully implemented and tested, demonstrating its ability to effectively monitor and control water usage.

Through the course of the project, several key findings and contributions have been made. Firstly, the use of sensors and a micro-controller enabled real-time monitoring of the water levels and temperature. Secondly, the integration of cloud storage and a mobile application allowed for remote control and monitoring of the system. Finally, the system demonstrated improved water efficiency and reduced water waste through its automated control of the water flow.

However, there were also some limitations and shortcomings of the system. One of the main limitations is that the system relies heavily on the availability of an internet connection to send and receive data from the cloud database, which may not always be feasible in certain environments. Another limitation is the accuracy of the sensor measurements.

In terms of future work and improvements, several areas could be addressed. Firstly, further research could be conducted to improve the accuracy of the sensor measurements and reduce their sensitivity to environmental factors. Secondly, alternative methods of communication between the system and the cloud database could be explored, such as using a local server. Finally, the system could be expanded to include more advanced features such as predictive analysis and machine learning algorithms to further optimize water usage.

Overall, this project has successfully developed and implemented a smart water tank monitoring system that effectively monitors and controls water usage. While there are limitations and areas for improvement, the project provides a foundation for future research and development in the field of smart agriculture.

6 Future works

Although the current system has achieved the project objectives, there is always room for improvement and further development to enhance its functionality and performance. Here are some potential areas of future work that could be explored:

1. **Integration with machine learning algorithms:** while the current system is capable of storing and analyzing data, there is room for improvement in terms of the accuracy and reliability of the data. Future work could involve exploring machine learning algorithms to improve the accuracy of the data analysis and decision-making processes.

2. **. Expansion to other use cases:**the current system is designed for a specific use case (Home Water Tanks), but it could be adapted for use in a variety of other scenarios. For example, the system could be used to monitor and control water levels in a swimming pool, or to automate the watering of plants in a garden. Future work could involve exploring these other use cases and designing new hardware and software components that can be easily adapted to different scenarios.

3. **Mobile application improvements:**there is also potential to improve the user interface of the system, making it more intuitive and user-friendly. This could involve redesigning the mobile application or developing a web-based interface that can be accessed from any device.

4. **Water Usage:**Even though we update and save water usage data to the cloud, we will still need to implement a functionality that would calculate and predict current and future water usage.

5. **Addressing potential cyber-security risks:**As the system is connected to the internet, it may be vulnerable to cyber-attacks. Therefore, future work should include identifying and addressing potential cyber-security risks to ensure the system's security

It is important to note that implementing these potential future work areas may come with challenges and obstacles such as cost, and potential impact. Therefore, careful consideration should be given to determine the feasibility and impact of each recommendation.

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