



A REVIEW ON FLOOD DETECTION SYSTEMS USING INTERNET OF THINGS: TECHNIQUES, COMPARATIVE ANALYSIS AND FUTURE DIRECTIONS

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Abstract:

Floods are among the most frequent and destructive natural disasters, and the ability to detect rising water levels early is critical for reducing loss of life and property. Over the past several years, the Internet of Things (IoT) has emerged as a dominant technological approach for automated, real-time flood monitoring, replacing slow and labour-intensive manual observation methods. This paper presents a structured review of IoT-based flood detection systems reported in the literature between 2018 and 2025. The reviewed works are classified into five broad categories — threshold-based sensor systems, machine-learning/AI-based predictive systems, cloud-integrated systems, GSM-based low-connectivity systems, and wireless-sensor-network (WSN) based systems — and are compared in terms of sensing technique, connectivity, and alerting mechanism. A low-cost ESP32-based prototype combining an ultrasonic sensor, float sensor, rain sensor and temperature-humidity sensor with the Blynk IoT platform is discussed as an illustrative case study within the threshold-based category. Based on the comparative analysis, this review identifies key open challenges, including limited predictive capability in threshold-based designs, dependency on internet connectivity in cloud-based designs, energy constraints in WSN deployments, and the general absence of large-scale field validation across the surveyed works. The paper concludes by outlining promising future research directions, including hybrid sensor-AI architectures, energy-efficient long-range communication, and integration with geographic information system (GIS)-based regional flood-risk mapping.



Keywords: Internet of Things (IoT), Flood Detection, Wireless Sensor Networks, Machine Learning, Early Warning Systems.

1. INTRODUCTION

Floods cause widespread damage to human life, property, agriculture, and infrastructure every year, and their frequency is increasing due to unpredictable rainfall patterns, urbanization, and inadequate drainage systems in many regions. Timely detection and early warning are essential to minimize this damage, yet conventional flood-monitoring practices — largely dependent on manual river-gauge readings — are slow, labour-intensive, and poorly suited to real-time decision-making.

The Internet of Things (IoT) has opened new possibilities for automated environmental monitoring by enabling networks of low-cost sensors to continuously collect data and transmit it to cloud platforms for analysis and remote visualization. Over the last few years, a substantial body of research has proposed IoT-based flood detection and early-warning systems, employing a wide range of sensing technologies, communication protocols, and analytical techniques, from simple threshold-based alerting to sophisticated machine-learning-based prediction.

Given the diversity of approaches reported in the literature, there is a need to systematically review and classify existing work in order to identify prevailing trends, compare design trade-offs, and highlight open research gaps. This paper addresses that need. Section II outlines the review methodology. Section III classifies IoT-based flood detection approaches into five categories and discusses representative works in each. Section IV presents a consolidated comparative analysis across the surveyed literature. Section V discusses a low-cost prototype system as an illustrative case study. Section VI identifies open challenges, and Section VII outlines future research directions, followed by the conclusion in Section VIII.

2. REVIEW METHODOLOGY

This review is based on thirty peer-reviewed articles, conference papers, and pre-print reports published between 2018 and 2025, covering IoT-based flood and water-level monitoring systems. Sources were drawn from repositories and publishers including IEEE, MDPI (Applied Sciences, Sensors), Springer, Elsevier (ScienceDirect), arXiv, and several regional engineering journals (IJERT, IJRASET, IJARST, IARJSET, IJECS). Works were selected on the basis of relevance to IoT-enabled flood or water-level sensing, and were then grouped according to their dominant sensing/processing technique to enable structured comparison, as presented in Sections III and IV.

3. CLASSIFICATION OF IOT-BASED FLOOD DETECTION APPROACHES

Based on the reviewed literature, existing IoT-based flood detection systems can be broadly classified into five categories, summarized in Table I.

**Table I CATEGORIES OF IOT-BASED FLOOD DETECTION APPROACHES**

Category	Representative Works	Strengths	Limitations
Threshold-based sensor systems	[2],[7],[12],[13],[16],[19],[20],[24]	Simple, low-cost, easy to deploy, fast response	No predictive capability; reactive rather than anticipatory
Machine-learning / AI-based systems	[1],[9],[11],[14],[15],[29]	Higher prediction accuracy; can anticipate flood events in advance	Requires training data, higher computational and design complexity
Cloud-integrated systems	[4],[9],[18],[21]	Enables remote access, historical data storage and large-scale monitoring	Dependent on continuous internet connectivity
GSM / low-connectivity systems	[17]	Functions in areas with poor or no internet access	Limited data richness; alerting via SMS only
Wireless Sensor Network (WSN) based systems	[5],[8],[22],[25],[26],[28]	Good spatial coverage; suited to distributed, large-area monitoring	Higher deployment cost and energy-management complexity

A. Threshold-Based Sensor Systems

This is the most widely adopted approach, in which sensors such as ultrasonic, float, or water-level sensors continuously measure the water level and compare it against a fixed threshold to trigger an alert [2], [7], [12], [13], [16], [19], [20], [24]. These systems are simple, inexpensive, and quick to deploy, making them attractive for student and low-resource projects, but they are inherently reactive and lack any predictive capability.

B. Cloud-Integrated Systems

Several works emphasize cloud connectivity as a means of enabling remote monitoring, historical data logging, and dashboard-based visualization [4], [9], [18], [21]. Cloud integration extends the reach of flood monitoring beyond the immediate deployment site but introduces a dependency on continuous internet connectivity, which can be a limiting factor in disaster scenarios where network infrastructure itself may be affected.

C. GSM-Based / Low-Connectivity Systems

To address connectivity limitations in rural or remote areas, some systems rely on GSM modules to deliver SMS-based alerts instead of internet-dependent notifications [17]. While this approach sacrifices the richness of a live dashboard, it offers wider accessibility in regions with limited or no internet infrastructure.



D. Wireless Sensor Network (WSN) Based Systems

A further category of works focuses on distributed wireless sensor networks designed for large-area or multi-point environmental monitoring, with particular attention to energy-efficient data transmission and network longevity [5], [8], [22], [25], [26], [28]. These systems provide broader spatial coverage than single-node designs but generally involve higher deployment cost and more complex power-management requirements.

4. COMPARATIVE ANALYSIS

Table II consolidates the thirty reviewed works, indicating the year of publication, core technique, connectivity method, and alerting mechanism employed in each. The table highlights a clear temporal trend: earlier works (2018–2020) favour simple WSN or threshold-based designs, whereas more recent works (2023–2025) increasingly incorporate machine-learning and cloud-based components, reflecting the broader shift toward predictive, data-driven disaster management.

Table II COMPARATIVE SUMMARY OF SURVEYED IOT-BASED FLOOD DETECTION SYSTEMS

Ref.	Year	Core Technique	Connectivity	Alert Mode
[1] Kumar & Singh	2025	Neuro-fuzzy prediction	IoT / Wi-Fi	App notification
[2] Sharma & Patel	2025	Real-time threshold monitoring	IoT platform	Automated alert
[3] Pahuriray & Cerna	2025	Systematic review of IoT flood systems	Various	N/A (review)
[4] Suryagan et al.	2025	Cloud-integrated monitoring	Wi-Fi / Cloud	Dashboard alert
[5] Ding et al.	2025	Sensor-network based monitoring	Wireless network	Real-time alert
[6] Febriani et al.	2024	Intelligent monitoring	IoT	Real-time notification
[7] Ratmini et al.	2024	Early warning via sensors	IoT	Alert system
[8] Singh et al.	2024	Urban flood monitoring	Wireless comm.	Continuous alert
[9] Verma & Gupta	2024	AI + cloud prediction	IoT / Cloud	Predictive alert
[10] Qian et al.	2024	Smart water-level sensing	IoT	Threshold alert
[11] Loong et al.	2023	Machine learning approach	IoT	Predictive alert
[12] Kumar et al.	2023	Basic IoT alarm system	IoT	Buzzer / alarm



[13] Murugan et al.	2023	Sensor-based warning	IoT	Alert system
[14] Reddy et al.	2023	LSTM-based prediction	IoT	Predictive alert
[15] Zheng et al.	2023	Adaptive environmental sensing	IoT	Adaptive alert
[16] Fikriyah et al.	2022	Water-level sensing	IoT	Threshold alert
[17] Khan & Ali	2022	Low-cost threshold detection	GSM	SMS alert
[18] Patil et al.	2022	Cloud-based monitoring	Cloud / IoT	Dashboard alert
[19] Joshi & Kulkarni	2022	Low-cost rural system	IoT	Basic alert
[20] Lobo et al.	2022	Real-time sensor monitoring	IoT	Real-time alert
[21] Mehta et al.	2021	Big-data based resilience	IoT / Cloud	Analytics-based alert
[22] Cui et al.	2021	Environmental WSN	WSN	N/A
[23] Zhang et al.	2020	Water-level IoT system	IoT	Threshold alert
[24] Roy & Das	2020	Basic flood/water monitoring	IoT	Alert system
[25] Feng et al.	2020	Sensor-network framework	WSN	N/A (framework)
[26] Ngxande et al.	2019	Data-analysis techniques	IoT / WSN	N/A
[27] Zahir et al.	2019	Smart IoT monitoring	IoT	Alert system
[28] Arshad et al.	2019	Sensor & comm. technologies	IoT	N/A (survey)
[29] Mohan Kumar et al.	2018	Intelligent detection & warning	IoT	Warning system
[30] ScienceDirect / Elsevier	2018	Flood alert system design	IoT	Alert system

5. CASE ILLUSTRATION: A LOW-COST PROTOTYPE SYSTEM

To ground the review in a concrete implementation, a low-cost prototype falling within the threshold-based category (Section III-A) was developed and tested. The prototype uses an ESP32 microcontroller interfaced with an ultrasonic sensor for water-level measurement, a float sensor for critical-level detection, a rain sensor for rainfall sensing, and a DHT11 sensor for temperature and humidity monitoring, connected to the Blynk IoT platform for remote visualization, as shown in

Fig. 1. When the water level crosses a predefined threshold, the system triggers a buzzer, an LED indicator, and a mobile push notification.

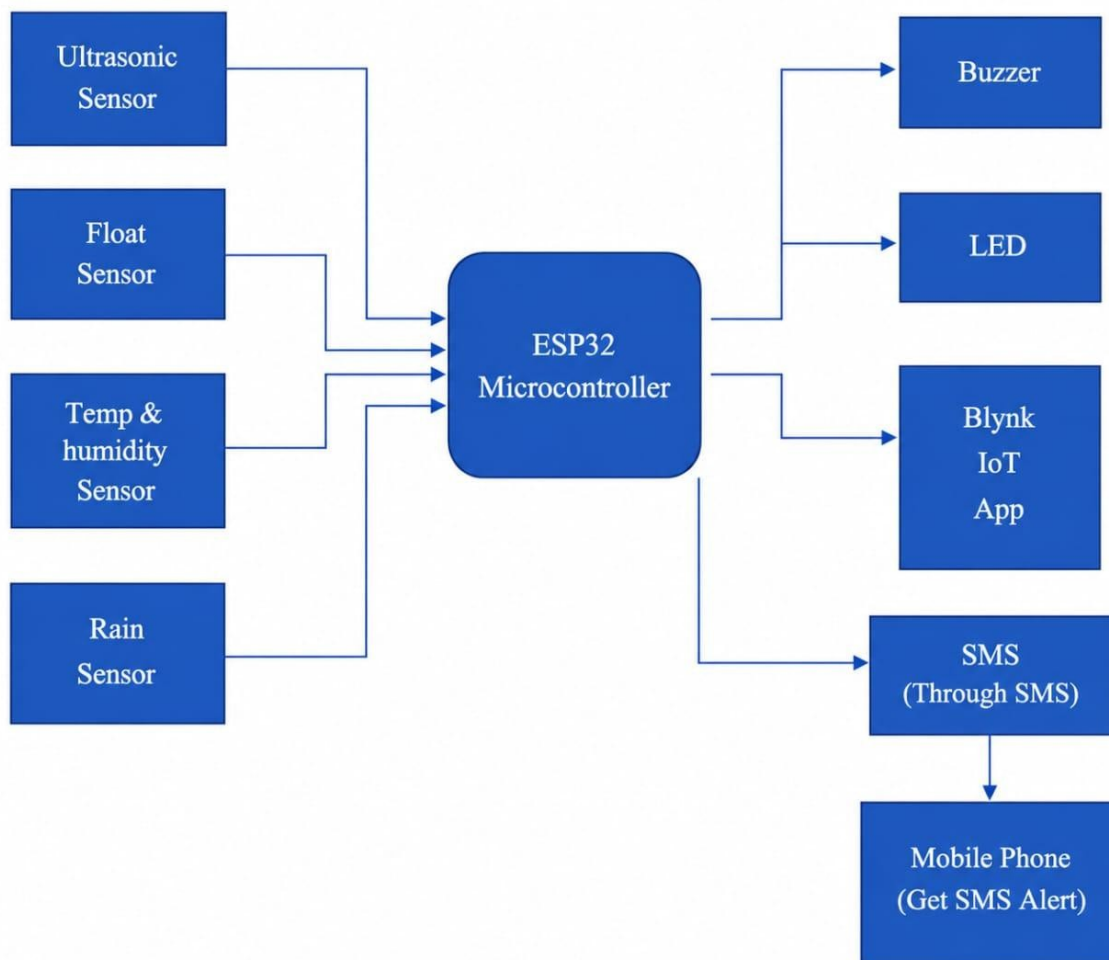


Figure 1 Architecture of the Illustrative Low-Cost Threshold-Based Prototype

During laboratory testing, the prototype recorded a water level of 42%, a temperature of 34°C, and a humidity of 10% on the IoT dashboard, with the float indicator and alert mechanism (buzzer, LED, and mobile notification) functioning correctly on threshold breach. This confirms the practical feasibility of the threshold-based category discussed in Section III-A, while also illustrating its central limitation relative to the ML-based category (Section III-B): the prototype reacts to a threshold rather than anticipating a flood event in advance.

6. OPEN CHALLENGES AND RESEARCH GAPS

Several recurring challenges emerge from the reviewed literature:



- Limited predictive capability: A majority of the reviewed threshold-based systems detect a flood condition only after it occurs, rather than forecasting it in advance.
- Connectivity dependency: Cloud-integrated systems generally assume stable internet access, which is often unavailable precisely in the remote or disaster-affected areas most in need of monitoring.
- Energy constraints: WSN-based deployments face a persistent trade-off between transmission frequency, sensing coverage, and battery/power longevity.
- Limited large-scale validation: Most reviewed works report prototype-level or laboratory testing; comparatively few document long-term field deployment across multiple flood seasons or diverse geographic conditions.
- Lack of standardized benchmarking: Differences in sensor accuracy, threshold definitions, and evaluation metrics across studies make direct, quantitative comparison of reported systems difficult.

7. FUTURE RESEARCH DIRECTIONS

Based on the identified gaps, the following directions appear promising for future work:

- Hybrid sensor-AI architectures that combine the simplicity and reliability of threshold-based local alerting with the anticipatory capability of machine-learning models such as LSTM or ANN.
- Energy-efficient, long-range communication protocols (e.g., LoRa) to reduce the connectivity dependency of cloud-based systems while retaining remote-monitoring capability.
- Integration with GIS-based dashboards to support regional flood-risk mapping and coordinated disaster response across multiple monitoring nodes.
- Standardized field-testing protocols and shared benchmark datasets to enable more rigorous, comparable evaluation of future systems across different climatic and geographic contexts.
- Solar-powered and other energy-harvesting designs to extend the operational lifetime of remote sensor nodes without frequent maintenance.

8. CONCLUSION

This paper reviewed thirty IoT-based flood detection systems reported between 2018 and 2025 and classified them into five categories: threshold-based sensor systems, machine-learning/AI-based predictive systems, cloud-integrated systems, GSM-based low-connectivity systems, and WSN-based systems. The comparative analysis shows a clear evolution from simple, reactive threshold-based designs toward predictive, data-driven approaches enabled by machine learning and cloud connectivity. A low-cost ESP32-based prototype was presented as an illustrative case study within the threshold-based category, demonstrating the practical feasibility of low-cost real-time monitoring while also highlighting its predictive limitations. Overall, the review indicates that no



single existing approach simultaneously achieves low cost, predictive capability, connectivity independence, and large-scale field validation, suggesting that hybrid, energy-efficient, and rigorously validated architectures represent the most promising direction for future research in IoT-based flood detection and early warning.

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