

Development of an IoT-Based Real-Time Flood Monitoring and Alert System Using GSM-Based SMS in Santo Tomas

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ABSTRACT

Flooding is a recurring environmental hazard that can affect communities, properties, transportation, and public safety, particularly in areas experiencing heavy rainfall and changes in water levels. One challenge during flooding is the lack of timely and localized information that can help residents become aware of increasing water levels. This study proposes the development of an Internet of Things (IoT)-based real-time flood monitoring and alert system using GSM-based Short Message Service (SMS) for Santo Tomas. The system is designed to continuously monitor water levels through a water-level sensor connected to a microcontroller. Measurements will be processed and compared with site-calibrated threshold levels to determine the corresponding flood condition. When a predefined warning threshold is reached, the system will automatically send an SMS notification to designated recipients through a GSM communication module.

The study will employ a descriptive-developmental research design with a quantitative evaluation component. The development process will include system requirements identification, site assessment, stakeholder consultation, system design, hardware and software integration, prototype development, testing, and evaluation. System performance will be evaluated based on water-level measurement accuracy, consistency of readings, alert-

triggering accuracy, SMS delivery, response time, reliability, and selected software and system quality characteristics. Repeated testing will determine whether the system can consistently detect changes in water levels and provide appropriate notifications based on established thresholds.

Keywords: *Flood Monitoring, Water Level Sensor, Real-Time System, GSM / SMS*

SECTION I — INTRODUCTION (THE PROBLEM AND ITS SETTING)

1.1 Introduction

Flood early warning systems play an important role in reducing the potential impacts of flooding by providing timely and relevant information to communities and responsible authorities. Early access to information about changing water conditions allows appropriate actions to be taken before flood conditions become hazardous. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) conducts flood monitoring and warning activities that involve the collection and assessment of hydrometeorological data, forecasting, and the dissemination of warnings. PAGASA also uses different warning conditions, including flood monitoring, flood alert, and flood warning, to communicate the level of potential flood risk. These practices emphasize the importance of timely water-level monitoring and effective communication in flood risk management.

Although national and regional monitoring systems provide important information, localized monitoring devices can serve as complementary tools by directly measuring water conditions at specific locations. The development of Internet of Things (IoT) technologies has made it possible to integrate sensors, microcontrollers, and communication modules into systems capable of continuously monitoring environmental conditions and automatically transmitting information. For instance, Zakaria et al. (2023) developed a LoRaWAN-based flood monitoring and warning system that utilized an HC-SR04 ultrasonic sensor and an Arduino microcontroller. Similarly, Wannoi and Wannoi (2022) demonstrated the use of ultrasonic sensing for real-time water-level monitoring with mobile-based notifications. These studies demonstrate the potential of IoT-based technologies for improving the continuous monitoring and communication of flood-related information.

In response to this need, the present study proposes the development of an IoT-based real-time flood monitoring and alert system using GSM-based Short Message Service (SMS) for Santo Tomas. The proposed system is intended to continuously measure water levels through a sensor-based monitoring device, process the collected measurements using predefined and site-calibrated threshold levels, and automatically send SMS notifications to designated recipients when specified water-level conditions are detected. Through this approach, the study aims to provide localized and timely information that may support community awareness and early response to potentially hazardous water-level conditions.

1.2 Background of the Study

The increasing application of Internet of Things (IoT) technologies in environmental monitoring has provided opportunities to develop automated systems that can collect, process, and transmit information with minimal human intervention. IoT-based monitoring systems commonly combine sensors, microcontrollers, communication technologies, and software platforms to obtain real-time measurements and provide users with relevant information. In flood monitoring, these technologies can be applied to continuously measure water levels and provide alerts when monitored conditions reach predetermined levels.

Several studies have demonstrated the application of IoT technologies in water-level and flood monitoring. Zakaria et al. (2023) developed a low-cost flood monitoring and warning system integrating an ultrasonic sensor, Arduino microcontroller, and LoRaWAN communication technology with web and mobile platforms. Their study demonstrated how sensor-based measurements can be processed and communicated to users according to identified water-level conditions. Pramono et al. (2023) also developed an ESP32-based prototype for river

water-level monitoring intended to support flood mitigation. In addition, Curumtally and Khoodeeram (2021) presented an IoT-based flood-monitoring approach using water-level sensors and a Raspberry Pi, highlighting the importance of obtaining timely information in areas vulnerable to flooding. Sihombing et al. (2022) further investigated an IoT-based web monitoring system for drainage water levels, demonstrating the application of networked sensors in monitoring water conditions.

Communication is a critical component of an early warning system because the detection of a potentially hazardous condition is only useful when the resulting information can be delivered promptly to the intended recipients. Previous studies have employed different communication and notification technologies, including LoRaWAN, Wi-Fi, web-based dashboards, and mobile applications. In contrast, the proposed study focuses on GSM-based SMS as the primary notification method. SMS provides a direct means of transmitting warning messages to designated mobile numbers and does not require recipients to continuously access a web-based monitoring platform.

The proposed study focuses on Santo Tomas, where a localized monitoring system may provide site-specific water-level information. However, the available materials for the study do not establish a verified historical dataset of flood depths or officially approved local water-level thresholds for the specific monitoring site. Therefore, the study will not assume or fabricate threshold values. Instead, the appropriate warning levels will be determined through site assessment, consultation with relevant stakeholders, consideration of the physical installation location and sensor configuration, and controlled system testing. The resulting thresholds should be reviewed and validated by appropriate local authorities and stakeholders before the system is considered for actual operational use.

Overall, the proposed system seeks to demonstrate how IoT-based sensing and GSM-SMS communication can be integrated into a localized flood monitoring and alert mechanism. By providing continuous water-level measurements and automated notifications, the system may serve as a supplementary tool for improving access to timely flood-related information at the selected study site.

1.3 Objectives of the Study

The general objective of this study is to develop an IoT-based real-time flood monitoring and alert system using GSM-based SMS to monitor water levels and send warnings in Santo Tomas.

This study aims to develop an IoT-based real-time flood monitoring and alert system using GSM-based SMS to monitor water levels and provide timely warnings in Santo Tomas. Specifically, it seeks to identify the following;

- Identify the functional and non-functional requirements needed for the flood monitoring and alert system.
- Determine the appropriate water-level sensor, microcontroller, GSM module, power supply, and other components needed to build the prototype.
- Design and develop a system that can measure water levels in real time and determine the current flood condition based on set water-level thresholds.
- Implement an automated GSM-based SMS feature that sends warning messages to designated recipients when the water level reaches a specified threshold.
- Establish and document normal, warning, and dangerous/critical water-level thresholds based on the conditions of the study area and controlled testing. These thresholds will be considered prototype values until they are validated by the appropriate local authorities.
- Evaluate the developed prototype based on its measurement accuracy, ability to trigger alerts, SMS delivery, response time, reliability, and selected system-quality characteristics.
- Identify the limitations of the developed system and provide recommendations for future improvements and

field deployment.

1.4 Scope and Limitation of the Study

Scope:

This study focuses on the analysis, design, development, and testing of an IoT-based water-level monitoring and GSM-SMS alert system for a selected monitoring location in Santo Tomas. The developed prototype will consist of a water-level sensor, microcontroller, GSM communication module, power source, programmed water-level thresholds, and a system for recording or displaying the measured water levels during testing.

The study will test the prototype under controlled water-level conditions to determine whether the sensor can measure water levels consistently, whether the programmed warning thresholds work as intended, and whether SMS alerts can be successfully sent to designated mobile numbers. If permission and site conditions permit, limited field observation will also be conducted to assess the prototype under actual environmental conditions. The evaluation of the system may also consider relevant software and system quality characteristics based on ISO/IEC 25010:2023.

Deimitation:

This study is limited to monitoring water levels and sending SMS alerts when the programmed thresholds are reached. It does not include rainfall forecasting, river-discharge measurement, or regional flood prediction. The system is intended to serve as a monitoring and alert tool and does not replace official flood forecasts, warnings, or disaster-risk-reduction procedures of PAGASA and the local government.

The study will not establish official evacuation or emergency thresholds. The performance of the system may also be affected by cellular network availability, sensor placement, debris, water movement, power interruptions, weather conditions, and the limitations of the prototype hardware. SMS delivery may be delayed or unsuccessful when the cellular network is weak or unavailable.

In addition, the study will only use historical flood or water-level data that can be obtained from reliable and authorized sources. If data for the exact monitoring location are unavailable, the study will not create or assume historical data and will identify their absence as a limitation.

1.5 Significance of the Study

- **Residents.** The proposed system may provide timely information about rising water levels through SMS notifications. This may help residents become aware of possible flooding conditions and take appropriate action based on official preparedness and evacuation instructions.
- **Barangay and Local Disaster Risk Reduction Personnel.** The system may provide an additional source of localized water-level measurements that can support flood monitoring and situation assessment. The information may be used alongside official monitoring systems and warning channels.
- **Researchers and Students.** The study may serve as a reference for researchers and students interested in developing systems that combine water-level sensors, microcontrollers, GSM communication, and automatic SMS alerts for flood monitoring.
- **Future System Developers.** The design and testing results of the prototype may provide a basis for future improvements, such as adding multiple monitoring points, backup communication methods, solar-powered

operation, cloud-based data storage, and possible integration with existing official warning systems..

1.6 Definition of Terms

- **Alert.** A system-generated notification sent when a configured water-level condition detected.
- **GSM.** A cellular communication technology used by the prototype's communication module to transmit SMS messages over an available mobile network.
- **Internet of Things (IoT).** An arrangement in which physical devices such as sensor and controllers collect, process, and communicate data through a network.
- **Prototype.** A working preliminary implementation developed for testing and evaluation rather than as a certified permanent emergency system.
- **Real-Time Monitoring.** Continuous or repeated measurement and processing of water-level conditions with sufficiently short intervals for the intended monitoring purpose.
- **SMS.** Short Message Service; the text-messaging mechanism used by the prototype to deliver warning notifications.
- **Threshold.** A predefined water-level value used by the system to determine when a warning state should be triggered.
- **Water-Level Sensor.** The sensing device used to estimate the distance from the sensor to the water surface and derive the water level.

SECTION II — LITERATURE REVIEW

2.1 Introduction to the Review

This chapter provides a structured and critical discussion of related literature and technical studies involving the use of Internet of Things (IoT) technologies for flood monitoring and automated early warning systems. The increasing effects of changing weather conditions and localized flooding have emphasized the importance of proactive and sensor-based early warning systems as part of disaster risk reduction and management.

To establish the theoretical and technical basis of the study, the review is arranged according to major themes. It first discusses global and national approaches to disaster risk management and hydrometeorological monitoring, including established practices implemented by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). The discussion then focuses on localized warning systems, particularly the use of Short Message Service (SMS) through Global System for Mobile Communications (GSM) technology.

The chapter also examines important technical aspects of flood monitoring systems, including hardware configurations, non-contact ultrasonic water-level sensing, microcontroller-based data processing, signal filtering, wireless communication, and the calibration of prototype water-level thresholds. In addition, the ISO/IEC 25010:2023 Systems and Software Quality Requirements and Evaluation (SQuaRE) framework is discussed as a basis for evaluating the performance and quality of the proposed prototype.

Through the integration of these topics, the review identifies existing technological approaches, discusses their limitations, and establishes the research gap that the proposed study intends to address in Santo Tomas.

2.2 Review of Related Literature and Studies

Global and National Context: IoT-Based Environmental Monitoring and Flood Warnings

The use of Internet of Things (IoT) technologies in environmental monitoring and disaster risk management has continued to expand as a means of improving real-time monitoring and community preparedness. In the Philippines, the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) performs flood monitoring and warning activities through the collection and analysis of hydrometeorological information, river basin forecasting, and the distribution of flood advisories. PAGASA uses different warning conditions, including flood monitoring, flood alert, and flood warning, to communicate possible flood risks in major river systems. Although these national and regional systems provide important large-scale information, localized IoT monitoring devices can complement them by collecting water-level information from specific community locations.

Advancements in affordable microcontrollers, environmental sensors, wireless communication technologies, and automated alert mechanisms have also supported the development of systems capable of continuously monitoring water levels. Zakaria et al. (2023) demonstrated that low-cost microcontrollers combined with wireless communication can support automated environmental monitoring through ultrasonic sensors. Likewise, Pramono et al. (2023) developed an ESP32-based IoT prototype for river water-level monitoring, demonstrating its potential contribution to localized flood mitigation and preparedness. Curumtally and Khoodeeram (2021) also examined IoT-based flood monitoring systems that use water-level sensors and microcontrollers, emphasizing the importance of obtaining timely and location-specific information in flood-prone communities.

Communication Technologies, Cellular Reliability, and Automated SMS Alerting Mechanisms

Communication is an important component of flood early warning systems because detecting a hazardous water level is only useful when the information can reach the intended recipients. Previous studies have explored different communication technologies, including LoRaWAN, Wi-Fi, web-based monitoring systems, and cloud platforms such as ThingSpeak (Sihombing et al., 2022; Yultrisna et al., 2025). While web-based dashboards and cloud systems can provide useful data visualization and storage, some of these approaches require internet connectivity, mobile data, or specific receiving infrastructure.

GSM-based Short Message Service (SMS) provides another approach for delivering localized emergency notifications. Through SMS, warning messages can be sent directly to registered mobile numbers using cellular networks. This allows recipients to receive notifications without continuously accessing a web dashboard, using a specialized application, or maintaining an active internet connection on their mobile devices.

Ma'Ti et al. (2025) developed an IoT-based flood detection and warning system that incorporated real-time data processing and automated alerts. Wannoi and Wannoi (2022) also demonstrated the use of ultrasonic water-level sensing together with mobile notifications for flood detection. These studies demonstrate the potential of combining water-level sensors, embedded processing, wireless communication, and automated notifications in developing flood monitoring and warning systems.

Sensor Selection, Microcontroller Processing, and Threshold Calibration

The selection of appropriate sensors, hardware components, and data-processing techniques is important in obtaining reliable water-level measurements. IoT-based water-level monitoring systems commonly use non-contact ultrasonic sensors, such as the HC-SR04, as well as other types of water-level sensors. Ultrasonic sensors estimate water levels by measuring the distance between the sensor and the water surface. However, factors such as water-surface movement, floating objects, and turbulence can affect sensor readings and produce temporary variations.

Signal-processing techniques can be used to reduce the effects of these fluctuations. Microcontrollers such as

the ESP32 can process multiple sensor readings and apply filtering techniques, including moving-average methods, before determining the water-level condition. Averaging successive measurements can help reduce temporary variations and improve the consistency of the readings used by the system.

The establishment of water-level thresholds is also an important part of flood monitoring system development. Categories such as Normal, Warning, and Critical or Dangerous must be established based on the characteristics of the monitoring location and the intended purpose of the prototype. Site assessment and controlled testing can be used to determine appropriate prototype threshold values. These values should be treated as testing parameters and require appropriate review and validation by local disaster risk reduction and management authorities before any operational deployment.

System Quality Assessment and Evaluation Standards

A structured evaluation framework is necessary to assess the operational performance and quality of an IoT-based monitoring prototype. The ISO/IEC 25010:2023 Systems and Software Quality Requirements and Evaluation (SQuaRE) model provides quality characteristics that can be considered when evaluating a system.

The study will focus on selected characteristics, including:

- 1. Functional Suitability:** Determines whether the system performs its intended functions, such as measuring water levels, identifying threshold conditions, and activating the appropriate alerts.
- 2. Performance Efficiency:** Examines the system's response and latency, including the time between the detection of a threshold condition and the transmission or receipt of an SMS notification.
- 3. Reliability:** Assesses the consistency and stability of the system during repeated testing, including sensor readings, hardware operation, and communication performance.

The use of selected ISO/IEC 25010:2023 characteristics allows the evaluation to consider not only whether the prototype functions but also its measurement consistency, response performance, and reliability during testing.

2.3 Conceptual Framework

The conceptual framework of the proposed flood monitoring and alert system follows the Input-Process-Output (IPO) model.

Narrative Description of the IPO Model

Input

- **Continuous Water-Level Measurements:** The ultrasonic water-level sensor provides repeated measurements of the distance between the sensor and the water surface. These measurements are used to determine changes in the water level.
- **Site-Calibrated Prototype Thresholds:** The system uses predetermined prototype reference levels representing Normal, Warning, and Dangerous/Critical conditions. These values will be established through site assessment and controlled testing.
- **Pre-Programmed Recipient Numbers:** Mobile phone numbers of designated recipients will be configured in the system so that they can receive SMS notifications when the specified alert conditions are detected.

Process

- **Data Collection and Transmission:** The ultrasonic sensor collects water-level measurements, which are processed by the system and transmitted through the LoRaWAN communication network.
- **Threshold Evaluation:** The system compares the processed water-level measurements with the programmed prototype thresholds to determine the current water-level condition.
- **GSM-SMS Alert Activation:** When a specified warning condition is detected, the system activates the GSM communication module to transmit the appropriate SMS notification to the designated recipients.

Output

- **Automated GSM SMS Flood Alerts:** Warning messages are transmitted through the GSM network to the registered mobile numbers when the corresponding threshold condition is reached.
- **Local Audio-Visual Alerts:** LEDs and/or a piezoelectric buzzer may provide an immediate local indication of the detected water-level condition at the monitoring location.
- **System Performance and Quality Evaluation:** The prototype will generate measurable evaluation results concerning water-level measurement accuracy, threshold detection, SMS response time, communication performance, and system reliability based on selected ISO/IEC 25010:2023 criteria.

2.4 Synthesis

Existing literature demonstrates the application of IoT technologies in water-level monitoring, environmental sensing, flood detection, and automated warning systems. Several studies have used web-based platforms, cloud services such as ThingSpeak, and wireless technologies such as LoRaWAN to transmit and monitor collected data. These approaches demonstrate the potential of connected technologies for improving flood monitoring and early warning.

However, existing studies differ in their communication methods, monitoring locations, system configurations, and intended users. There remains a need for a localized and low-cost flood monitoring prototype that combines real-time water-level monitoring with GSM-based SMS notifications for designated recipients in Santo Tomas.

The proposed study aims to address this gap by developing, testing, and evaluating a supplementary IoT-based

flood monitoring and alert prototype that uses ultrasonic water-level sensing, LoRaWAN communication, and GSM-based SMS notifications. The system will use site-calibrated prototype thresholds to determine when notifications should be triggered and will be evaluated based on its measurement accuracy, threshold detection, communication performance, SMS response, and reliability.

SECTION III — METHODOLOGY

3.1 Research Design

This study will use a Descriptive-Developmental Research Design with a Quantitative Approach. The developmental component will focus on designing and developing the proposed IoT-based real-time flood monitoring and alert system, while the descriptive-quantitative component will be used to assess its water-level measurement accuracy, alert activation, SMS delivery, response time, and reliability through measurable testing results.

3.2 System Development Methodology

The project will follow a Prototype Development Methodology in creating and improving the proposed flood monitoring and alert system. The development process will involve identifying system requirements, assessing the selected site, designing the system, integrating the hardware and communication components, developing the prototype, calibrating the system, and conducting testing and evaluation. Data will be collected through site observations, consultation with selected stakeholders, and controlled system tests.

3.3 Requirement Specification and Analysis

The system requirements will be determined according to the monitoring needs of the selected study area. Its functional requirements will include measuring water levels, identifying threshold conditions, sending automatic

SMS notifications, and activating local warning indicators. System flowcharts, Input-Process-Output (IPO) models, and system architecture diagrams will be used to represent the movement of water-level data from the sensor through the LoRaWAN communication network, the evaluation of threshold conditions, and the transmission of alerts to the designated recipients.

3.4 System Design Specification

The proposed system will be described through its logical and physical specifications. The logical specification will present the processes involved in collecting sensor data, transmitting water-level information through LoRaWAN, evaluating thresholds, and generating SMS alerts. The physical specification will identify the hardware components required for the prototype, including the ultrasonic water-level sensor, LoRaWAN-compatible device, LoRaWAN gateway, GSM communication module, SIM card, power supply, LED indicators, buzzer, and other necessary components.

3.5 Implementation

The implementation phase will involve assembling and connecting the hardware and communication components of the prototype. The LoRaWAN-compatible device will be configured to receive water-level measurements from the ultrasonic sensor and transmit the collected data through the LoRaWAN network. The system will evaluate the transmitted water-level information according to the programmed thresholds. When the specified warning condition is detected, the GSM module will be configured to send SMS notifications to designated recipients. The completed prototype will then be calibrated and prepared for controlled testing.

3.6 Testing and Evaluation

The prototype will undergo controlled testing to assess its water-level measurement accuracy, threshold detection, LoRaWAN data transmission, SMS transmission, response time, and reliability. The testing process will include repeated water-level measurements, threshold activation tests, LoRaWAN communication tests, and GSM-SMS transmission tests. Selected characteristics of ISO/IEC 25010:2023, particularly functional suitability, performance efficiency, and reliability, will also be used as references in assessing the overall performance of the developed prototype.

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