

IoT Based Smart Water Distribution and Leakage Detection Network

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Abstract

An IoT-based smart water distribution and leakage detection system employs a network of sensors to continuously monitor water flow and detect leakages in real-time. These sensors identify anomalies indicating leaks or abnormal usage, enabling early detection and precise localization. Data is wirelessly transmitted to a centralized platform where advanced sensors and algorithms analyze the information to predict leaks and optimize water distribution. The system generates instant alerts to operators, supporting timely maintenance actions that reduce water wastage, prevent infrastructure damage, and promote sustainable water management. Integration of automated valve control mechanisms further enhances operational efficiency. This approach improves resource conservation, lowers operational costs, and supports environmental sustainability by minimizing water loss across distribution networks. The system is designed to be scalable and suitable for deployment in both urban and rural settings.

Keywords: IoT (Internet of Things), Smart Water Distribution, Leakage Detection, Sensor Network, Automated Valve Control, Water Loss Minimization.

1. Introduction

Water scarcity and distribution inefficiencies have become global concerns due to rapid urbanization, industrialization, and population growth. A significant portion of water loss in urban and rural water distribution systems (WDS) arises from leakages, bursts, and inefficient monitoring mechanisms. Studies have indicated that non-revenue water loss due to leakage can reach up to 30% of total supply in some regions, contributing to economic, environmental, and social challenges [9]. Traditional leakage detection techniques—such as acoustic sensors, pressure tests, and manual inspection—are often labor-intensive, expensive, and unsuitable for large-scale distribution networks [6], [11]. In response to these limitations, modern water management is increasingly leveraging the Internet of Things (IoT). IoT-based smart systems enable real-time monitoring, remote control, and predictive maintenance of pipelines by integrating sensors,

wireless networks, and intelligent data analytics [1], [4], [7]. These systems allow timely fault detection and provide decision-makers with actionable insights, thereby reducing wastage, minimizing operational costs, and improving the reliability of water supply networks. Artificial intelligence (AI), machine learning (ML), and data-driven algorithms are further enhancing the effectiveness of IoT-enabled systems by improving anomaly detection, optimizing sensor placement, and automating control strategies [8], [9], [10]. The integration of IoT with statistical models and AI techniques.

2. Literature Survey

IoT has emerged as a transformative technology in water monitoring and leakage detection. Ali et al. [1] presented an IoT-based approach to water management, highlighting its role in reducing losses and improving efficiency. Similarly, Panjwani et al. [3] designed an IoT framework for water usage

control, demonstrating its relevance in residential networks. Pasika and Gandla [4] further explored IoT for water quality monitoring, showcasing the adaptability of IoT in cost-sensitive environments. Krishnavenia et al. [7] extended IoT applications to irrigation tanks, were real-time monitoring optimized water level management. Collectively, these studies confirm the scalability and versatility of IoT for smart water distribution. Leakage detection has long relied on statistical and data-driven techniques. Hashim et al. [2] employed a statistically based fault detection system for non-residential buildings, proving the reliability of anomaly detection in complex environments. Romano et al. [5] introduced a statistical process control system capable of approximating leakage locations, while Ishidoa and Takahashi [6] proposed a real-time indicator validated by simulations. These works demonstrate that statistical models can effectively identify abnormal flow patterns, but they often require calibration and may lack adaptability under dynamic network conditions. The use of AI and machine learning has greatly advanced leakage detection. Hu et al. [9] proposed a multiscale neural network approach for detecting urban water supply leakages, achieving higher accuracy than traditional models. Rayaroth and Sivaradje [8] introduced random bagging and shuffled frog leaping algorithms to optimize sensor placement, improving detection efficiency. Adedeji [10] offered a detailed overview of AI-driven leakage detection algorithms, stressing their potential for real-world WDS applications. These findings suggest that integrating AI with IoT provides a strong basis for predictive and adaptive leakage detection. WSNs form the backbone of IoT-enabled monitoring. Al-Kadi et al. [11] surveyed WSN-based leakage detection in underground pipelines, underlining their suitability for hard-to-access areas. Cataldo et al. [12] further demonstrated the role of sensors in effective water monitoring within distribution systems. While WSNs are crucial for IoT deployment, challenges such as energy efficiency, signal reliability, and large-scale cost remain critical barriers. The literature highlights that while IoT provides the foundation for real-time water management [1], [3], [4], [7], statistical and AI-based

methods [2], [5], [6], [8], [9], [10] enhance its detection reliability and decision-making capacity. WSN enables physical deployment and data acquisition in complex pipeline networks [11], [12]. However, most existing approaches address these aspects in isolation. Therefore, there is a research gap in integrating IoT with AI-driven models and optimized WSN frameworks into a unified smart water distribution and leakage detection network that is scalable, cost-effective, and adaptive to real-world conditions.

3. Proposed System

A leak detection system is designed to identify and control unwanted water leakage in a pipeline network. The principle of operation is based on comparing the readings of two flow sensors positioned at different points in the pipeline.

3.1. Normal Condition

When there is no leakage, the flow rate measured by both sensors remains almost the same. This indicates that the entire volume of water entering the pipeline is being delivered without any losses.

3.2. Leakage Condition

If a leak occurs at any point between the two sensors, there will be a difference in the readings. The first sensor, positioned upstream, will measure a higher flow rate, whereas the second sensor, positioned downstream, will show a reduced flow rate. This variation is a clear indication of water leakage in the network. Once the leakage is detected, the system takes the following actions:

3.3. Communication of Information

The leak detection data is immediately sent through a Wi-Fi communication module. This ensures that the information about leakage is transmitted in real-time to the concerned person or authority. The same information can also be received and continuously monitored by end-users through a dedicated interface such as a mobile application or a computer-based dashboard.

3.4. User Monitoring

Users are able to regularly monitor the flow conditions, leakage status, and pipeline performance. This helps in early detection and quick response to minimize water wastage and possible damage caused by leaks.

3.5. Automatic Control (Solenoid Valve)

To prevent further water loss, the system is integrated with a solenoid valve. When a leak is confirmed, the solenoid valve automatically closes the water supply. This immediate action prevents unnecessary wastage, protects resources, and ensures system efficiency.

3.6. Advantages of the System

- Provides real-time detection and control of leaks.
- Reduces wastage of water, which is a critical natural resource.
- Ensures safety and prevents structural damage caused by water leakage.
- Enables remote monitoring through Wi-Fi and IoT-based systems.
- Automatic shutoff enhances reliability without requiring human intervention.

4. Method

The system uses sensors to monitor water flow, pressure, and quality in real time. A microcontroller collects and sends the data through a wireless network to an IoT platform. Statistical and AI methods analyze the data to detect and predict leakages. Smart valves and pumps automatically control water distribution. A cloud dashboard and mobile alerts provide users with real-time updates.

4.1. Figure

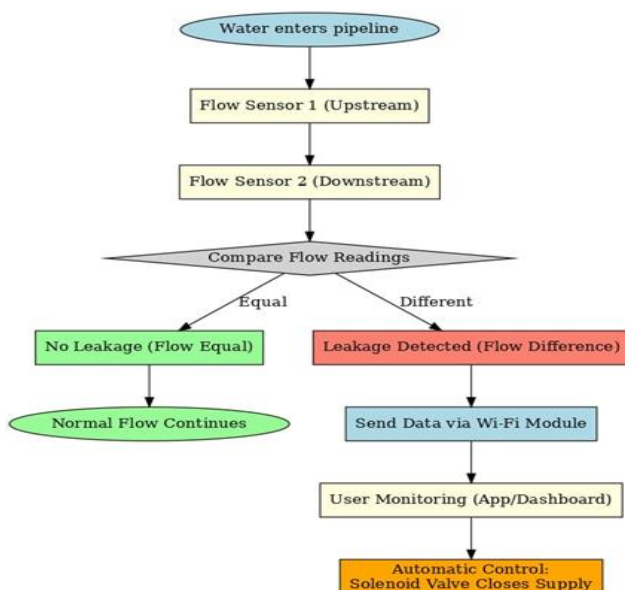


Figure 1 Flow Chart of Proposed System

The flowchart shows an IoT-based leakage detection system. Water passes through two flow sensors, and their readings are compared. If the readings are equal, water flows normally; if different, a leakage is detected. The system then sends data via Wi-Fi to a user dashboard and automatically closes the supply using a solenoid valve Shown in Figure 1.

5. Results and Discussion

The proposed leak detection system successfully detects leakage in the pipeline network by identifying variations in flow readings between two flow sensors. When a leak occurs, the system sends an alert message through the Wi-Fi module to the concerned user and automatically closes the solenoid valve to prevent further wastage of water. The system ensures continuous monitoring and provides real-time updates to the user.

The results demonstrate that the system is effective in accurately detecting leaks and providing an immediate response. The flow sensor-based measurement technique is reliable, as any significant difference between inlet and outlet flow directly indicates leakage. The use of a Wi-Fi module allows for remote communication, making the system suitable for integration into smart home and smart city applications. Furthermore, the automatic operation of the solenoid valve ensures safety and eliminates the need for manual intervention. This approach not only reduces water wastage but also increases the efficiency of the distribution system. However, factors such as sensor calibration, network connectivity, and power supply must be carefully managed to ensure accurate and uninterrupted operation. Overall, the system offers a cost-effective and practical solution for water conservation and leak management.

Conclusion

The leak detection system provides an efficient, reliable, and automated solution for identifying and controlling water leakages in pipelines. By comparing the flow readings of two sensors, leaks can be detected accurately and in real-time. The integration of a Wi-Fi module ensures instant communication and continuous monitoring by users, while the automatic closure of the solenoid valve prevents further water wastage. Thus, the system not

only conserves water but also supports sustainable resource management and smart monitoring.

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References

- [1]. Ahmed S. Ali, Mahmoud N. Abdelmoez, M. Heshmat, Khalil Ibrahim, "A solution for water management and leakage detection problems using IoTs based approach", Internet of Things, 2022.
- [2]. Hafiz Hashim, Paraic Ryan, Eoghan Clifford, "A statistically based fault detection and diagnosis approach for non-residential building water distribution systems", Advanced Engineering Informatics, 2020.
- [3]. Arish Panjwani, Swati Chand, Ajay More, Rushabh Panjwani, "Water usage Control and Management Based on IoT", International Journal of Scientific Research in Computer Science, Engineering and Information Technology, volume 6, 2020.
- [4]. Sathish Pasika, Sai Teja Gandla, "Smart water quality monitoring system with cost-effective using IoT", Heliyon, 2020.
- [5]. Michele Romano, Kevin Woodward and Zoran Kapelan, "Statistical process control-based system for approximate location of pipe bursts and leaks in water distribution systems", Procedia Engineering, 2016
- [6]. Y. Ishidoa, S. Takahashi, "A New Indicator for Real-Time Leak Detection in Water Distribution Networks: Design and Simulation Validation", Procedia Engineering, 2014
- [7]. Muthiah Krishnavenia, S. K. Praveen Kumar, E. Arul Muthusamy, J. Kowshickand K. G. Arunya, "Real-time monitoring of water level and storage dynamics of irrigation tank using IoT", H2Open Journal, volume 3, 2020
- [8]. Rejeesh Rayaroth & Sivaradje G, "Random Bagging Classifier and Shuffled Frog LeapingBased Optimal Sensor Placement for Leakage Detection in WDS", Water Resources Management ,2019
- [9]. Xuan Hu, Yongming Han, Bin Yu, Zhiqiang Geng, Jinzhen Fan, "Novel leakage detection and water loss management of urban water supply network using multiscale neural networks", Journal of Cleaner Production, 2021
- [10]. KAZEEM B. ADEDEJI, "Towards Achieving a Reliable Leakage Detection and Localization Algorithm for Application in Water Piping Networks: An Overview" Toward Achieving a Reliable Leakage Detection and Localization Algorithm, volume 5, 2017
- [11]. Tariq AL-Kadi, Ziyad AL-Tuwaijri, Abdullah AL-Omran, "Wireless Sensor Networks for Leakage Detection in Underground Pipelines: A Survey Paper" ScienceDirect, 2013
- [12]. Andrea Cataldo, Giuseppe Cannazza, Egidio De Benedetto, and Nicola Giaquinto, "Andrea Cataldo, Giuseppe Cannazza, Egidio De Benedetto, and Nicola Giaquinto", IEEE SENSORS JOURNAL, VOL. 12, 2012