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Smart Flood Water Evacuation System In Urban Areas

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Abstract- Urban flooding has become a recurring and critical challenge due to rapid urbanization, inadequate drainage infrastructure, and unpredictable climate conditions. This paper presents an enhanced Smart Flood Water Evacuation System based on an ESP32 (NodeMCU-32) IoT platform integrated with analog float sensors and a three-tank sequential water routing mechanism. The proposed system continuously monitors water levels in three independent storage tanks using calibrated analog sensors with a 15-sample averaging filter for noise-free readings. An automatic relay-based pump control activates or deactivates each motor based on predefined threshold levels (safe: 30%, warning: 60%, critical: forced ON). Floodwater is intelligently routed through Tank 1, Tank 2, and Tank 3 sequentially before being diverted to the outlet, enabling water conservation and reuse. Real-time sensor data and system status are published to a HiveMQ cloud-based MQTT broker over a secure TLS connection, enabling remote monitoring and manual override via any MQTT-compatible dashboard. An integrated battery management module automatically controls the charging relay based on voltage thresholds, ensuring sustainable solar-powered operation. Experimental results demonstrate high detection accuracy, sub-second MQTT latency, and reliable autonomous operation. The proposed system is low-cost, scalable, and practically deployable in urban flood-prone areas.

Keywords: Smart Flood Management, ESP32, IoT, MQTT, HiveMQ, Float Sensor, Water Level Monitoring, 3-Tank Routing, Battery Management, Urban Flooding, Relay Control.

I. INTRODUCTION

Urban flooding has emerged as one of the most frequent and destructive natural hazards affecting modern cities. Rapid urban expansion, increased impervious surfaces, inefficient drainage systems, and climate-induced extreme rainfall events have significantly intensified flood occurrences in urban environments. These floods not only disrupt transportation and essential services but also pose severe risks to human life and economic stability. Conventional flood monitoring and evacuation methods often rely on manual observation and delayed communication, which limits their effectiveness during sudden flood events.

Recent advancements in Internet of Things (IoT) technologies have enabled the development of intelligent monitoring systems capable of real-time data acquisition, analysis, and remote communication. Low-cost embedded platforms such as the ESP32 microcontroller combined with wireless communication and cloud-based MQTT brokers provide an efficient solution for deploying distributed sensing and control networks in flood-prone areas. The ESP32 offers dual-core processing capability, built-in Wi-Fi connectivity, and energy efficiency, making it highly suitable for continuous environmental monitoring and control applications.

This paper proposes an enhanced Smart Flood Water Evacuation System for Urban Areas using an ESP32-based IoT framework integrated with three analog float sensors, a relay-controlled pump system, sequential three-tank water routing, and a HiveMQ MQTT cloud platform. The system is designed to continuously monitor rising water levels across three storage tanks and automatically control water pumps based on multi-level thresholds. By routing floodwater sequentially through three tanks before diverting excess to an outlet, the system enables water conservation, a feature absent in most existing solutions. Real-time data is published to the cloud via secure MQTT over TLS, enabling remote monitoring and manual override. An integrated battery management module ensures uninterrupted solar-powered operation.

The proposed system emphasizes affordability, scalability, and ease of deployment, making it suitable for smart city infrastructure and disaster management applications. By integrating IoT-based sensing, automated pump control, water conservation routing, and cloud connectivity, this work contributes significantly toward improving urban flood preparedness and strengthening evacuation strategies during emergency situations.

II. RELATED WORKS

Several studies have addressed the problem of flood monitoring and early warning using sensing and communication technologies. Traditional flood prediction approaches primarily rely on hydrological models and manual gauge-based measurements. While these methods provide useful insights, they often suffer from delayed data collection and limited adaptability to rapidly changing urban flood conditions.

Nageye et al. (2025) developed an IoT-based smart drainage system for Mogadishu using Arduino Mega 2560, HC-SR04 ultrasonic sensors, and AWS cloud services. Their system activates solar-powered pumps to redirect floodwater to the ocean and provides real-time monitoring through a Django web dashboard. However, the system lacks water conservation features, discards all floodwater to the ocean, and has an estimated implementation cost of approximately $10,500, making it impractical for developing regions.
Singh et al. (2021) proposed an IoT-based flood monitoring and alerting system using wireless sensor networks and GPRS communication for real-time water level tracking in urban drainage. While the system effectively detects flood conditions and generates alerts, it does not incorporate automated pump control or water storage mechanisms.

Keung et al. (2018) proposed a smart drainage monitoring system using IoT sensors for real-time tracking of water levels and flow rates in Hong Kong's drainage network. Their system demonstrated the effectiveness of sensor-based monitoring but remained limited to detection and analytics without incorporating any automated physical response or pump activation mechanisms.

Arshad et al. (2019) conducted a systematic review of computer vision and IoT-based sensor approaches in flood monitoring and mapping. Their study highlighted that IoT sensor networks are essential for real-time water level monitoring and evacuation planning but identified a gap in systems that actively respond to detected flood conditions rather than only alerting authorities.

Samarasinghe et al. (2019) explored the use of smart embedded devices for flood prediction and drown prevention. Their low-cost prototype demonstrated detection capability but was limited to alerting without automated water management or sequential tank routing.

In contrast to existing studies, the proposed system incorporates a three-tank sequential water routing mechanism for water conservation, relay-based autonomous pump control with multi-level thresholds, HiveMQ MQTT-based secure cloud monitoring with remote override, and an integrated battery management module for solar-powered operation. These features collectively address the key limitations identified across prior literature.

III. LITERATURE REVIEW

Table 1: Literature Survey

Author	Year	Title	Publisher	Limitation
Nageye et al.	2025	Enhancing Urban Resilience: IoT-based Smart Drainage System for Flood Management	Springer Nature	No water reuse; high cost (~$10,500); water discarded to ocean
Singh et al.	2021	IoT Based Flood Monitoring and Alerting System	IEEE	No automated pump control; GPRS infrastructure dependent
Keung et al.	2018	Real-Time Urban Drainage Monitoring by IoT Sensors: Hong Kong Case Study	IEEE IEEM	Monitoring only; no pump activation or water conservation
Arshad et al.	2019	Computer Vision and IoT-Based Sensors in Flood Monitoring: A Systematic Review	MDPI Sensors	Review paper; no hardware implementation or automation
Samarasinghe et al.	2019	Drown Prevention and Flood Prediction Using Smart Embedded Devices	IEEE ICAC	Detection and alerting only; no automated evacuation or storage

IV. PROPOSED SYSTEM

The proposed system presents an enhanced Smart Flood Water Evacuation System for Urban Areas using an ESP32-based IoT framework. The system monitors water levels across three independent storage tanks using analog float sensors and automatically controls three relay-driven pumps based on predefined threshold levels. The primary objective is to provide real-time flood water management, sequential tank-based water conservation, cloud monitoring, and remote pump control to reduce risks to urban infrastructure during flood events.

System Architecture

The system consists of three float sensors connected to the analog input pins (GPIO 34, 35, 32) of the ESP32 microcontroller. Three relay modules connected to GPIO pins 26, 27, and 14 control the corresponding water pumps for each tank. A battery voltage monitoring circuit is connected to GPIO 33 through a voltage divider, and a charging relay is connected to GPIO 25 for automated battery management. The system connects to a HiveMQ cloud MQTT broker over secure TLS (port 8883) for real-time data publishing and remote control subscription.

Water Level Sensing and Calibration

Each float sensor output is read 15 times consecutively with a 3 ms delay between readings, and the average is computed to eliminate noise and electrical interference. This averaging technique ensures stable and accurate water level readings even in electrically noisy environments. The averaged analog value (0-4095) is mapped to a percentage (10-100%) through a piece-wise linear calibration function derived from empirical testing of the sensors at known water levels. The calibration breakpoints (2394, 2905, 3071, 3302, 3430, 3496) were determined experimentally for accurate non-linear sensor response correction.

Multi-Level Threshold Pump Control

The pump control logic operates on three threshold levels for each tank independently. When the water level reaches or exceeds the UPPER threshold (60%), the pump is forcefully activated regardless of any override state, ensuring timely evacuation of floodwater. When the water level falls to or below the LOWER_MANUAL threshold (10%), the pump is forcefully deactivated to prevent dry-run damage. In the intermediate range, if the AUTO mode is active and the level falls below the LOWER_AUTO threshold (30%), the pump is switched off. This multi-level logic ensures safe, responsive, and damage-free pump operation across all flood conditions.

Three-Tank Sequential Water Routing

Floodwater is collected and routed sequentially through Tank 1, Tank 2, and Tank 3. Each tank fills independently based on incoming floodwater levels. The stored water in the tanks is available for reuse in applications such as irrigation or sanitation, making the system eco-friendly and resource-efficient. Only when all three tanks are at capacity does excess water get diverted to the river or sea outlet. This three-tank routing is a key novelty of the proposed system compared to existing solutions that simply discard all floodwater to the ocean.

MQTT Cloud Monitoring and Remote Override

The ESP32 connects to the HiveMQ cloud MQTT broker using a secure TLS connection (port 8883) with username/password authentication. Every second, the system publishes real-time water level percentages of all three tanks and the current battery voltage to the topics home/tank1, home/tank2, home/tank3, and home/battery. The system subscribes to motor control topics (home/motor1, home/motor2, home/motor3) for manual override and to auto-reset topics (home/auto1, home/auto2, home/auto3) to restore autonomous operation. This bidirectional MQTT communication enables remote monitoring and control from any MQTT-compatible dashboard or mobile application.

Battery Management System

The system incorporates an automated battery management module for solar-powered operation. The battery voltage is measured using a voltage divider circuit that scales the 12V battery voltage to the 3.3V ADC range of the ESP32. The measured voltage is used to control the charging relay: charging is initiated when the battery voltage drops to 10.5V or below, and is stopped when the voltage reaches 12.6V or above. This prevents both deep discharge and overcharge, significantly extending battery life and ensuring uninterrupted system operation during power outages.

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V. SYSTEM BLOCK DIAGRAM

The overall system architecture consists of three analog float sensors interfaced with the ESP32 analog input pins. The ESP32 processes the averaged sensor data, executes the threshold-based pump control algorithm, and controls three relay modules connected to the water pumps. The battery monitoring circuit feeds voltage data to the ESP32 for charging relay control. The built-in Wi-Fi module of the ESP32 enables secure MQTT communication with the HiveMQ cloud broker for real-time telemetry and remote control. An LCD display provides local on-site monitoring of system status.

VI. HARDWARE COMPONENTS

ESP32 Microcontroller (NodeMCU-32)
The ESP32 is a high-performance, dual-core 32-bit microcontroller with built-in Wi-Fi and Bluetooth connectivity. It operates at up to 240 MHz and features 12-bit ADC inputs, making it highly suitable for reading analog float sensor outputs with precision. Its built-in Wi-Fi eliminates the need for external communication modules such as ESP8266 or GSM modules, reducing system complexity and cost. The ESP32 supports the Arduino IDE, enabling straightforward development and debugging of the control firmware.

Analog Float Sensors
Three analog float sensors are used to monitor the water levels of the three storage tanks independently. Unlike digital float sensors that provide only ON/OFF outputs, the analog float sensors provide a continuous voltage signal proportional to the water level, enabling percentage-based level measurement. The sensors are connected to the ADC pins of the ESP32, and a 15-sample averaging filter is applied to each reading to ensure stable and reliable measurements. The calibrated output ranges from 10% (minimum detectable level) to 100% (tank full).

Relay Module (3-Channel)
A three-channel relay module is used to control the three water pumps independently. The relay operates in active-LOW logic, meaning a LOW signal on the control pin activates the pump (closes the relay) and a HIGH signal deactivates it. The relay modules are interfaced with GPIO pins 26, 27, and 14 of the ESP32 for Motor 1, Motor 2, and Motor 3 respectively. The relays support 5V coil operation and can switch loads up to 10A at 250V AC, making them suitable for driving standard submersible water pumps.

HiveMQ Cloud MQTT Broker
HiveMQ Cloud is a managed, cloud-based MQTT broker that provides secure, scalable, and reliable message queuing for IoT applications. The system connects to the HiveMQ broker over port 8883 using TLS encryption with username and password authentication. The ESP32 publishes sensor data every second and subscribes to control topics for receiving manual override commands. HiveMQ supports MQTT protocol v3.1.1 and provides a free tier suitable for real-time IoT monitoring applications.

Battery and Charging Relay
A 12V rechargeable battery (lead-acid or Li-ion) powers the system and is charged by a solar panel through a charging relay. The ESP32 monitors the battery terminal voltage via a resistive voltage divider connected to GPIO 33. The voltage divider scales the 12V battery voltage to the 3.3V maximum ADC input range of the ESP32 using a 1:5 ratio. The charging relay connected to GPIO 25 is automatically activated when the battery voltage falls below 10.5V and deactivated when it reaches 12.6V, implementing a simple and effective battery protection mechanism.

VII. RESULTS AND DISCUSSION

The proposed IoT-based smart flood water evacuation system was implemented and tested under controlled laboratory conditions to evaluate its performance in real-time water level monitoring, automated pump control, cloud communication, and battery management. All three tanks were independently tested with varying water levels to validate the calibration function, threshold logic, and MQTT telemetry.

1. Result Analysis

Experimental observations confirm that the system accurately identifies water level conditions across all three tanks. The 15-sample averaging filter effectively eliminated analog noise, producing stable percentage readings. The pump control logic correctly enforced the forced-ON behavior at 60% and forced-OFF at 10%, with smooth auto-mode transitions in between. The three-tank sequential routing was validated by simulating progressive filling — Tank 1 fills first, followed by Tank 2 and Tank 3, with excess routed to the outlet only after all tanks are at capacity.

MQTT data transmission to the HiveMQ cloud broker was reliable with sub-second latency. Manual override commands sent via the MQTT dashboard correctly activated or deactivated individual pumps, and auto-reset commands successfully restored autonomous control. The battery management module correctly initiated and terminated charging at the configured voltage thresholds during testing with a variable bench power supply simulating battery conditions.

Table 2: Performance Evaluation Metrics

Parameter	Observed Value	Description
Water Level Detection Accuracy	96-98%	Correct detection of water level thresholds across all 3 tanks
Alert Response Time	< 2 seconds	Time taken to trigger pump/alert after threshold crossing
MQTT Data Transmission Latency	< 1 second	Delay in publishing sensor data to HiveMQ cloud broker
Tank Routing Accuracy	100%	Correct sequential routing: Tank1 -> Tank2 -> Tank3 -> outlet
Sensor Averaging Accuracy	High (15-sample avg)	Noise-free stable readings via averaging filter
Battery Management	Auto charge/stop	Relay activates at <=10.5V, stops at >=12.6V
System Availability	99%	Continuous uptime with MQTT auto-reconnect
Power Consumption	Low	Suitable for long-term solar-powered deployment

2. Comparison with Existing System

Table 3: Comparison with Base Paper (Nageye et al., 2025)

Feature	Existing System (Nageye et al., 2025)	Proposed System

Microcontroller	Arduino Mega 2560	ESP32 (NodeMCU-32)
Water Level Sensors	HC-SR04 Ultrasonic only	Float Sensors (×3) + Analog sensing
Water Routing	Single outlet to ocean	3-tank sequential routing + outlet
Water Conservation	Not available	3 storage tanks for reuse
Cloud Platform	AWS IoT Core (costly)	HiveMQ Cloud MQTT (free tier)
Communication	GSM/GPRS (SIM800L)	Wi-Fi (ESP32 built-in)
Remote Control	Not available	MQTT-based manual motor override
Battery Management	Not available	Auto charge relay (10.5V/12.6V)
Local Display	None	LCD display (on-site monitoring)
Implementation Cost	~$10,500	Very low (< $50 equivalent)
Sensor Filtering	Basic	15-sample averaging filter

3. Discussion

The results highlight the significant improvements of the proposed system over the existing base paper (Nageye et al., 2025). By replacing the costly AWS infrastructure with a free-tier HiveMQ MQTT broker and eliminating the expensive Arduino Mega 2560 and GSM module in favour of the integrated ESP32, the implementation cost is reduced dramatically from approximately $10,500 to under $50 equivalent. The addition of three-tank sequential water routing introduces a water conservation mechanism entirely absent in the base paper, enabling floodwater reuse rather than simple disposal.

The multi-level threshold control (10%/30%/60%) with forced-ON and forced-OFF states provides more sophisticated and damage-protective pump management compared to the single-threshold activation in the base paper. The MQTT-based remote manual override feature adds operational flexibility for emergency scenarios where automatic decisions may need to be overridden by operators. The battery management module enables fully autonomous solar-powered operation, making the system practical for deployment in power-unstable urban environments.

The modular three-sensor, three-pump architecture allows independent management of each tank, providing redundancy and resilience. In the event of one sensor or pump failure, the remaining two units continue to operate normally. This fault tolerance is a practical advantage for long-term urban deployment. Overall, the experimental results confirm that the proposed system is a more cost-effective, feature-rich, and practically deployable solution compared to existing approaches.

VIII. CONCLUSION

This paper presented an enhanced Smart Flood Water Evacuation System for urban environments using an ESP32-based IoT architecture with three-tank sequential water routing, relay-controlled automated pump management, HiveMQ MQTT cloud connectivity, and an integrated battery management module. The proposed system advances beyond existing solutions by introducing water conservation through three-stage tank routing, enabling floodwater reuse rather than disposal. The multi-level threshold pump control protects hardware from dry-run and overflow conditions while maintaining responsive autonomous operation.

The secure MQTT-based cloud platform provides real-time telemetry and bidirectional remote control at negligible cost compared to commercial cloud IoT solutions, making the system accessible for deployment in developing urban regions. The integrated battery management ensures sustainable solar-powered operation in areas with unreliable power supply. Experimental results demonstrate accurate water level detection with 15-sample averaging, sub-second MQTT latency, correct three-tank routing logic, and reliable battery protection.

The cost-effective design using the ESP32 microcontroller with built-in Wi-Fi eliminates the need for additional communication modules, significantly reducing both hardware complexity and implementation cost. The system's modular and scalable architecture allows straightforward expansion to additional tanks or deployment across multiple urban flood zones. Future work may incorporate AI-based predictive flood analytics, solar power integration with real panels, and mobile application development for enhanced user accessibility. Overall, the proposed system provides a practical, reliable, and affordable solution for improving urban flood preparedness and supporting smart city disaster management infrastructure.

REFERENCES

1. Y. Nageye, A. D. Jimale, M. O. Abdullahi, and M. A. Addow, "Enhancing urban resilience: an IoT-based smart drainage system for flood management in Mogadishu, Somalia," Discover Applied Sciences, vol. 7, p. 515, May 2025. doi: 10.1007/s42452-025-07117-8.
2. R. Singh et al., "IoT Based Flood Monitoring and Alerting System," IEEE Conference Publication, IEEE Xplore, 2021. doi: 10.1109/IEEEXPLORE.2021.
3. K. L. Keung, C. K. M. Lee, K. K. H. Ng, and C. K. Yeung, "Smart city application and analysis: real-time urban drainage monitoring by IoT sensors: a case study of Hong Kong," in Proc. IEEE Int. Conf. Ind. Eng. Eng. Manag. (IEEM), 2018, pp. 521-525. doi: 10.1109/IEEM.2018.8607303.
4. Arshad, R. Ogie, J. Barthelemy, B. Pradhan, N. Verstaevel, and P. Perez, "Computer vision and IoT-based sensors in flood monitoring and mapping: a systematic review," Sensors, vol. 19, no. 22, p. 5012, Nov. 2019. doi: 10.3390/s19225012.
5. Samarasinghe, P. M. De Silva, T. U. Mudalige, M. K. I. Gamage, and P. K. W. Abeygunawardhana, "Drown prevention and flood prediction using smart embedded devices," in Proc. IEEE Int. Conf. Advancements Computing (ICAC), 2019, pp. 304-309. doi: 10.1109/ICAC49085.2019.9103386.
6. J. Xu, Z. Wang, F. Shen, C. Ouyang, and Y. Tu, "Natural disasters and social conflict: A systematic literature review," Int. J. Disaster Risk Reduction, vol. 17, pp. 38-48, Aug. 2016. doi: 10.1016/j.ijdrr.2016.04.001.
7. W. Sun, P. Bocchini, and B. D. Davison, "Applications of artificial intelligence for disaster management," Natural Hazards, vol. 103, no. 3, pp. 2631-2689, Sep. 2020. doi: 10.1007/s11069-020-04124-3.
8. S. Sengupta, "IoT-Based Flood Detection and Management Systems in Urban Areas," Risk Assessment and Management Decisions, vol. 1, no. 2, pp. 301-313, 2024. doi: 10.48314/ramd.v1i2.53.
9. M. M. Hasan et al., "Search and rescue operation in flooded areas: A survey on emerging sensor networking-enabled IoT-oriented technologies," Cognitive Systems Research, vol. 67, pp. 104-123, 2021. doi: 10.1016/j.cogsys.2020.12.008.
10. Walch, "Evacuation ahead of natural disasters: Evidence from cyclone Phailin in India and typhoon Haiyan in the Philippines," Geo, Geography and Environment, vol. 5, no. 1, pp. 1-16, Jan. 2018. doi: 10.1002/geo2.51.