

Smart Leak Net: Wireless Leak Monitor for Irrigation

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Abstract—Efficient and intelligent water management is vital for modern urban and rural infrastructures. This project proposes a Machine Learning-based Water Supply Monitoring Network that ensures transparency, minimizes water loss, and enhances consumer utility tracking. The system integrates flow sensors and turbidity sensors across the distribution pipeline from the main storage tank to individual client endpoints. A Long Short-Term Memory (LSTM) based machine learning model is used to analyze sensor data, detect anomalies such as leakages, forecast future water demand, and monitor water quality. An Android app allows users to track daily water usage, receive alerts, and pay bills digitally, while an administrative dashboard enables authorities to monitor real-time data for informed decision-making. This smart water distribution system promotes sustainability, reduces wastage, and enhances the efficiency and accountability of water resource management.

Index Terms— Hybrid CEEMDAN-CNN-LSTM, Machine Learning, SoftMax-ELM, Adaptive Crow Search Optimization, ESP32, YFS201, Analog Turbidity Sensor.

I. INTRODUCTION

Water is a critical resource for domestic, agricultural, and industrial activities, and its efficient management is essential for sustainable development. However, increasing population growth, rapid urbanization, and aging water distribution infrastructures have resulted in significant challenges such as water leakage, uneven supply, and poor monitoring. Conventional water management systems lack real-time tracking and transparency, which often leads to water wastage and inefficient utilization. Therefore, the development of intelligent and automated water monitoring solutions has become a necessity.

Recent advancements in Internet of Things (IoT) technologies and Machine Learning (ML) techniques have enabled the design of smart monitoring systems capable of collecting and analyzing large volumes of data in real time. Sensors deployed across distribution networks can measure parameters such as flow rate, pressure, and water quality. These data-driven approaches help detect anomalies, improve operational

efficiency, and support better decision-making compared to traditional manual methods.

In this work, a Machine Learning-based Water Supply Monitoring Network is proposed to ensure efficient distribution, minimize losses, and enhance transparency in the water supply chain. The system incorporates multiple flow sensors and turbidity sensors placed at key locations, including the main storage tank, intermediate regions, and individual consumer endpoints. These sensors continuously monitor water volume and quality throughout the distribution pipeline, enabling comprehensive tracking of water movement.

To accurately detect leakages and abnormal patterns, the system utilizes Long Short-Term Memory (LSTM) models trained on historical flow and consumption data. The predictive capabilities of the model allow real-time anomaly detection, leakage identification, and demand forecasting. Additionally, turbidity measurements support monitoring of water quality, ensuring safe and reliable supply to consumers. This intelligent analysis enhances the reliability and efficiency of the overall distribution system.

Furthermore, the proposed framework includes an Android-based user application for customers to monitor usage, receive alerts, and perform digital billing, along with an administrative dashboard for authorities to supervise operations and respond promptly to issues. By integrating sensing technologies, machine learning, and user-centric applications, the system aims to create a smart, transparent, and sustainable water management infrastructure suitable for both urban and rural environments. The implementation of this smart monitoring network also supports long-term resource planning and water conservation by analyzing consumption patterns and identifying high-demand areas. It reduces operational costs by minimizing manual inspections and enabling faster responses to pipeline faults or leakages, ultimately contributing to a more reliable, efficient, and environmentally sustainable water supply management system.

A. Problem Statement

Traditional water leakage detection methods are often inefficient because they rely on manual inspection and delayed reporting, making it difficult to identify leaks quickly. This leads to significant water wastage, increased maintenance costs, and damage to water distribution infrastructure. In many water supply networks, there is also a lack of real-time monitoring systems capable of continuously tracking water flow and detecting abnormal patterns. As a result, small leaks often remain unnoticed for long periods and eventually develop into major pipeline failures. Therefore, there is a need for an intelligent, automated, and cost-effective system that can monitor water networks in real time, accurately detect leakages, and immediately alert authorities or users to reduce water loss and improve the efficiency of water management systems.

II. LITERATURE SURVEY

Recent research in smart water management emphasizes the use of IoT sensors, wireless communication, and machine learning to improve water distribution efficiency and reduce losses. Flow, pressure, and turbidity sensors enable real-time monitoring and early detection of leaks and contamination. Predictive models such as ANN, SVM, and LSTM are used to forecast demand and identify anomalies from historical data, while cloud-based platforms and mobile applications support remote monitoring and automated billing. However, most existing systems lack an integrated approach. This project addresses that gap by combining sensor networks, LSTM-based prediction, and a mobile application into a unified, intelligent water monitoring system.

A. Prediction of Water Quality Using SoftMax-ELM Optimized Using Adaptive Crow-Search Algorithm

The system classifies water as potable or non-potable using machine learning and optimization techniques applied to water quality data. Physicochemical parameters such as pH, turbidity, hardness, and dissolved solids are collected and preprocessed using KNN-based imputation to handle missing values. An Extreme Learning Machine (ELM) with SoftMax activation is used for classification, while an Adaptive Crow Search Optimization algorithm fine-tunes model weights and biases for improved performance. This hybrid approach outperforms traditional classifiers and achieves around 96% accuracy, providing a fast and reliable solution for real-time water quality monitoring.

The proposed approach also improves the efficiency and reliability of water quality assessment by reducing manual testing and enabling automated decision-making. By continuously analyzing water quality parameters, the system can quickly identify unsafe water conditions and support timely action from authorities or users. This intelligent monitoring framework can be integrated with IoT-based sensing devices for continuous data collection, making it suitable for smart water management systems in both urban and rural environments. Ultimately, the system helps ensure safe drinking water,

supports public health protection, and enhances sustainable water resource management.

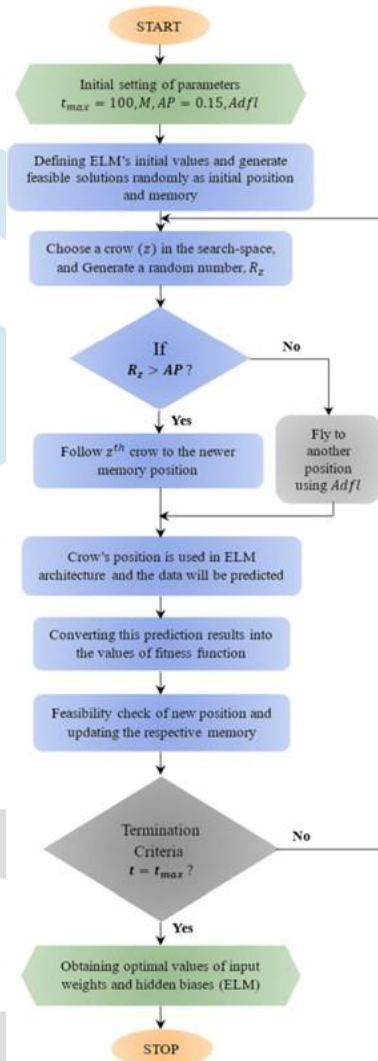


Fig. 1. Flowchart of Adaptive Crow Search Optimization (AdCSO)

B. A Hybrid Deep Learning Model for Water Quality Prediction

The Hybrid Deep Learning Model for Water Quality Prediction is designed to improve the accuracy of water quality forecasting by addressing the nonlinear and noisy nature of environmental time-series data. Traditional prediction methods often fail to capture the complex spatial-temporal relationships present in water quality parameters. To overcome these limitations, the proposed framework integrates CEEMDAN, CNN, and LSTM networks, along with a Self-Attention mechanism. CEEMDAN is first applied to decompose the raw sensor data into multiple intrinsic mode functions (IMFs), which helps in reducing noise and separating different frequency components of the signal. This preprocessing step enhances the quality

of input data and enables more effective feature extraction in subsequent stages.

The decomposed IMFs are then processed through a hybrid CNN-LSTM architecture that extracts both spatial and temporal features. The CNN layers capture local patterns and short-term variations in water quality indicators such as turbidity, pH, and dissolved oxygen, while the LSTM network models long-term temporal dependencies in the time-series data. This combination allows the model to effectively learn complex patterns and dynamic fluctuations in water systems. By integrating these complementary deep learning techniques, the framework generates a more comprehensive representation of water quality behavior over time.

Finally, a Self-Attention mechanism is incorporated to highlight the most relevant temporal features that influence prediction outcomes. This mechanism assigns different importance weights to various time steps, allowing the model to focus on critical patterns within the data. The weighted features are then passed to a fully connected layer to generate the final prediction of water quality parameters. Overall, the hybrid CEEMDAN-CNN-LSTM model improves prediction accuracy, robustness, and interpretability, making it suitable for real-time water quality monitoring and smart water management systems.

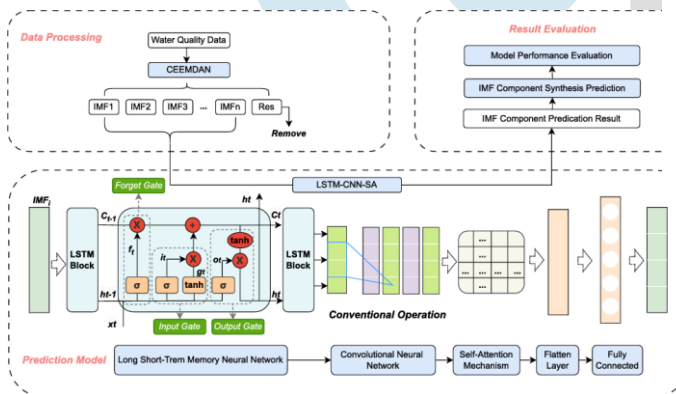


Fig. 2. Framework of the Hybrid CEEMDAN-CNN-LSTM Water Quality Prediction Model.

C. An Intelligent IoT and ML-Based Water Leakage Detection System

Freshwater losses from undetected pipeline leaks are addressed through an IoT-based, real-time leakage detection system using edge machine learning. Audio and vibration signals captured by a piezoelectric sensor are processed into spectrograms and classified using a lightweight neural network achieving 98.96% accuracy. The model runs locally on a low-power IoT node, enabling immediate alerts, reduced energy consumption, and long-term operation, making it an efficient and practical solution for smart water leak detection. The system also supports continuous monitoring of pipeline conditions without the need for complex infrastructure. Real-time detection allows authorities to respond quickly and prevent

large-scale water loss. This approach improves the reliability and efficiency of modern water distribution networks.

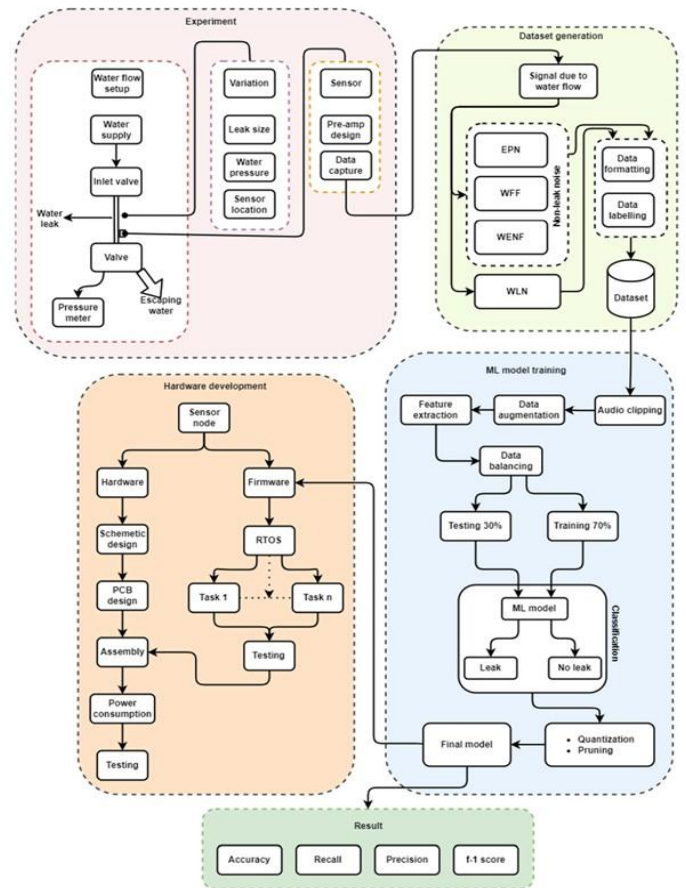


Fig. 3. Proposed Workflow of the IoT and ML-Based Water Leakage Detection System

III. METHODOLOGY

Recent research in intelligent water monitoring systems combines Machine Learning, Deep Learning, and IoT technologies to improve the accuracy and efficiency of water management systems. Based on the literature studies such as Prediction of Water Quality using SoftMax-ELM with Adaptive Crow Search Optimization, Hybrid CEEMDAN-CNN-LSTM Water Quality Prediction Model, and Intelligent IoT and ML-Based Water Leakage Detection System, the proposed system integrates data preprocessing, machine learning prediction, and real-time monitoring for effective water management.

A. Data Collection and Preprocessing : Sensor data such as water flow, turbidity, and environmental parameters are collected using IoT-enabled sensors installed across the water distribution network. The collected data undergoes preprocessing techniques such as noise removal, normalization, and handling missing values to ensure accurate analysis.

B. Machine Learning-Based Prediction : Inspired by SoftMax-Extreme Learning Machine and hybrid deep learning models from previous studies, machine learning algorithms are

applied to analyze water quality and detect anomalies. These models learn patterns from historical sensor data and predict abnormal conditions such as leakage or contamination.

C. **Deep Learning Feature Extraction** : Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks are used to extract spatial and temporal features from time-series sensor data. This hybrid architecture helps capture both short-term variations and long-term trends in water distribution systems.

D. **IoT-Based Monitoring System** : IoT communication technologies enable real-time transmission of sensor data to a central monitoring server. The system continuously analyzes incoming data and updates the monitoring platform.

E. **Web-Based Monitoring Dashboard** : A web-based administrative dashboard allows authorities to visualize water flow patterns, detect leakages, and analyze water quality trends using graphical representations.

F. **Mobile Application for Users** : A mobile application enables consumers to monitor their water usage, receive alerts regarding water quality or leakage issues, and access system notifications.

G. **Alert and Notification System** : When abnormal conditions such as leakage or poor water quality are detected, the system automatically generates alerts and sends notifications to users and authorities for immediate action.

IV. PROPOSED SYSTEM

The proposed system is a Machine Learning-Based Water Supply Monitoring Network that uses IoT sensors and data analytics to improve water distribution management. Flow sensors and turbidity sensors are placed at different points in the pipeline to monitor water flow and quality in real time. The collected data is transmitted to a central system where it is processed and analyzed using a Long Short-Term Memory (LSTM) machine learning model. By comparing flow readings at different stages, the system can detect leakages and identify abnormal patterns, while turbidity analysis helps monitor water quality.

The system also provides an administrative dashboard for authorities and a mobile application for consumers. The dashboard allows real-time monitoring of the entire water network and helps locate leaks quickly, while the mobile app enables users to track water usage, receive alerts, and manage digital billing. Overall, the system improves efficiency, reduces water loss, ensures water quality, and supports sustainable water management.

V. FEASIBILITY STUDY

The feasibility study for this system is divided into the following major aspects: technical feasibility, operational feasibility, economic feasibility, legal feasibility, and social/environmental feasibility.

A. *Technical Feasibility*

The proposed Machine Learning-based Water Supply Monitoring Network is technically feasible because it uses widely

available and reliable technologies such as IoT sensors, wireless communication modules, and machine learning algorithms. Flow sensors and turbidity sensors can be easily installed in water pipelines to collect real-time data, while microcontrollers and communication technologies like Wi-Fi or LoRa enable efficient data transmission to a central server. The Long Short-Term Memory (LSTM) model can be implemented using existing machine learning frameworks to analyze time-series sensor data for leakage detection and demand prediction. Additionally, Android applications and web-based dashboards can be developed using standard software tools to provide user interaction and system monitoring. Since all required hardware components, software platforms, and communication technologies are already available and cost-effective, the implementation of this smart water monitoring system is practical and achievable in real-world environments.

B. *Operational Feasibility*

The proposed Machine Learning-based Water Supply Monitoring Network is operationally feasible as it automates water monitoring with minimal human intervention. IoT sensors continuously collect flow and turbidity data, while the LSTM model analyzes the data to detect leaks and monitor water quality. Authorities can monitor the system through an administrative dashboard, and consumers can track usage and receive alerts through an Android app. This makes the system easy to operate and effective for real-time water management.

C. *Economic Feasibility*

The proposed Machine Learning-based Water Supply Monitoring Network is economically feasible because it uses affordable IoT sensors and existing communication technologies. It reduces costs by detecting leakages early, minimizing water loss, and reducing the need for manual inspections. The system also lowers administrative expenses through automated monitoring and digital billing, making water management more cost-effective.

VI. PROPOSED SYSTEM DESIGN

The system architecture of the Machine Learning-Based Water Supply Monitoring Network is designed to integrate hardware sensors, communication modules, cloud processing, and user interfaces into a unified framework for intelligent water monitoring. The architecture clearly illustrates how data flows from the physical water distribution system to the cloud platform and finally reaches the end users through interactive dashboards and mobile applications.

The architecture begins with the water distribution network, where multiple flow sensors and turbidity sensors are installed at various points such as the main storage tank, sub-branches, and consumer pipelines. These sensors are connected to ESP32 microcontrollers, which serve as the local data acquisition units. The ESP32 modules collect continuous readings of water flow and turbidity, process them, and transmit the data wirelessly through a Wi-Fi network to the cloud backend. This stage represents the edge or sensing layer of the system.

The collected sensor data is securely transferred over HTTP/HTTPS protocols to the cloud backend, which forms the core processing layer of the architecture. The cloud infrastructure consists of several key services including Firebase Realtime Database (RTDB) for data storage, Firebase Authentication for secure access management, and a cloud-based machine learning model hosted on the platform. The sensor data undergoes preprocessing, anomaly detection, and forecasting through the machine learning model, which is responsible for identifying abnormal flow patterns that may indicate leakages or changes in water quality.

The cloud also handles transaction-related operations such as billing and payment through integration with a payment gateway. Data stored in the Firebase RTDB is continuously updated, allowing for real-time synchronization between the backend and user interfaces. The backend also manages authentication for both administrators and end-users, ensuring that only authorized personnel have access to critical system features.

The system has multiple user roles, including authorities, maintenance personnel, end consumers, and machine learning engineers. Authorities can access real-time dashboards to monitor network status, review leak alerts, and analyze consumption reports. Maintenance personnel use the system to identify problem locations and plan timely repairs. End consumers interact with the system through the Android application, which provides real-time usage statistics, billing details, and notifications about water quality or leakages. Machine learning engineers monitor and update the predictive model in the backend to ensure accuracy and reliability.

The application interface layer consists of two main components: the Admin Dashboard and the Android Mobile Application. The Admin Dashboard allows the utility authorities to visualize real-time sensor data, analyze trends, detect leakages, and manage the network efficiently. The Android app, on the other hand, provides the end user with personalized access to their water usage data, alerts, billing information, and digital payment facilities. Both interfaces communicate directly with the cloud backend, ensuring consistent synchronization and up-to-date information across all devices.

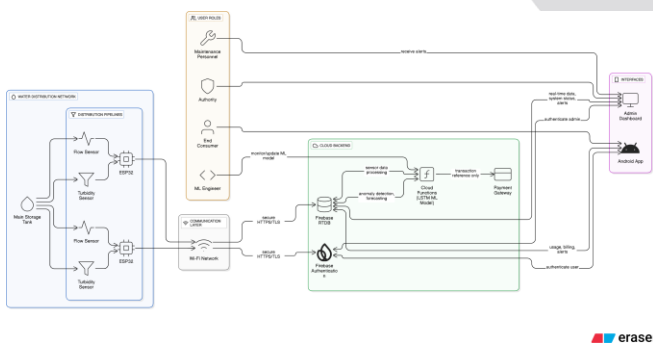


Fig. 4. Architecture diagram

VII. RESULT

The system shows the SmartLeakNet user login interface where registered users enter their email and password to access the system. After successful authentication, users are directed to their personal dashboard where they can monitor water usage and billing details. The interface provides secure and easy access to the platform and also allows new users to create an account.

The admin login interface allows administrators to access the system using a username and password. Once authenticated, the administrator can enter the admin dashboard to monitor system performance, manage the network, and observe sensor data related to water flow, leakage, and quality.

The admin dashboard displays real-time monitoring information of the water distribution network. It shows leakage detection results when the leakage value exceeds the defined threshold, indicating a possible leak in the pipeline. The dashboard also displays water quality information such as turbidity levels, helping administrators quickly identify and respond to issues.

The user dashboard presents detailed information about water usage, including current reading, previous reading, tariff, and total consumption. It also displays billing details and payment history, allowing users to track their water usage and make bill payments through the digital payment option provided in the system.

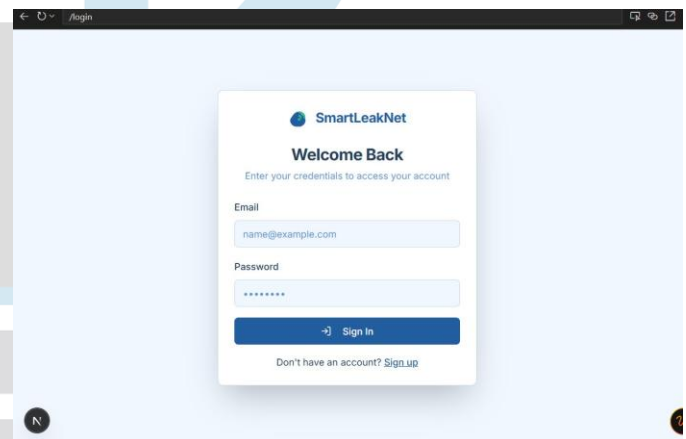


Fig. 5. LOGIN INTERFACE

This figure illustrates the SmartLeakNet User Login Interface, which acts as the secure entry point to the system. It allows registered users to access their personalized dashboard for monitoring water usage and bills.

The login page requires users to enter their registered email address and password. These credentials are verified through backend authentication mechanisms to ensure that only authorized users can access the system. This helps maintain data privacy and prevents unauthorized access to sensitive water consumption information.

The interface is designed to be simple and user-friendly, providing a smooth login experience. It also includes a "Sign

Up” option for new users to create an account, making the system accessible to both existing and new consumers. Overall, this module ensures secure, reliable, and transparent access to the SmartLeakNet platform.

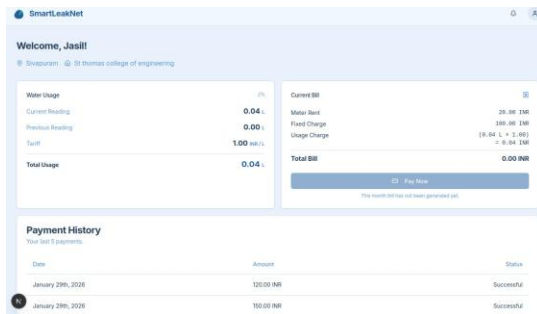


Fig. 6. USER DASHBOARD

This figure represents the SmartLeakNet User Dashboard Interface displayed after successful login. It provides a complete overview of the user’s water consumption, billing details, and payment history in a structured and user-friendly format.

The dashboard shows the current water usage readings, including previous reading, current reading, tariff per liter, and total usage. This helps users clearly understand how much water they have consumed and how the bill is calculated. Real-time monitoring ensures transparency in water usage tracking.

The billing section displays detailed information such as meter rent, fixed charges, usage charges, and total bill amount. It also includes a “Pay Now” option that enables users to make digital payments directly through the platform. This simplifies the billing process and reduces the need for manual payment methods.

Additionally, the dashboard provides a payment history section where users can view past transactions along with dates, amounts, and payment status. This ensures proper record maintenance and improves accountability. Overall, this interface enhances user convenience, transparency, and efficient water management.

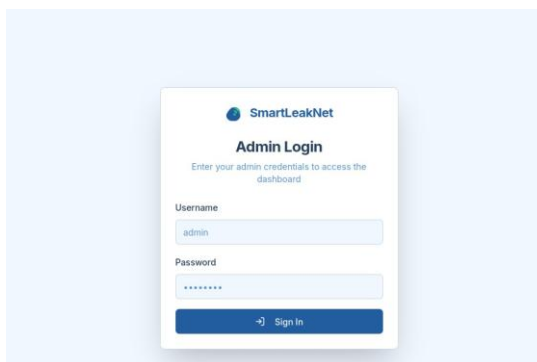


Fig. 7. ADMIN LOGIN

This figure illustrates the SmartLeakNet Admin Login Interface, which provides secure access to the administrative

dashboard of the system. It is specifically designed for authorized utility authorities or system administrators to monitor and manage the overall water distribution network.

The admin login requires a valid username and password to access the dashboard. These credentials are authenticated through the backend server to ensure that only authorized personnel can view system-wide data and control operations. This security mechanism prevents unauthorized access to sensitive monitoring and analytics information.

Once authenticated, the administrator can access features such as real-time water flow monitoring, leakage detection alerts, user management, and system performance analysis. The interface is designed to be simple and secure, ensuring efficient management of the SmartLeakNet platform while maintaining data confidentiality and system integrity.

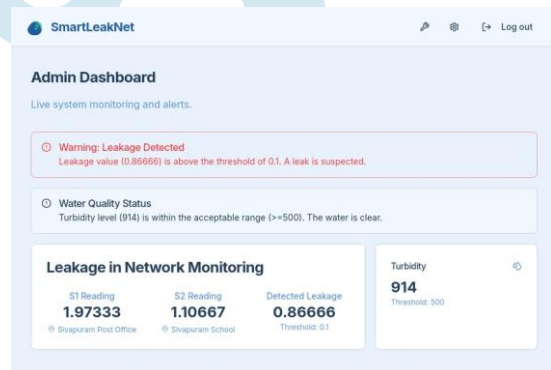


Fig. 8. ADMIN DASHBOARD

This figure represents the SmartLeakNet Admin Dashboard, which provides live system monitoring and real-time alerts for the entire water distribution network. It is designed to help authorities quickly identify leaks, monitor water quality, and ensure efficient resource management.

The dashboard displays a warning notification when a leakage is detected. The system compares sensor readings from different points in the network and calculates the leakage value. If the detected value exceeds the predefined threshold, an alert message is generated to notify the administrator immediately. This enables quick action to minimize water loss.

The interface also shows water quality status by monitoring turbidity levels. The turbidity value is compared with the acceptable threshold range to determine whether the water is clear and safe. This ensures that both quantity and quality of water are continuously supervised.

Additionally, the dashboard provides detailed sensor readings such as S1 and S2 values, along with the calculated leakage amount. By analyzing these readings, administrators can identify the exact location and severity of the issue. Overall, this module supports data-driven decision-making, improves transparency, and enhances sustainable water management.

VIII. CONCLUSION

The Machine Learning-Based Water Supply Monitoring Network improves traditional water management by using

IoT sensors and an LSTM-based model to monitor flow, pressure, and water quality. This enables early leak detection, accurate demand prediction, and reduced water loss. A mobile interface allows users to track usage, receive alerts, and make digital payments, improving transparency and reducing manual work. With a modular cloud-based design, the system is scalable for both urban and rural areas, supporting efficient and sustainable smart water management.

IX. FUTURE SCOPE

The Machine Learning-Based Water Supply Monitoring Network can be improved by adding edge-based AI for faster leak detection and reduced latency. Using advanced models like CNN-LSTM and including data such as rainfall and seasonal trends can improve prediction accuracy. Future systems may also include automatic valve control to quickly isolate leaks and reduce water loss. Integrating blockchain can improve data security and transparency, while cloud support will allow large-scale smart city deployment.

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