Review of Computer Engineering Research
2025 Vol. 12, No. 2, pp. 66-79
ISSN(e): 2410-9142
ISSN(p): 2412-4281
DOI: 10.18488/76.v12i2.4216

Smart water leak detection using wireless sensor networks

Mahfujur Rahman[1+]
Md. Raishul Islam[2]
S. M. Atikul Islam[3]
Md. Afjal Hossan Shajal[4]

[1,4]*Institute of Information Technology, Jahangirnagar University, Savar, 1342, Dhaka, Bangladesh.*
[1]*Email: mahfuj.ece@gmail.com*
[4]*Email: afjalhossan.ece@gmail.com*
[2,3]*Electronics and Communication Engineering, Institute of Science, Trade & Technology (Affiliated by National University, Bangladesh), Gazipur, 1704, Dhaka, Bangladesh.*
[2]*Email: raishul2019@gmail.com*
[3]*Email: smatik.ece@gmail.com*

(+ Corresponding author)

Article History
Received: 17 March 2025
Revised: 24 April 2025
Accepted: 5 May 2025
Published: 22 May 2025

Keywords
Arduino
GSM technology
Leak detection
Remote sensor systems
Smart water leakage detection
Water distribution networks.

ABSTRACT

This study explores the use of remote sensor systems to detect leaks in underground water pipelines, aiming to tackle the problem of water loss in distribution networks. Identifying and preventing such leaks is essential for the sustainable management of natural water resources. To address this challenge and improve leak detection, the authors designed a remote system that utilizes flexible wireless sensors to identify leaks while minimizing energy consumption. This system also evaluates the time and cost efficiency of smart water leakage detection (SWLD) in pipelines, monitors water levels in storage tanks, and automatically activates controls when water levels drop below a set threshold. The proposed approach is built around two main components. The first utilizes GSM (Global System for Mobile Communications) technology to send SMS alerts to the owner. Core elements of this system include sensors, a GSM module, an Arduino board, and a switch for device control. The second component features an Android-based application that allows for remote management of the system. By enabling early leak detection, the system aims to lower the costs and time involved in pipeline maintenance, enhance operational efficiency, and reduce long-term repair efforts.

Contribution/Originality: This research presents an intelligent and energy-efficient leak detection system that combines flexible wireless sensors with GSM notifications and Android-based remote access. Its two-part design supports real-time monitoring, efficient maintenance, and automatic water level control, providing an effective approach to sustainable water resource management.

1. INTRODUCTION

Water distribution systems are essential for supplying clean water to communities, but leakage in underground pipelines remains a major challenge, leading to significant water wastage, higher operational costs, and inefficiencies in resource management. Detecting and preventing leaks in water pipelines is crucial for ensuring sustainable water conservation and efficient distribution.

To tackle this issue, this paper presents a smart water leakage detection (SWLD) system that utilizes remote sensor technology. The system is designed to accurately identify leaks in underground pipelines while optimizing energy usage and reducing maintenance costs. It integrates wireless sensors, Global System for Mobile

Communications (GSM) technology, and an Arduino-based control mechanism to detect leaks in real time and notify users via Short Message Service (SMS). Additionally, an Android-based application is incorporated to enable remote monitoring and system control.

The proposed system enhances the efficiency of water distribution networks by minimizing maintenance delays and lowering the long-term costs associated with pipeline repairs. By leveraging advanced sensor technology and automated control mechanisms, this system provides a reliable and cost-effective solution for smart water management.

2. LITERATURE REVIEW

This framework is developed to manage and operate a Wireless Sensor Network (WSN) that monitors the condition of water bodies by utilizing data gathered from sensors placed in the water. It also includes functionality to initiate corrective actions for restoring contaminated water, thereby ensuring the water meets the necessary quality standards for local usage. An Arduino Nano microcontroller powers the system for detecting water leakage and enabling remote control. Users can access features such as leak detection via a mobile application and automated water level management in storage tanks. The primary objective of this system is to enhance convenience in daily life while promoting efficient water management. The remote voice services began with original circuit-switched technology, which was exclusively for voice communication and lacked SMS or other data services. Misiunas et al. [1] the shift from this original system to the Second Generation (2G) represented a significant advancement, introducing features such as data storage, billing, encryption, and compression, allowing for error correction in data transmission without loss. Daadoo et al. [2] second-generation technologies, including GSM, utilize both Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA). In Daraghmi and Daadoo [3], in this system, the frequency spectrum is divided into smaller segments, which are further divided into time slots, allowing users to be assigned specific frequencies and time slots for communication. The evolution to 2.5G technologies introduced GSM/GPRS (General Packet Radio Services), which is a data-oriented technology that enhances GSM voice services, theoretically providing speeds of up to 200 Kbps and paving the way for a new era of mobile communication [4].

Third Generation (3G) cellular networks were designed to provide high-speed data rates of up to 2 Mbps or higher in service areas, allowing operators to offer multimedia and various data services to end users. Technologies such as Code Division Multiple Access (CDMA) and Universal Mobile Telecommunications System (UMTS) enable these data speeds. To enhance packet data performance, High-Speed Packet Access (HSPA) was developed as an upgrade to Wideband Code Division Multiple Access (WCDMA) systems. Kadar, et al. [5] and Nguyen and Le [6]. As the demand for faster download speeds and greater data volume per user has increased, High-Speed Downlink Packet Access (HSDPA) was introduced to achieve even higher data rates, reaching up to 14.4 Mbps. This was made possible by using advanced transmission techniques and Multiple-Input Multiple-Output (MIMO) technology to improve downlink data flow [7, 8].

The transition to Fourth Generation (4G) networks is motivated by the growing data demands expected in the future. Long Term Evolution (LTE), the standard for 4G, was created to handle this surge in data consumption. However, 4G has yet to capture a large market share, mainly due to a lack of devices that support LTE's Orthogonal Frequency-Division Multiple Access (OFDMA) method and the existing network infrastructure. As noted by Daadoo and Daraghmi [9], LTE currently focuses on data services rather than voice communication, although improvements are underway to enable voice capabilities, which will then be known as "advanced LTE." Depending on the network architecture and frequency spectrum, LTE can support speeds over 100 Mbps.

This paper focuses on improving user security when they are away from home, with SMS, a feature of GSM technology, enabling remote communication from anywhere. Tarapiah et al. [10] propose the use of an Arduino microcontroller to design a system for detecting water leakage and providing remote control capabilities. This system sends instant notifications to users' GSM mobile phones via SMS and allows them to activate or deactivate the system through text messages. The system also includes features such as water leakage detection and water level monitoring in tanks via a mobile application. The goal of this system is to improve operational efficiency, reduce response times, and lower maintenance costs associated with pipeline repairs after a leak is detected [11].

2.1. Problem Statement

The primary issue arises when pipelines are formed and the pressure exceeds the maximum allowable threshold. This excess pressure causes the pipelines to fail, leading to bursts or ruptures within the system. Bowling [11], as a result, the water flowing through these pipelines deviates from its intended path, causing significant leakage and spills. Such incidents not only waste valuable water resources but also result in potential damage to property and increased maintenance costs. The problem is further compounded by the difficulty in detecting these failures early and preventing water wastage. Zulhani and Mohd [4]. This paper aims to address the issues of pipeline pressure management, early leak detection, and effective control to prevent water spillage in hydraulic systems.

3. METHODOLOGY

The block diagram of the proposed system, as shown in Figure 1, outlines the various functions that the system will perform based on the system requirements and specifications. A modular system design approach has been employed, with the Arduino Nano microcontroller at its core. This paper highlights some of the key circuit concepts utilized in the system's design.

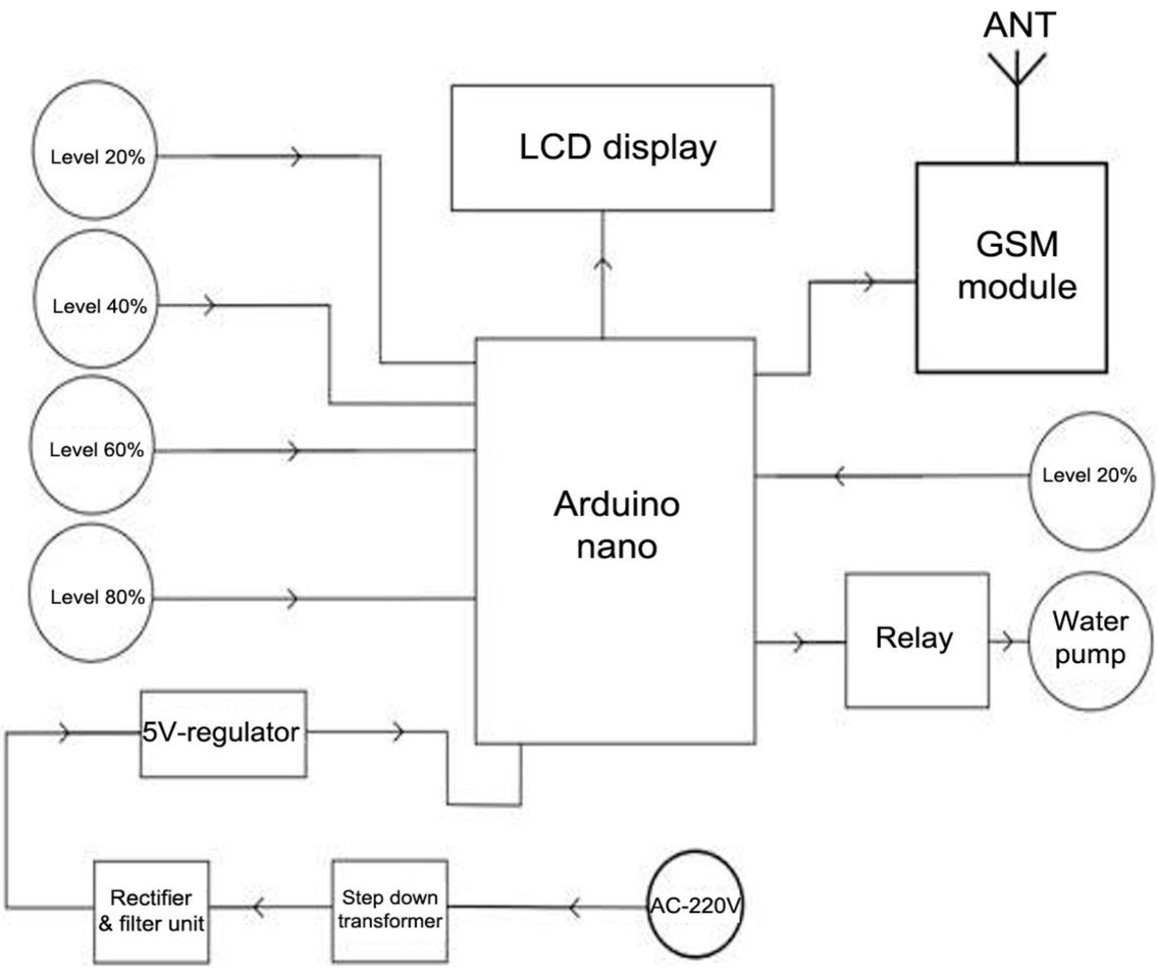

Figure 1. Block diagram for smart water leak detection using wireless sensor networks.

The system is equipped with water sensors in the tank to detect leaks and ultrasonic sensors to measure the water level. These sensors collect data, which is processed by the Arduino Mega. Based on this information, SMS alerts are sent to the owner through the GSM module. Kumar and Jagadeep [12] and Penteado et al. [13], the system consists of two primary components: the first is an alert mechanism that sends an SMS via GSM when a leak is detected, while also reducing the risk by opening the solenoid valve to stop the water flow. The second component allows the system to be controlled through an Android application, which operates the pump and activates it when the water level in the tank is low. The system monitors water levels to prevent flooding and regulate the flow within the water tank. This water control framework improves the functionality of home automation systems. The current automated level detection method allows the device to be activated or deactivated as needed. In contrast, the traditional method of level control for home appliances typically involves turning on the feed pump when the water level is low and leaving it on until the tank reaches a higher level. However, this method lacks efficient control. Additionally, liquid level control systems are widely used for monitoring fluid levels in applications such as reservoirs, silos, dams, and more.

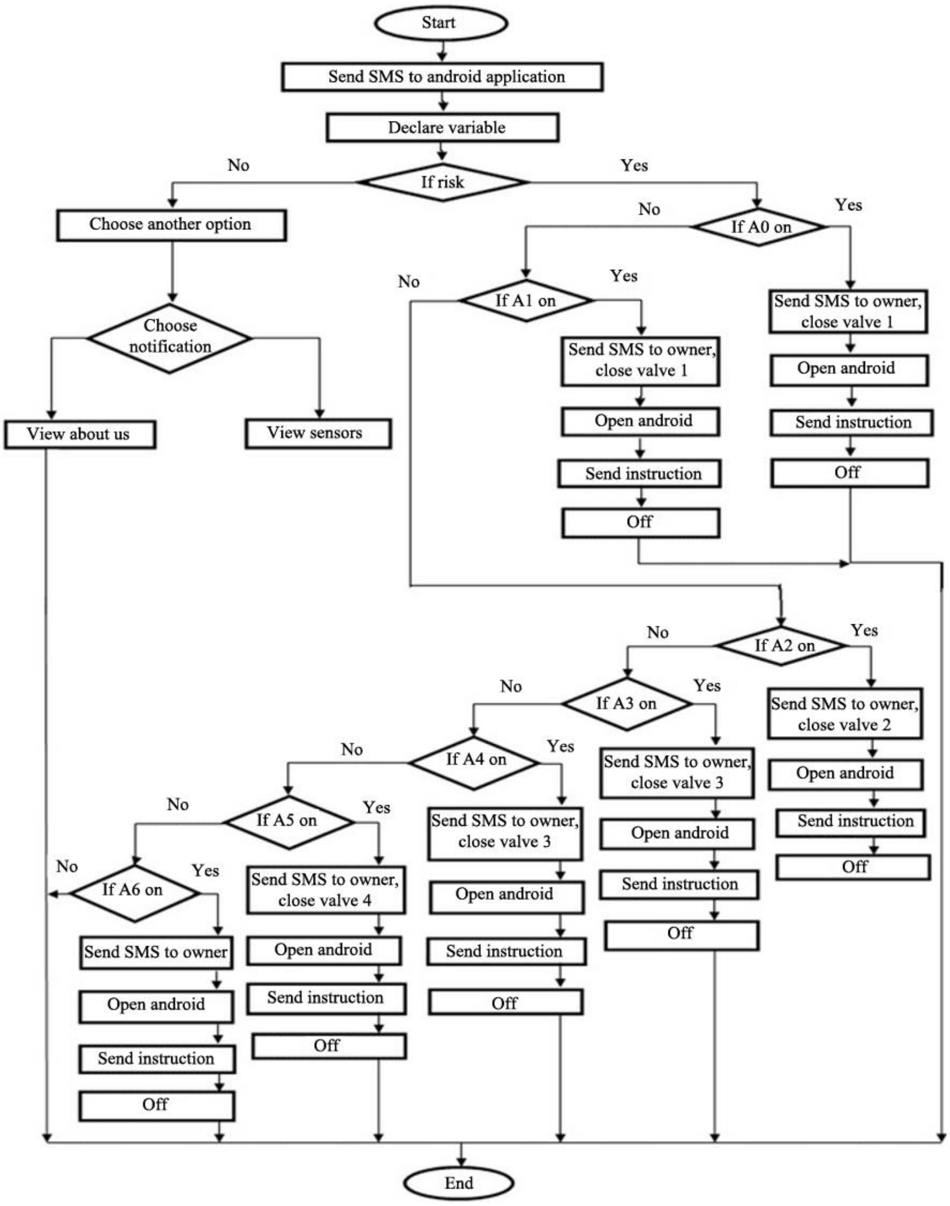

Figure 2. Flowchart of the system.

Figure 2 shows the flow of an integrated system that controls the pump and valves by sending an SMS to the user's mobile phone for ease of use. The system monitors the water and water level sensors, and if there is a drop or reduction in the tank's water level, it will take appropriate actions to alert the homeowner. If there is any potential risk, an SMS alert will be sent to the owner. The homeowner can control the system within the designated area by turning the pump on or off upon receiving an SMS from the device.

The flowchart in Figure 2 outlines the following steps for the system.

1. Start Process: The system begins its operation.
2. Sending SMS to the Android Application: The system sends an SMS to an Android application to establish communication.
3. Declare Variable: Variables are declared to track conditions and make decisions.
4. Risk Assessment: The system checks for risks.

- If No Risk: The user can select from options such as.
- View About Us (General system information).
- View Sensors (Monitoring sensor data).
- If Risk Exists: The system takes automated actions.
- Example (For A0 ON).
- Sends an SMS to the owner.
- Closes Valve 1.
- Opens the Android application.
- Sends instructions.
- Turns off the system.
- This process continues through various AI levels (A1, A2, A3, A4, A5, A6), each controlling different valves and sending notifications.

5. Multiple AI Levels and Valve Control: The system checks each AI level sequentially (A1 → A2 → A3 → A4 → A5 → A6).

- If AI is ON.
- Sends SMS alerts.
- Closes the corresponding valve.
- Opens the Android application.
- Sends further instructions.
- If AI is OFF, it proceeds to check the next AI level.

6. End Process: After performing the necessary actions (closing valves, sending notifications, etc.), the system shuts down and ends the process.

4. IMPLEMENTATION

Figure 3 illustrates the Smart Water Level Detection (SWLD) and Control System, which automates water management using sensors, a microcontroller, and a GSM module. Water and ultrasonic sensors measure the tank's water level, while a solenoid valve controls the water flow, and a pump refills the tank when necessary. The microcontroller processes the sensor data to manage the pump's operation. Additionally, the GSM module sends real-time alerts to the user's mobile device, allowing for remote monitoring and control. This system optimizes water usage, prevents overflow, and reduces the need for manual supervision, improving overall efficiency.

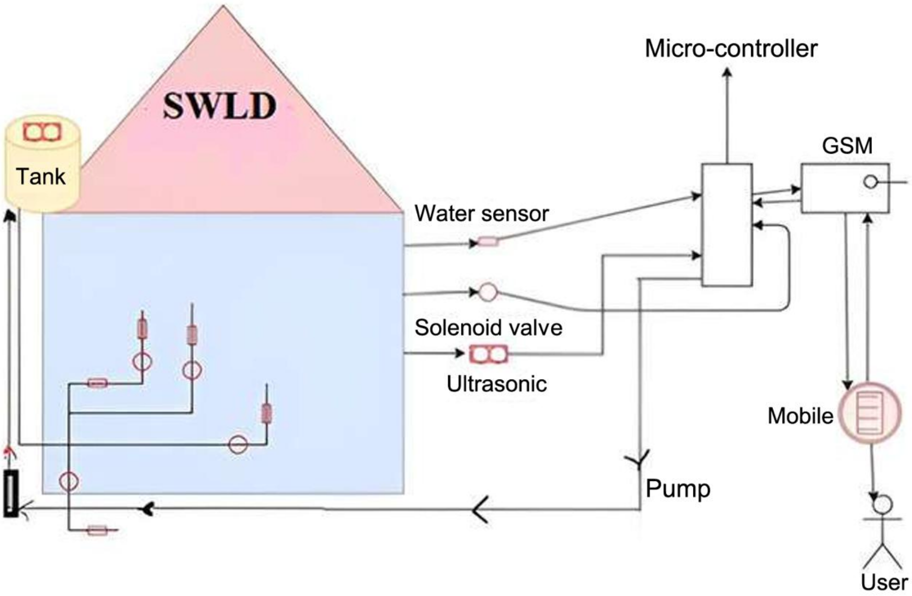

Figure 3. Architecture for smart water leak detection.

4.1. Hardware Design

Figure 4 presents the components of the equipment. In this paper, we will establish the system's structure by using well-known commands and selecting appropriate manufacturers to integrate these components into a well-functioning system that operates seamlessly with the machine's parts. *Farah and Shahrour [14]* Product instructions will guide the choice of mechanical detection units and actuators. The framework tools have been designed to be straightforward and user-friendly, featuring controllers that manage the Arduino Nano, water level sensor, LED display, registry, water siphon, electric relays, valve actuators, and siphon collectors. Additionally, the system uses a sensor, and the output pin of the controller is connected to both a buzzer and an electric relay.

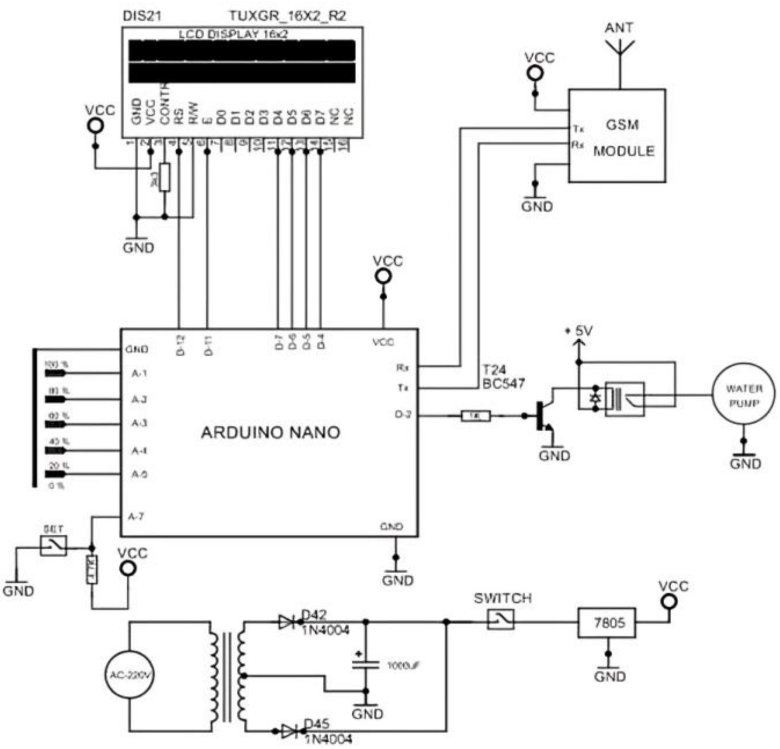

Figure 4. Circuit diagram of system.

4.2. Theory of Operation

Figure 5 depicts a parallel plate capacitor containing a dielectric material between its two plates. One plate holds a positive charge (+Q), while the other holds an equal negative charge (−Q), creating an electric field EEE that is illustrated by blue arrows pointing from the positive to the negative plate. According to Abate et al. [15], the dielectric, shown as orange ovals with "+" and "−" signs, consists of molecules that become polarized in the presence of the electric field. This polarization reduces the overall electric field within the capacitor, allowing it to store more charge for the same voltage. Boudhaouia and Wira [16]. The diagram also highlights key physical parameters: the surface area of the plates (A) and the separation between them (d). In summary, the image demonstrates how the dielectric material enhances the capacitor's ability to store electric charge by decreasing the effective electric field [17, 18].

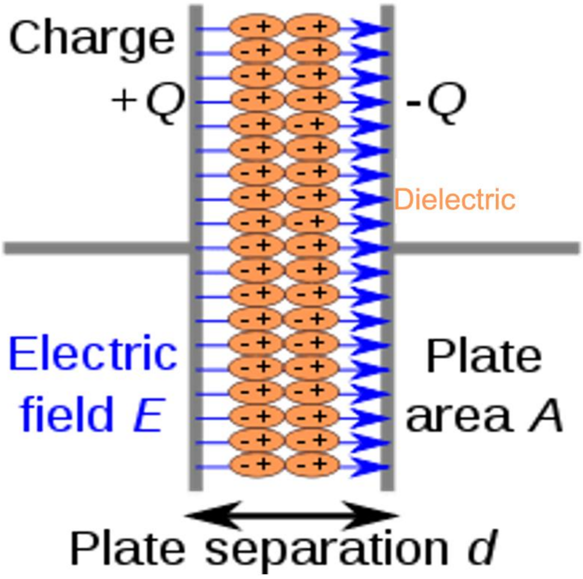

Figure 5. Construction of capacitors.

A capacitor consists of two conductors separated by a non-conductive material known as the dielectric, which serves as an electrical insulator. Common dielectric materials include glass, air, paper, vacuum, and even chemically altered semiconductor regions that maintain electrical properties similar to those of the conductors. A capacitor is generally regarded as a self-contained and isolated component, meaning it carries no net electric charge and is not influenced by external electric fields. The conductors hold equal but opposite charges on their facing surfaces, while the dielectric creates an electric field between them.

In the International System of Units (SI), a capacitance of one farad means that when each conductor carries a charge of one coulomb, a voltage of one volt is applied across the device.

An ideal capacitor is entirely defined by a constant capacitance *C*, which is expressed as the ratio of charge ±Q on each conductor to the voltage *V* between them.

$$C = \frac{Q}{V}$$

As the conductive plates are placed close to one another, the opposing charges generate an attractive force through their electric fields. This interaction allows the capacitor to store more charge for a given voltage compared to when the conductors are farther apart, leading to higher capacitance.

In some cases, the stored charge can mechanically affect the capacitor, altering its capacitance. Under such conditions, capacitance is defined in terms of small variations:

$$C = \frac{dQ}{dV}$$

4.3. User Management System

Figure 2 shows that the mortgage holder must first log in before proceeding. After logging in, they need to make a decision that determines the policy display, offering options such as warnings, sending guidance, and accessing the "About Us" section. Once the initial decision is made, the process involves seven categories (A0, A1, A2, A3, A4, A5, A6) and evaluates risk by filling out two specific forms. After completing these steps, an SMS is sent.

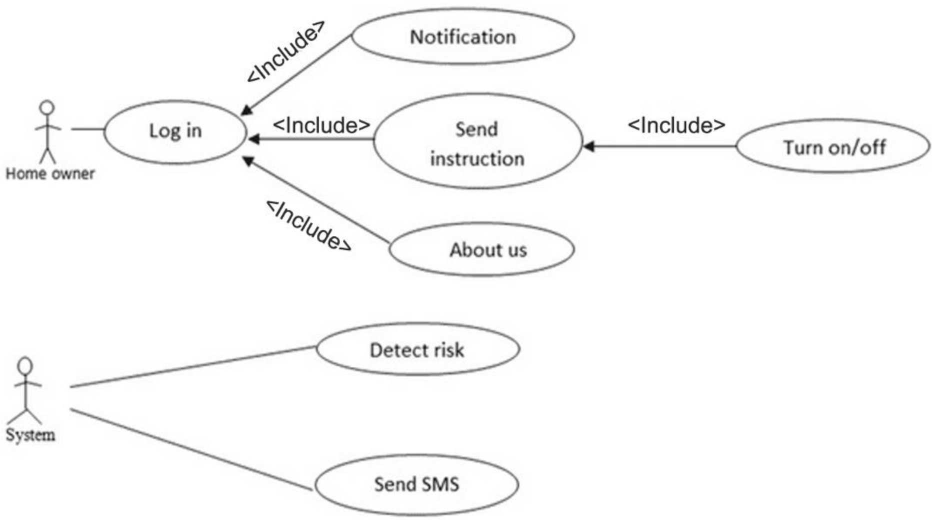

Figure 6. Use case diagram.

Figure 6 is a Use Case Diagram that depicts the interactions between a Homeowner and a System in a home automation or security setup. The Homeowner is responsible for logging in, sending commands, and accessing system information. The login process includes a notification feature, while sending commands involves turning the system on or off. Additionally, the system functions autonomously by detecting risks and sending SMS alerts. The "include" relationships show that certain actions, like notifications and turning the system on/off, are essential components of the main functions. This diagram effectively illustrates the interaction between the user and the system to manage home security and automation.

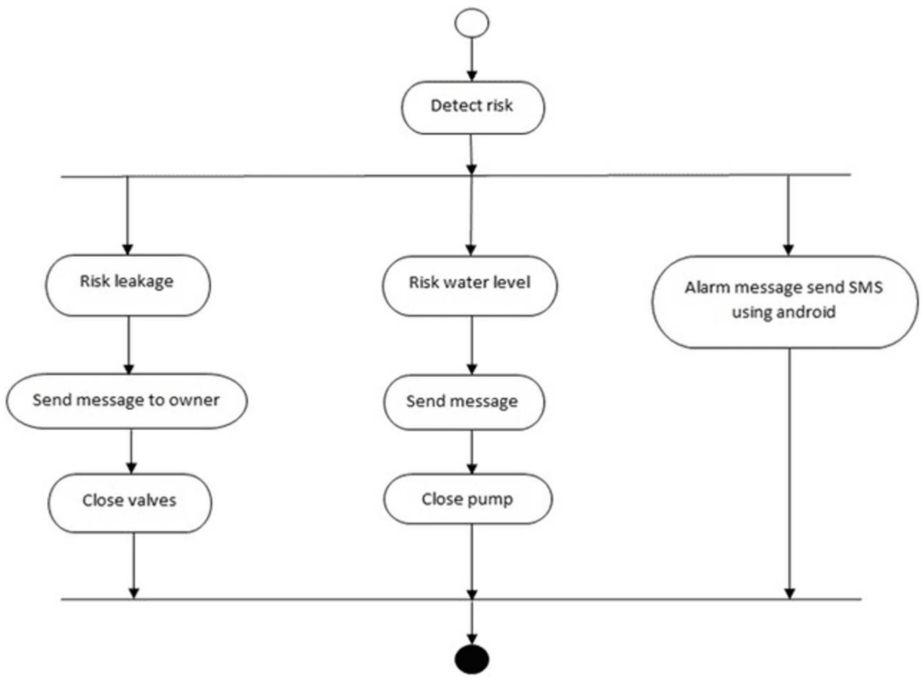

Figure 7. Activity diagram.

Figure 7 represents an automated system for detecting and responding to water-related risks. The process starts with risk detection and then branches into three actions: (1) If a leak is detected, a notification is sent to the owner, followed by closing the valves; (2) If an abnormal water level is identified, a message is sent, and the pump is turned off; (3) An alert message is sent via SMS using an Android-based system. These automated responses help mitigate potential hazards, ensuring system safety and preventing damage.

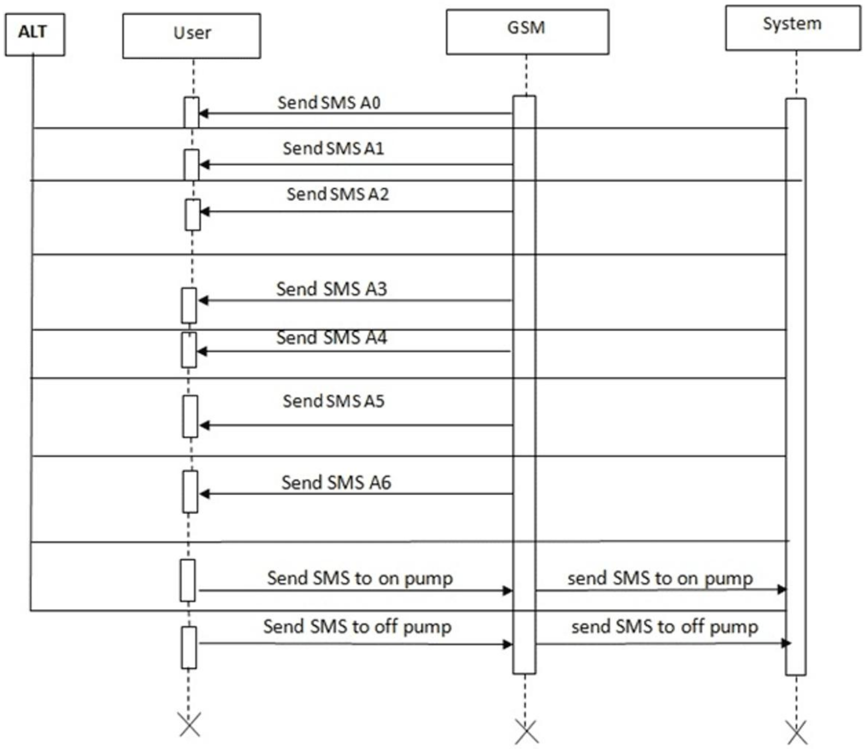

Figure 8. Activity diagram.

Figure 8 is a Sequence Diagram illustrating the interaction between a User, a GSM module, and a System for controlling a pump via SMS. It follows an Alternative (ALT) flow, meaning different SMS commands are sent based on conditions.

Initially, the user transmits multiple SMS messages (A0 to A6) to the GSM module. After these messages, the user sends specific SMS commands to either turn the pump on or off. The GSM module relays these commands to the system, which processes and executes the corresponding action.

5. SYSTEM DESIGN

In this paper, we present a framework for water leak detection and hydraulic pump control, specifically designed for residential use. This system can be applied to a simple model, demonstrating its effective operation. The main objective of this paper is to introduce the structure we have developed for the system. In a similar approach, we use a home model to classify the plumbing system and integrate control components and sensors to detect water leaks and monitor water levels on upper floors. Furthermore, the system includes a water supply campaign channel and the GATHERER, as depicted in Figure 1, which shows the system's engineering design. Figure 1 displays the control components, including the microcontroller (Arduino), water pump (actuator), GSM module, and their interconnections.

Figure 9: Evaluation of existing system design.

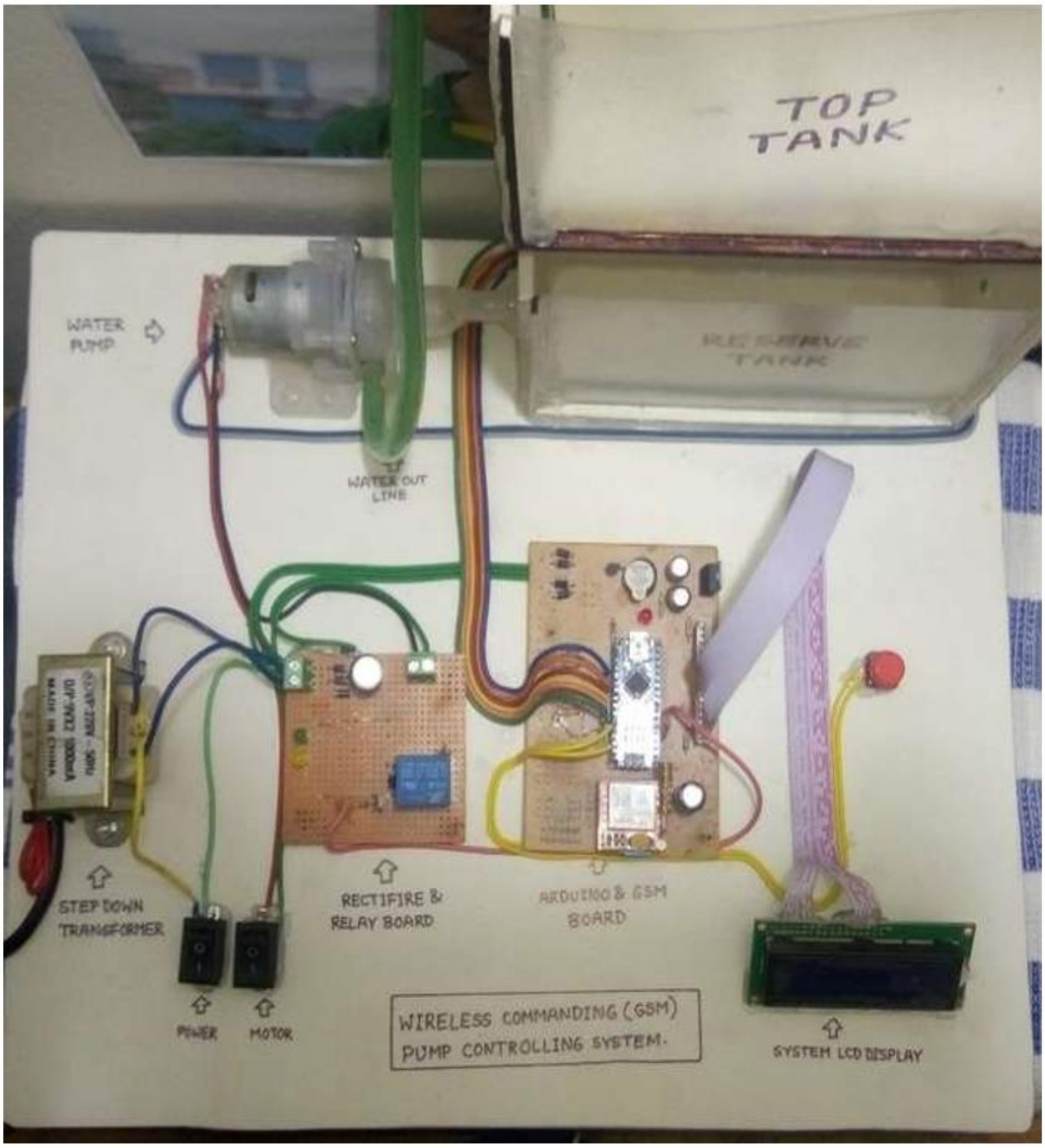

Figure 9. Existing System design.

Water pumps are powered by DC voltage, with all actuators operating at a consistent 12-volt level. When the water level drops, water suppliers are activated to restore the water supply. The homeowner can use the Android Multipurpose application to receive a notification when the water level in the top tank is low, ensuring that the Saipan collector is alerted accordingly.

6. RESULTS

Figure 10 showcases a mobile application interface named SWLD, designed for remotely controlling a system, possibly via SMS or Bluetooth. The interface includes two main buttons: "ON" and "OFF," indicating that the app is used to toggle a device or system on and off. A notification at the bottom states "running in the background," signifying that the app continues to operate even when not actively in use. The background features an Android-themed design, suggesting that the app is developed for Android devices. This application likely supports remote system control, such as home automation or device management.

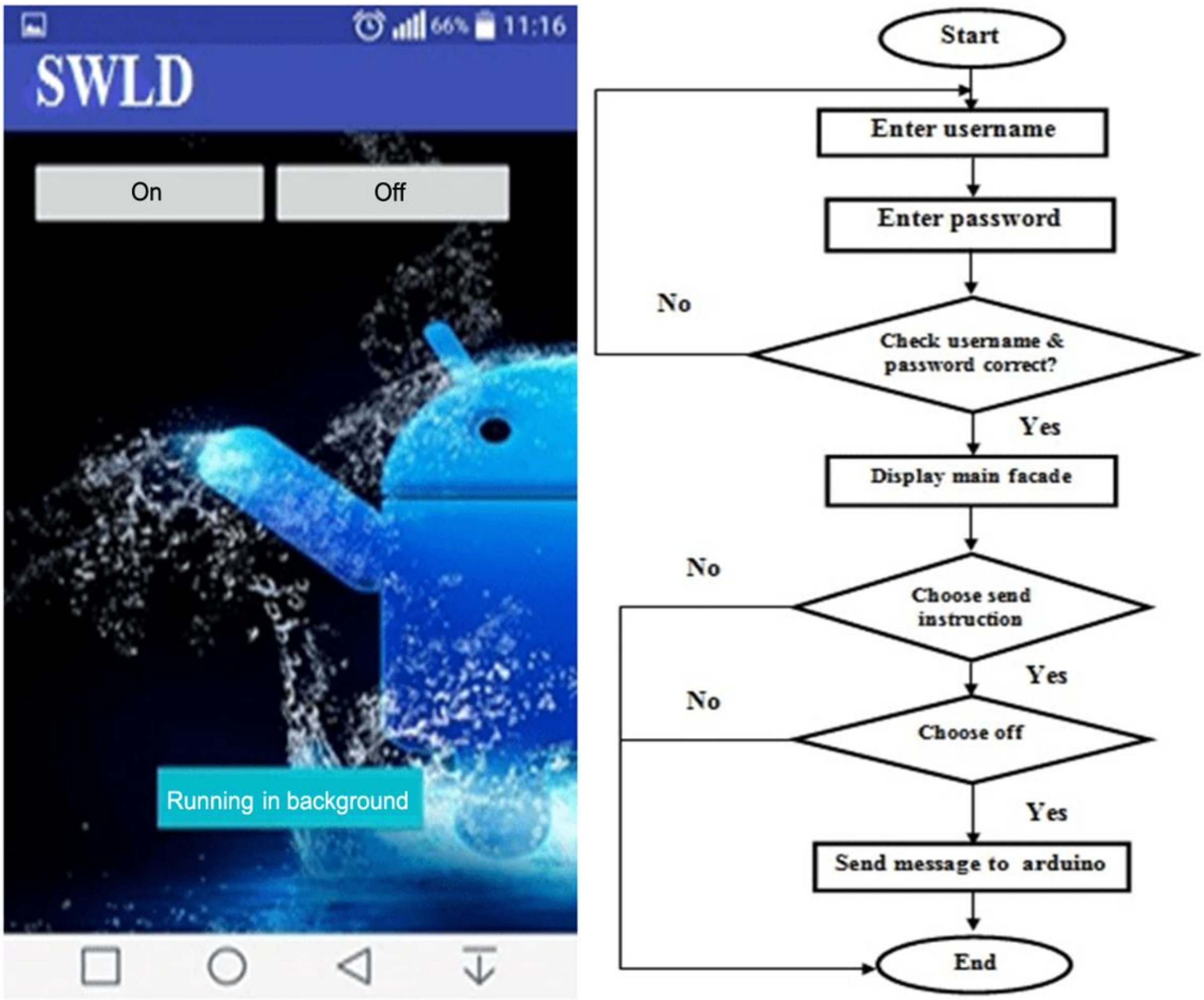

Figure 10. App view and working diagram.

Test Case 1.

We recorded the system's response during a leakage event, and the results were as follows:

Title: Water Leakage

System: SWLD

Input Instructions: Check the Water Sensor (A0) of Garden Pipe 1 spheres.

Output: The Android interface app and Closing Valve 1 send an SMS to the user at their designated location.

Result: The test was successful**.**

Figure 11: Observed a leak in the garden hose line.

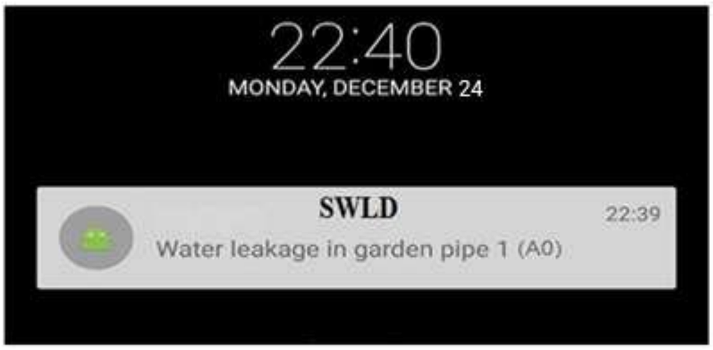

Figure 11. Observed water leakage in the garden hose line.

Test Case 2: Water Leakage

System: SWLD

Input Instructions: Check the Water Sensor (A2) while monitoring the kitchen pipes.

Output: Send an SMS alert to the user via the Android Mobile Application and activate Intimate Valve 2.

Result: The test was successful.

Figure 12: Discovered a leak in the kitchen piping system.

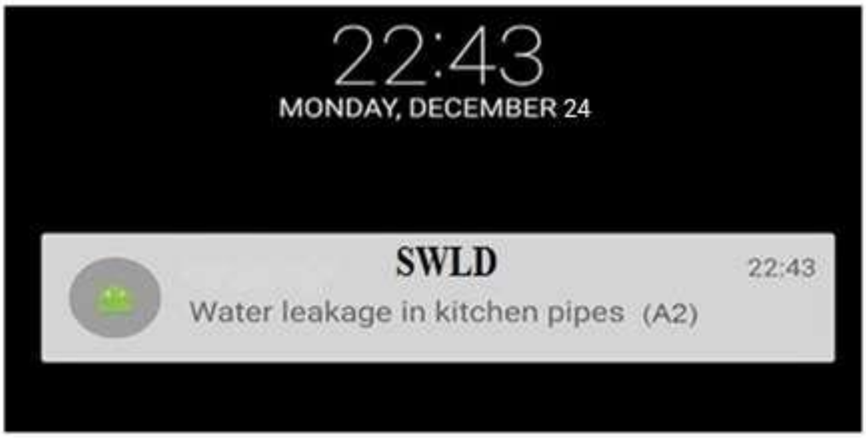

Figure 12. Detected water leakage in the kitchen pipeline.

6.1. The Response of the Solenoid Valve

As shown in Figure 13, the system is activated when the image is rotated on channels and when the pipe hose hole in the house detects a response. To address this, we have selected a leakage sensor with a sensitivity of 80 microliters (μL). If the sensor detects water splashes for 80 milliseconds or longer, the controller will activate the solenoid valve, causing it to close. This action halts the water flow, effectively stopping the supply within the pipeline system.

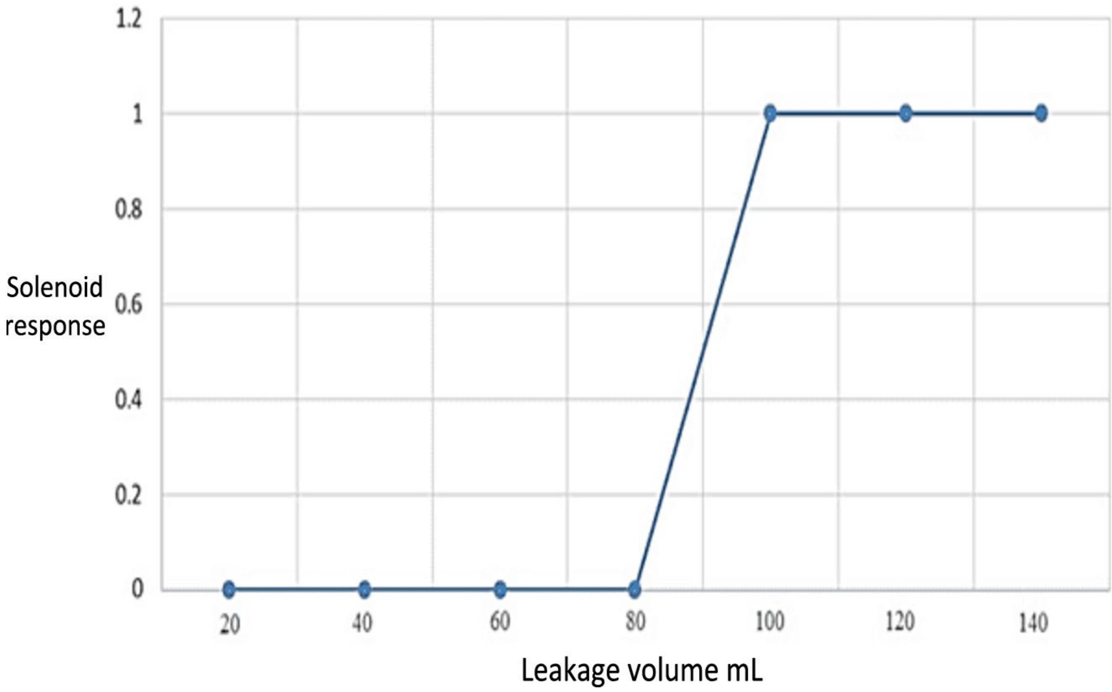

Figure 13. Solenoid valve response due to leakage volume.

7. CONCLUSION

The proposed frameworks are tested on the SWLD model, as shown in Figure 1. This framework is expected to attract considerable attention in the coming decades. Water is one of the most essential resources for all living beings. Unfortunately, a significant amount of water is wasted due to uncontrolled usage and leakage. The primary focus of this framework is to utilize an efficient, remote sensor-based water monitoring system. The framework emphasizes two main approaches for water monitoring: water level monitoring and pipeline leakage detection. Ultimately, the research concept for water monitoring in homes and offices will be realized using remote sensor technology. By implementing this system, we can effectively conserve water, helping to preserve it for future generations.

Funding: This study received no specific financial support.
Institutional Review Board Statement: Not applicable.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] D. Misiunas, M. Lambert, A. Simpson, and G. Olsson, "Burst identification and area in water dissemination systems," *Water Science and Technology: Water Supply*, vol. 5, no. 3–4, pp. 71–80, 2005.

[2] M. Daadoo, S. Tarapiah, and S. Atalla, "Assessing efficiency of multi-layered switch architecture on the whole optical networks," *Global Journal of Applied Engineering Research*, vol. 11, no. 22, pp. 11030-11036, 2016.

[3] Y. A. Daraghmi and M. Daadoo, "Savvy smartphone based framework for identifying hindrances and lessening vehicle speed," presented at the In MATEC Web of Conferences (Vol. 77, p. 09006). EDP Sciences, 2016.

[4] R. Zulhani and A. Mohd, "Water spillage monitoring system using Zigbee-based wireless sensor network," *International Journal of Engineering and Technology*, vol. 2, no. 3, pp. 180-185, 2005.

[5] H. H. Kadar, S. S. Sameon, and M. E. Rusli, "SMART2L: Smart water level and leakage detection," *International Journal of Engineering and Technology (UAE)*, vol. 7, no. 4.36, pp. 448-452, 2018. https://doi.org/10.14419/ijet.v7i4.36.23914

[6] P. H. Nguyen and M. P. Le, "Energy consumption optimization for smart water meters: A hardware design experience," *Available at SSRN 5160054*, 2025.

[7] M. Daadoo, S. M. A. Atallah, and S. Tarapiah, "Advancement of low-cost safety home automation system utilizing GSM network," *European Journal of Scientific Research*, vol. 53, no. 3, pp. 338-353, 2016.

[8] M. Daadoo, S. Tarapiah, and S. M. A. Atallah, "Examination and performance of a low-cost multiple alarm security system for smart home based on GSM technology and controlling based on Android smartphone," *European Journal of Scientific Research*, vol. 143, no. 2, pp. 136-165, 2016.

[9] M. Daadoo and Y. Daraghmi, "Seeking of ideal qualities of multi-layer exchanging engineering taking all things together optical systems," presented at the Heterogeneous Networking for Quality, Reliability, Security and Robustness (QSHINE), 2015 Eleventh International Conference on (pp. 50-55). IEEE, 2015.

[10] S. Tarapiah, S. Atalla, K. F. B. Hashim, and M. Daadoo, "Portable network planning process case study-3G network," *PC and Information Science*, vol. 9, no. 3, p. 1-19, 2016. https://doi.org/10.5539/cis.v9n3p115

[11] M. Bowling, "Spillage testing strategy for a plate heat exchanger (U.S. Patent No. 6,062,068). United States Patent and Trademark Office," 2000.

[12] D. M. Kumar and T. Jagadeep, "Water pipeline leakage detection and monitoring system using smart sensor with iot," presented at the Journal of Physics: Conference Series, vol. 2267, p. 012122, IOP Publishing, 2022.

[13] C. Penteado, Y. Olivatti, G. Lopes, P. Rodrigues, R. Filev, and P. T. Aquino, "Water leaks detection based on thermal images," presented at the 2018 IEEE International Smart Cities Conference (ISC2), pp. 1–8, IEEE, 2018.

[14] E. Farah and I. Shahrour, "Water leak detection: A comprehensive review of methods, challenges, and future directions," *Water*, vol. 16, no. 20, p. 2975, 2024.

[15] F. Abate, M. Carratù, C. Liguori, and A. Pietrosanto, "Smart meters and water leakage detection: A preliminary study," presented at the 2019 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), pp. 1–6, IEEE, 2019.

[16] A. Boudhaouia and P. Wira, "Water consumption analysis for real-time leakage detection in the context of a smart tertiary building," presented at the 2018 International Conference on Applied Smart Systems (ICASS), pp. 1–6, IEEE, 2018.

[17] M. Daadoo, A. Eleyan, and D. Eleyan, "Optimization water leakage detection using wireless sensor networks (owld)," presented at the Proceedings of the International Conference on Future Networks and Distributed Systems, pp. 1–11, 2017.

[18] L. Fabbiano, G. Vacca, and G. Dinardo, "Smart water grid: A smart methodology to detect leaks in water distribution networks," *Measurement*, vol. 151, p. 107260, 2020.