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# Disaster management-based internet of things using wireless sensor networks

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## HIGHLIGHTS

- A threshold of 26 is set; exceeding it activates the buzzer, while lower values deactivate the alarm
- The system is designed to give people early warning and ensure safety from potential flooding
- ZigBee features include low power use, easy setup, and long battery life for reliable operation
- The device is cost-effective to install and requires minimal maintenance

**Keywords:**

Wireless sensor networks
Zigbee
Internet of things
Arduino
Dams

## ABSTRACT

Wireless Sensor Networks (WSNs) have become essential in the monitoring and managing environmental disasters, providing real-time data collection and transmission functionalities. Their application is especially crucial in flood-prone areas, where prompt detection and action can reduce substantial human, economic, and infrastructural losses. Wireless Sensor Networks (WSNs) comprise spatially distributed sensors that monitor environmental parameters, including water levels, temperature, and humidity, relaying data to a centralized system for analysis and response. This paper proposes a flood monitoring system based on a wireless sensor network, emphasizing installing water-level sensors in dam basements. The system employs the ZigBee communication protocol to provide low-power, wireless data transmission between sensor nodes and a base station (BS), which subsequently transmits information to a mobile device through Internet of Things (IoT) integration. This approach is significant due to its capacity for continuous, automated monitoring and early warning of abnormal water levels. When the water level surpasses a specified threshold (26 °C, utilized here as an indicator of water height in the sensor design), the system activates an audio alarm via a buzzer to notify adjacent personnel of potential flooding hazards. The temperature-based surrogate threshold is adjusted according to the sensor's sensitivity and the dam's structural safety restrictions. Experimental findings illustrate the system's efficacy in precisely detecting and conveying real-time variations in water levels. Furthermore, a comparative study demonstrates that the ZigBee-enabled system provides enhanced energy efficiency, scalability, and transmission range compared to previous technologies employed for analogous applications. This research implies that catastrophe resilience can be improved by integrating IoT and WSN technologies, hence facilitating proactive infrastructure management and enhancing community safety in at-risk areas.

## 1. Introduction

Dams are a crucial source of water supply for urban systems. Many of the dams are designed to meet various requirements and have distinct advantages. Establishing a correspondence between the monitoring structures and the administrators' models to support the dams is essential. Typically, dams are evaluated using conventional perception procedures, and monitoring water levels in certain sections of the dams is not automated. The primary collective of water resources generated by dams is remarkable, given the substantial number of users reliant on them, who may also possess divergent objectives. This state is increasingly improving as the available resources are restricted, and any rupture or leakage of the pipeline will be promptly communicated to the responsible individual. During floods, managing floodwater should be more efficient, considering the water levels across numerous dams. Monitoring areas next to the dams should be feasible through cameras that feed live footage to the base station, aiding in detecting humans near the dams and contributing to safety measures while simultaneously managing water release during floods. Web of Things [1]. For flood monitoring, WSNs collect data wirelessly and send it to a central station [2]. Each sensor node can be strategically placed when there is a need for an instantaneous response to changes in water conditions, such as near rivers, tanks,



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dams, or coastlines. To collect data for predictive modelling and early warnings which can save lives and decrease economic losses it is vital to utilize WSN technology with IoT-based flood monitoring devices [3-8]. Over the last decade, substantial progress has been made in deploying Wireless Sensor Networks (WSNs) and Internet of Things (IoT) technologies for disaster monitoring and management. WSNs have been applied across diverse domains such as flood detection, wildfire surveillance, earthquake alert systems, and smart water management. Theint Win La [4], proposed an IoT platform integrated with Twilio API for real-time water level monitoring and SMS-based flood alerts. Lutakamale et al. [5], implemented a WSN to monitor wildfires in Tanzania, demonstrating the technology's applicability in forest environments. Haziel et al. [6], developed a system for early earthquake and landslide detection using sensor networks, while Mohamed et al. [7], reviewed IoT-cloud infrastructures for earthquake alerting. Kulkarni et al. [10], introduced a GSM-based alert system for domestic water levels, suitable in offline environments. Huque et al. [11], designed a smart tank monitoring and motor control system using IoT and cloud platforms to prevent water waste. Natmauk Road et al. [12], constructed a cloud-connected water level monitoring platform using ultrasonic sensors. Nishmitha et al. [13], proposed automatic pump shut-off mechanisms to minimize water wastage and enhance convenience via mobile applications. Additional studies include energy-efficient disaster WSN protocols [12], IoT-based flood forecasting using fuzzy logic [13], and mobile flood alert systems with historical cloud data [14]. Jain and Goel [17], also explored WSNs for monitoring infrastructure damage post-disaster. These studies underscore the flexibility and effectiveness of WSN-IoT systems in real-time environmental hazard detection and mitigation. Now Table 1 that shown below is a comparison of the proposed work with literature survey works.

**Table 1:** Comparission proposed work with litreture survey works

| Application area | Technology used | Key contribution | Ref. |
|---|---|---|---|
| Water Level Monitoring | IoT, Twilio API, SMS | IoT-based flood alert system using SMS integration for real-time monitoring. | [4] |
| Wildfire Monitoring (Tanzania) | WSN | Wireless sensor deployment in forests for wildfire detection. | [5] |
| Earthquake and Landslide Detection | WSN | Proposed a sensor-based early warning system for seismic hazards. | [6] |
| Earthquake Alert System | IoT, Cloud Infrastructure | Reviewed cloud-IoT frameworks for earthquake detection systems. | [7] |
| Domestic Water Monitoring | GSM, Water Sensors | An alert system using GSM calls to detect overflow in homes and workspaces. | [8] |
| Smart Tank Monitoring | IoT, Cloud, Sensors | Prevents overflow and water shortages via real-time sensor data. | [9] |
| Cloud-based Water Monitoring | Ultrasonic Sensors, Twilio API | Designed a minimal-hardware system with replaceable precision sensors. | [10] |
| Water Waste Reduction | IoT, Pump Automation | Automated pump shut-off with app integration for household use. | [11] |
| General Disaster Monitoring | WSN, Energy-efficient Protocols | Surveyed power-optimized WSN protocols for disaster response. | [12] |
| Flood Forecasting | IoT, Fuzzy Logic, WSN | Implemented a fuzzy-logic-based prediction model for flood alerts. | [13] |
| Smart Flood Alert | IoT, GSM, Cloud | Developed a mobile-based flood notification system with historical tracking. | [14] |
| Post-disaster Structural Monitoring | WSN, Structural Sensors | Explored WSN applications for assessing infrastructure damage post-catastrophe. | [15] |

## 2. System structure

Distributed wireless water level sensors have been used to monitor the network in a specific area according to the characteristics of the wireless ZigBee module. We can get more monitoring data using this method. Water level sensors, Arduino, buzzers, and ZigBee end devices make up the Node in Figure 1, while ZigBee coordinators, computers, and mobile devices make up the base station. This way, the water level sensor data transfer, Zigbee network setup, network administration, and maintenance may all be carried out. The end nodes are dispersed throughout the area and send data to the Zigbee coordinator at the base station (BS). The BS collects the data from the end nodes and stores it in an upper PC. The Red Node software tool transfers the data to a mobile phone through the Remote Node Red Application, allowing remote system monitoring. If the water level provides higher data, the system regulating the disaster can reduce it to a minimum state by powering on the buzzer.

### 2.1 System hardware design

The provision of water is crucial for the sustenance of human life both presently and in the future. Consequently, humanity must safeguard natural resources to prevent water scarcity in future generations. This paper illustrates the application of IoT technology for monitoring water levels in tanks and visualizing data through various devices, including cellphones, PCs, and laptops. The system employs IoT technologies, including Arduino UNO, ultrasonic sensors, Wi-Fi, motor pumps, mobile phones, tablets, PCs, or laptops. Consequently, water depletion is absent, thereby preventing water loss and eliminating the necessity for manual water level monitoring. In the commercial realm, IoT technology is compact and cost-effective yet serves many functions. The system hardware design consists of two main components: the base station and the end node.

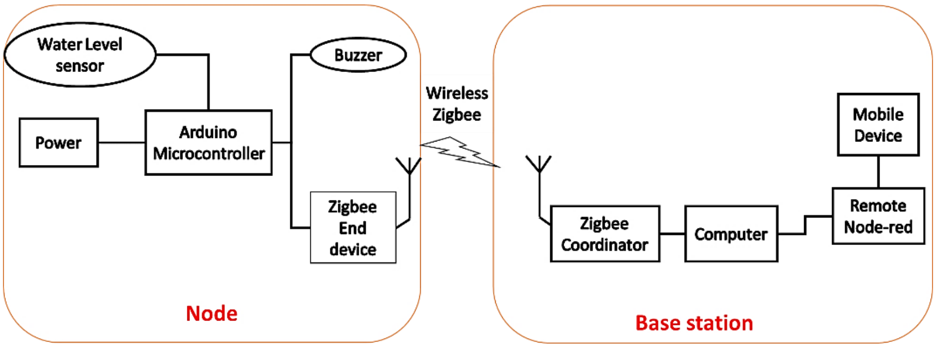



**Figure 1:** Overall system design

### 2.1.1 Node part hardware design

Figure 2 shows the end node components, including the water level sensor, water level controller (Arduino UNO), buzzer, and wireless ZigBee end device. The latter transmits data received from the water level sensor to the coordinator ZigBee device on the base station side.

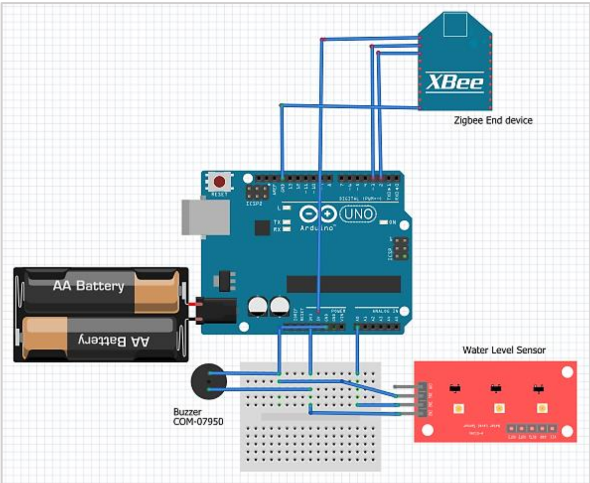



**Figure 2:** Hardware end node

## 2.2 Water level sensor

The water level sensor, illustrated in Figure 3, plays a critical role in flood prevention by continuously monitoring the height of the water. This sensor operates based on a variable resistor principle, functionally similar to a potentiometer, wherein its resistance varies proportionally with the water level. Specifically, as the distance between the top of the sensor and the water's surface changes, the electrical resistance changes accordingly. When the water level rises and the sensor becomes more submerged, the increased contact with water enhances conductivity, which results in a lower resistance value. Conversely, when the water level falls and the sensor is only partially submerged, the effective conductivity decreases, thereby causing the resistance to increase. This dynamic relationship enables precise measurement: by monitoring the corresponding output voltage across the sensor, it becomes possible to determine the water level in real time. This voltage-resistance correlation provides an effective mechanism for early detection of rising water levels and allows for timely activation of warning systems or pumps to mitigate flooding risks.

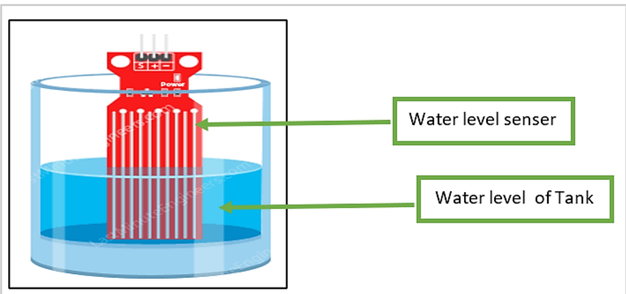



**Figure 3:** A variable resistor operates the sensor [15]

## 2.3 Zigbee end device

The ZigBee Alliance software specifies the network, security, and application layers. Readers can access more details about the media access control and physical layers based on IEEE802.15.4 (hardware) [15]. Because of the decreased power demand, smaller batteries might have longer life spans. Zigbee transceiver considers the following factors, as indicated in Table 1: a 2.4 GHz system that follows IEEE 802.15 specifications. Now table (2) that shown below is The IEEE 802.15.4 Standard for a ZigBee Transceiver Operating at 2.4 GHz .

**Table 2:** The IEEE 802.15.4 Standard for a ZigBee Transceiver Operating at 2.4 GHz [16]

| Configuration settings | Values |
|---|---|
| Data transfer speed | 250 kbps |
| Frequency of operation | 2.4 GHZ |
| amount of channel | 16 |
| Spacing between channels | 5 MHZ |
| Chip rate | 2 Mbps |
| Pulse shaping | Half sine |
| Spreading technique | DSSS |
| Method of modulation | OQPSK |

### 2.3.1 Hardware design of the base station part

The base station's components include a computer, a Zigbee wireless coordinator, and an Arduino Uno. The coordinator device's primary function is to receive data transmitted by Zigbee end devices and store it in a computer. The Base Station is illustrated in Figure 4.

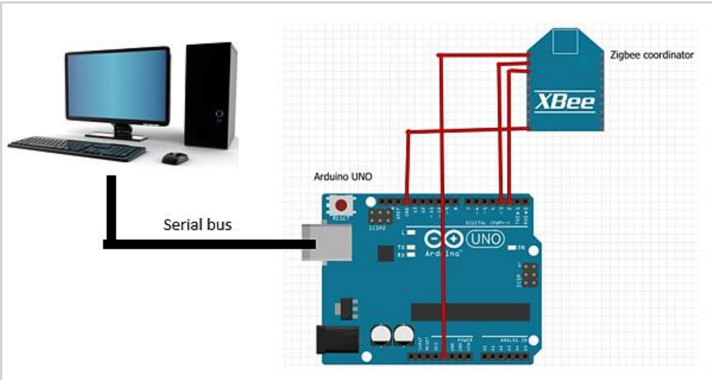



**Figure 4:** Base station

## 2.4 System software design

The software system has several components (XCUT, Arduino IDE, Node-RED):

### 2.4.1 XCUT software tool

XCUT is an easy-to-use graphical user interface (GUI) program for configuring Zigbee devices; it allows developers to work with Zigbee RF modules. In Figure 5, the software's front end comprises two devices: one that acts as a coordinator and another as an end device.

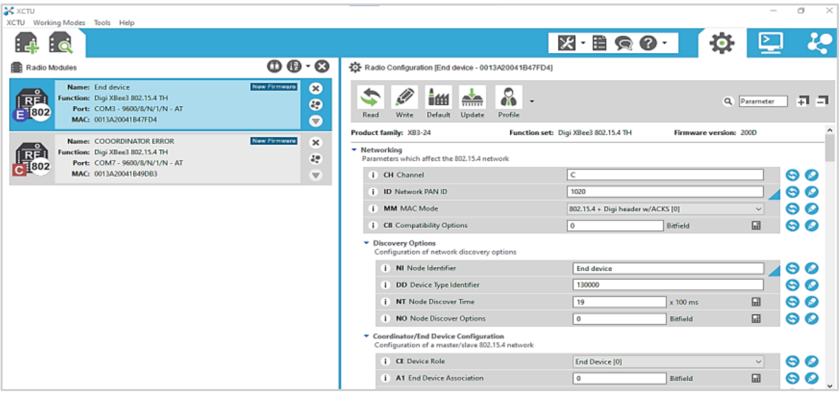


**Figure 5:** Front end of XCUT

### 2.4.2 Software design for end node

The programming of the end node component requires it. This can be accomplished by utilising the Arduino IDE application to program the Arduino UNO microcontroller. The first step in the code flow diagram for an Arduino, as shown in Figure 6, is to turn on the board and set up the variables. Then, to send data between the end device and the coordinator, you need to connect the two Zigbee devices. If the water level sensor readings are greater than the threshold (26), the buzzer will alert people to impending danger (flooding), if they are lower than 26, the buzzer will not sound. This may be accomplished by utilising the Zigbee libraries.

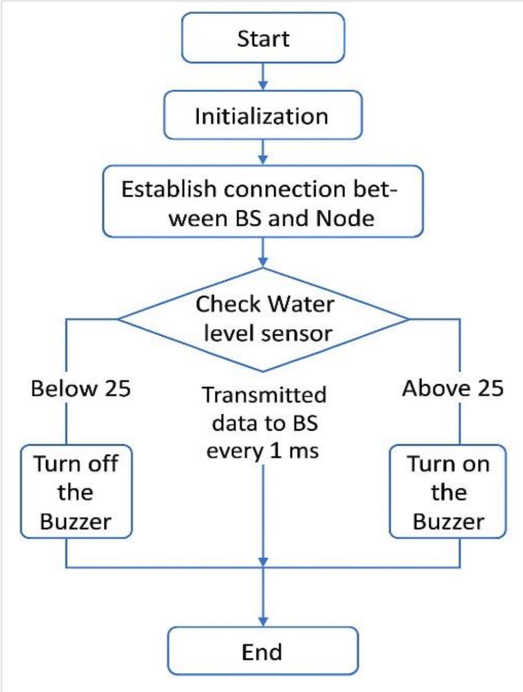



**Figure 6:** End node programming flow chart

### 2.4.3 Software design of base station part

Two platforms make up the base station software. The first is the Arduino IDE, which is used to program Zigbee and receive data from end devices. Just like the node code, the initialization and Zigbee library code must be written to establish a link between two Zigbee wireless devices. Figure 7 displays the programming flowchart.

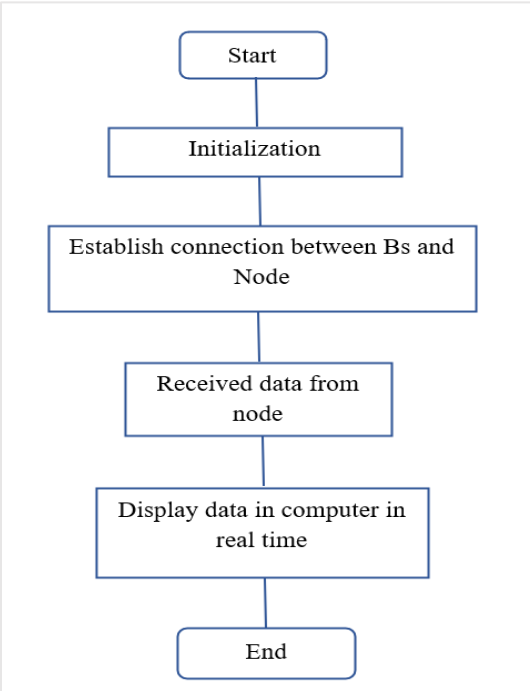
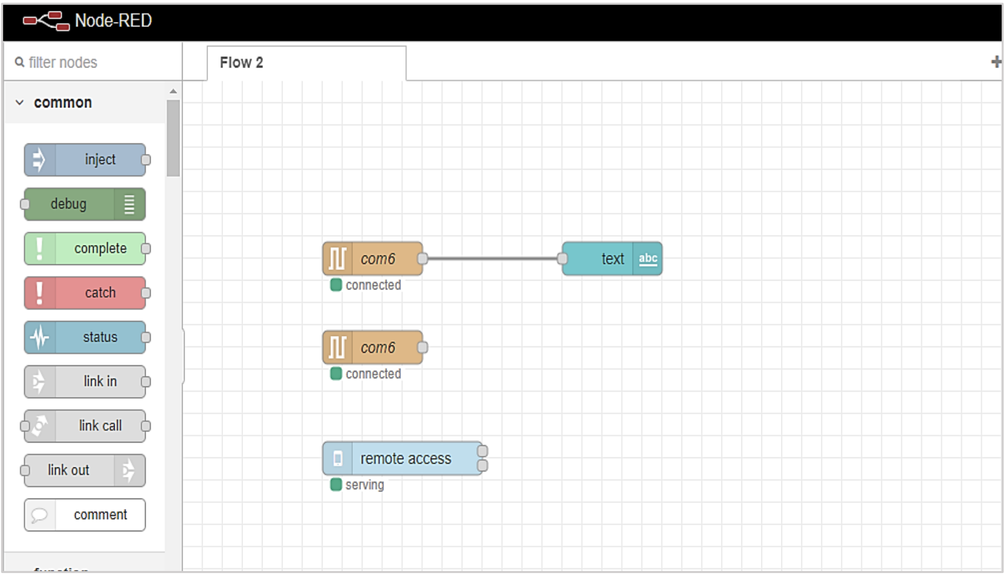
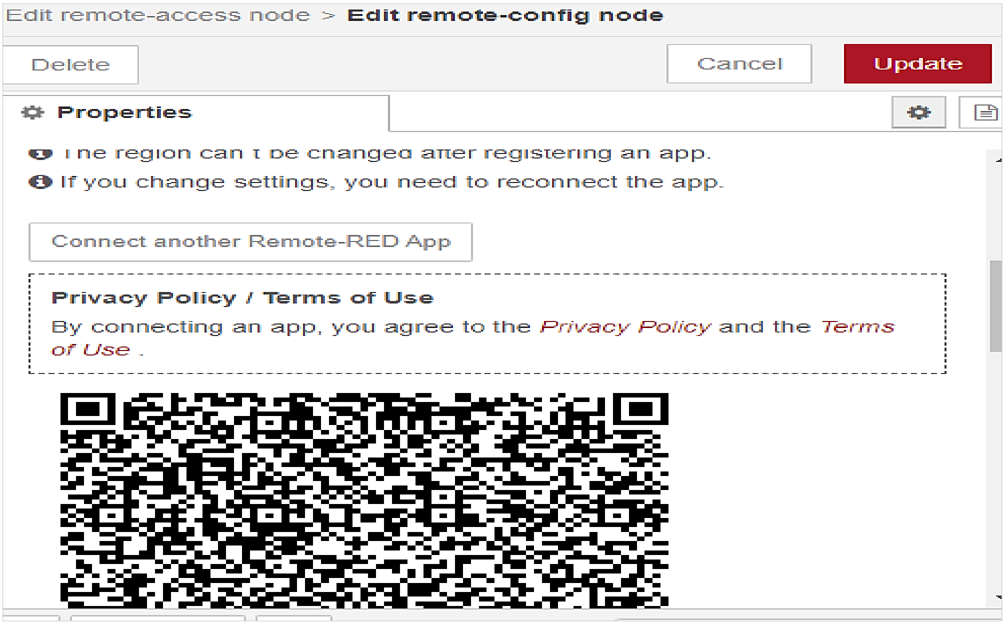



**Figure 7:** Flow chart of arduino IDE base station part

The second platform is Node-Red, a great way to transmit data from an Arduino. By installing the Remote Red software on our mobile devices, we may send data to our phones over the Node Red platform, as shown in Figure 8a. By installing the Remote Red software on our mobile devices, we may send data to our phones over the Node Red platform, as shown in Figure 8a. By installing the Remote Red software on our mobile devices, we may send data to our phones over the Node Red platform, as shown in Figure 8b. Scanning the QR code shown in Figure 8b will transfer the record data to our mobile device.




**(a)**




**(b)**

**Figure 8:** a) Node-Red platform, b) QR code

## 3. System test result

The proposed system was designed to monitor water levels and issue early warnings in flood-prone areas. The system operates by continuously reading data from a water level sensor interfaced with an Arduino microcontroller. A predefined threshold value of 26 analog units was established, such that:

1) If the sensor value exceeds 26, the system activates a buzzer, signaling a potential flood threat.
2) If the sensor value falls below 26, the system deactivates the buzzer, indicating a safe condition.

This threshold correlates to approximately 5 cm of water in a 12 cm-high container used for experimental validation. Real-time sensor values are displayed via the Arduino IDE's serial monitor Figure 9 and transmitted to a base station using ZigBee wireless communication Figure 10. Subsequently, the data is relayed to a Node-Red dashboard, accessed from a browser or through the Remot-Red mobile application, enabling remote, real-time monitoring Figures (11,12).

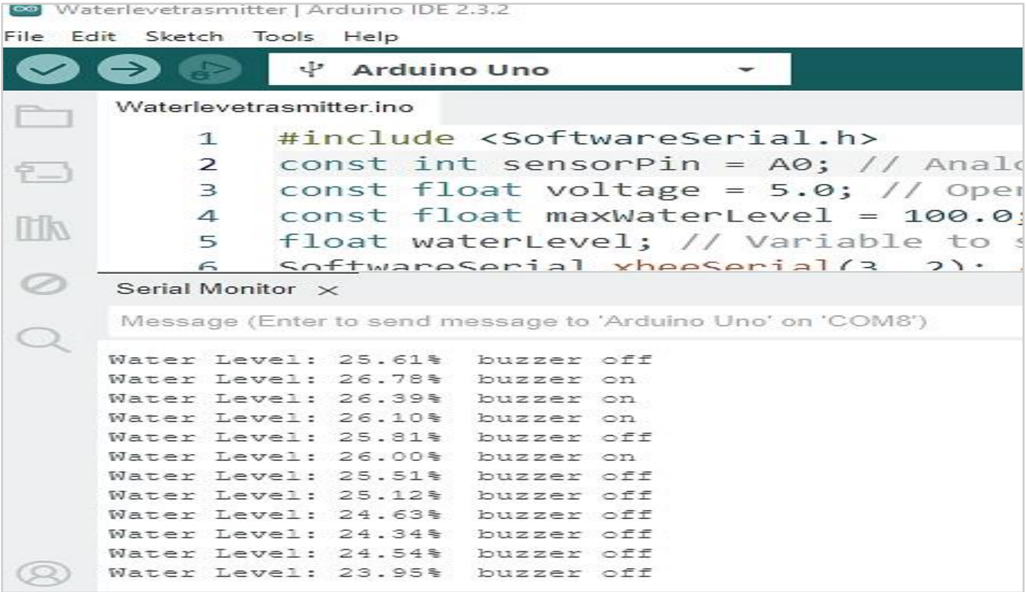



**Figure 9:** Serial monitor of the Arduino IDE

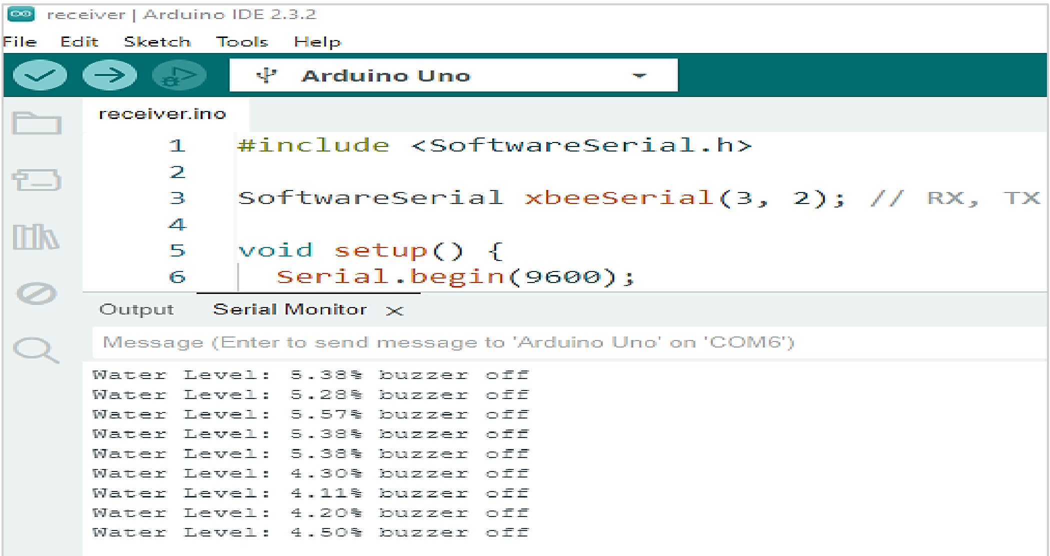



**Figure 10:** The system switches off the buzzer

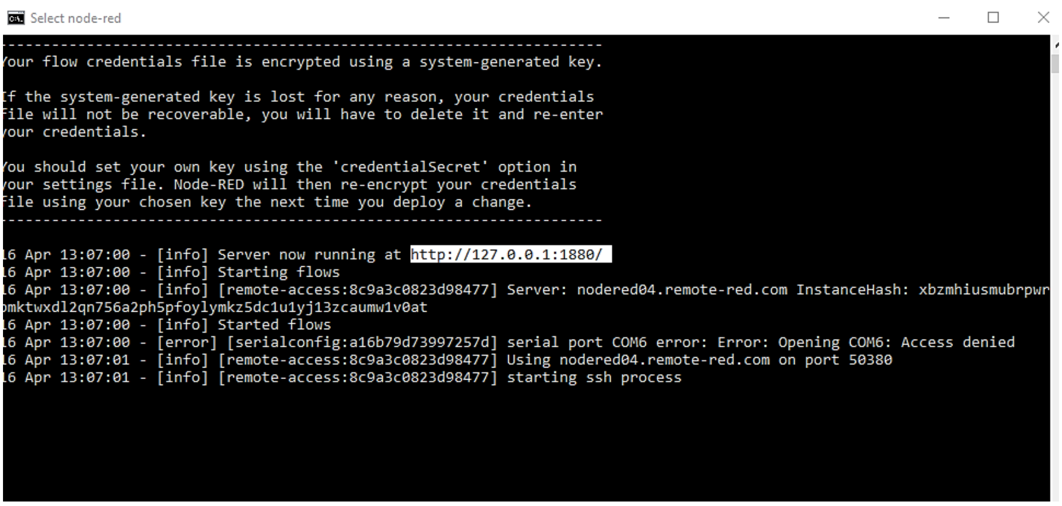



**Figure 11:** The results of opening Node-Red

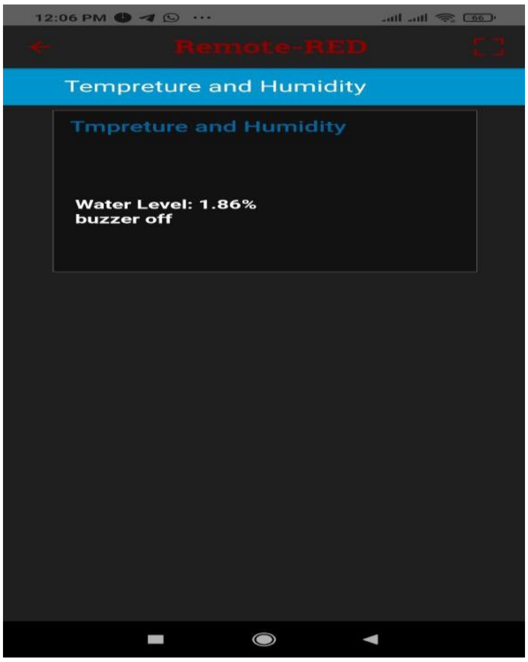
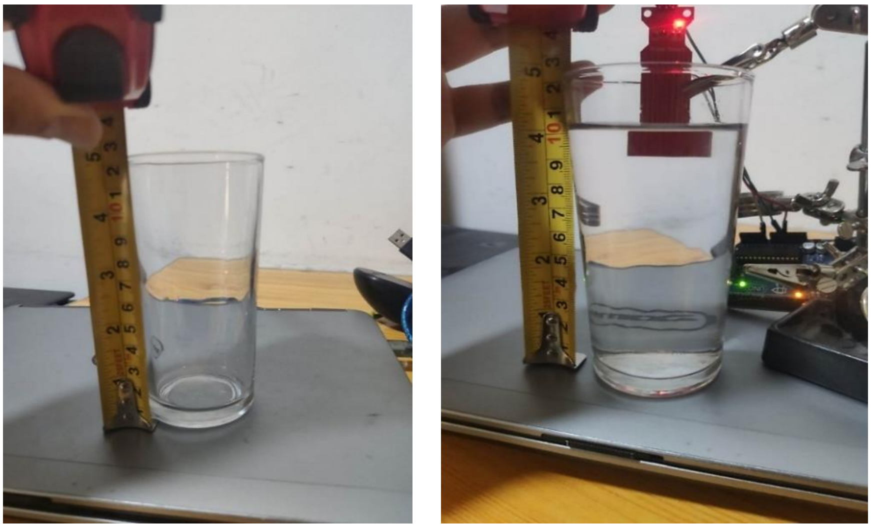



**Figure 12:** Remot-Red app on the mobile device

## 3.1 Sensor Accuracy Testing

The water level sensor was gradually immersed in a container to assess sensor accuracy, and analog values were recorded as shown in Figure 13 (a and b) of Design for Automated Water Level Detection and Notification. These readings were mapped against actual water levels and summarized in Table 3. The relationship between sensor values and physical water depth validates the system's precision in detecting subtle changes in water levels.



**(a)** **(b)**

**Figure 13:** a) and b) System design for automated water level detection and notification

**Table 3:** Sensor accuracy based on water depth

| Water Depth (cm) | Sensor Reading |
|---|---|
| 3.5 | 17 |
| 5.0 | 25 |
| 7.5 | 30 |
| 9.5 | 36 |
| 10.0 | 45 |
| 11.0 | 55 |
| 12.0 | 62 |

These results confirm that the sensor reliably maps water levels to analog readings, and the selected threshold of 26 offers timely early warnings in flooding scenarios.

## 3.2 Comparison with related works

Table 4 below provides a detailed comparison between the proposed system and related research studies available in the literature. This comparison highlights the clear advantages of the proposed approach across several critical performance criteria, including:

- ✓ **Communication Technology:** The system utilizes a modern and robust communication protocol that improves data transmission reliability compared to traditional methods.
- ✓ **Power Efficiency:** The design emphasizes low power consumption, extending operational life and reducing maintenance frequency.
- ✓ **Cost:** The solution offers a cost-effective implementation by leveraging affordable components without sacrificing accuracy or performance.
- ✓ **Range of Detection**: The system achieves a superior detection range, making it suitable for broader monitoring areas compared to earlier systems.

These strengths collectively demonstrate that the proposed system delivers improved performance and practicality over previous works, supporting its adoption in real-world flood monitoring applications.

**Table 4:** Result of preposed work with related works

| Technology Used | Threshold Mechanism | Communication | Alert System | Limitations | Ref. |
|---|---|---|---|---|---|
| GSM + Float Sensor | Float-triggered | GSM | SMS, phone calls | Relies on GSM only; no IoT/cloud integration | [10] |
| IoT + Smart Tank System | Float sensor | Wi-Fi | App-based alerts | Focus on water saving, not disaster prevention | [11] |
| Ultrasonic + Twilio (Cloud API) | Ultrasonic sensor (JSN-SR04T) | Internet (Cloud) | Node-Red dashboard | Requires continuous internet connectivity | [12] |
| IoT + Relay | App-based threshold | Wi-Fi | Pump control and alerts | Not designed for flood warning or ZigBee-based | [13] |
| Analog Sensor + ZigBee | Analog threshold (26) | ZigBee + IoT | Buzzer + Mobile + Node-Red | Low-cost, scalable, energy-efficient, real-time | Proposed System |

The proposed system demonstrates a robust, low-cost, and energy-efficient solution for real-time flood detection and early warning. Integrating accurate analog water level sensing with ZigBee-based communication and a flexible IoT platform surpasses previous systems adaptability, accuracy, and scalability. The experimental results validate its practical applicability in flood-prone regions, while the comparative evaluation confirms its superiority in communication efficiency, operational range, and user accessibility.

## 4. Conclusion

The system emphasises two essential elements the implementation of a threshold-based alert system and the benefits of employing ZigBee technology for real-time environmental monitoring.

1. Threshold-Dependent Notification System the system has a water level threshold of 26 as the essential parameter for activating alarms. This signifies that, should the water level surpass 26, the system presumes that flooding is imminent or in progress, and a bell is activated to notify others around. Should the water level go below 26, the risk is deemed diminished, and the buzzer is deactivated. This threshold is meticulously chosen to issue timely alerts, allowing individuals sufficient time to escape or implement safety protocols prior to the escalation of the incident. Achieve equilibrium between false positives and delayed answers, guaranteeing that notifications are both prompt and precise.
2. Benefits of ZigBee Technology, ZigBee has been selected as the primary communication protocol for this system due to its numerous attributes that are well-suited for a disaster monitoring context because:

- Minimal energy usage ZigBee devices necessitate little energy consumption, which is crucial for prolonged remote functionality.
- Simplified implementation the system is easy to install and does not necessitate intricate infrastructure.
- Extended battery longevity is optimal for sensors situated in remote or inaccessible sites.
- Economical and minimal upkeep the hardware is inexpensive, and maintenance is little, rendering the system cost-efficient.
- Elevated node density a ZigBee network can accommodate numerous devices simultaneously, which is crucial for overseeing extensive areas.
- ZigBee is extensively utilised and endorsed, guaranteeing compatibility and facilitating integration.

These attributes collectively render ZigBee a resilient and scalable solution for IoT-based flood monitoring systems. The capacity to link numerous water level sensors to a central monitoring unit with real-time data transmission improves the system's dependability and responsiveness in emergencies. Therefore, the system provides a realistic, cost-effective, and efficient solution for flood risk monitoring and early warning by integrating a precisely calibrated threshold alarm mechanism with the scalability and efficacy of ZigBee communication. This technology can greatly enhance community safety, disaster preparedness, and infrastructure resilience in flood-prone regions.

## Author contributions

Conceptualization, **A. Abed, A. Hussien,** and **L. Falah**; data curation, **A. Abed**; formal analysis, **A. Abed**; investigation, **A. Abed**; methodology, **A. Hussien**; project administration, **A. Hussien**; resources, **L. Falah**; software, **A . Hussien**; supervision, , **A. Hussien**; validation, **A. Abed**, **A . Hussien,** and **L. Falah**; visualization, **L. Falah**; writing—original draft preparation, **L. Falah**; writing—review and editing, **L. Falah**. All authors have read and agreed to the published version of the manuscript.

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## Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

## Conflicts of interest

The authors declare that there is no conflict of interest.

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