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IOT BASED WATER LEAKAGE DETECTION USING MACHINE LEARNING APPROACH

[1]Mr. Y. Pavan kumar,[2]R. Jhansi Pravachana, [3]SK. Dilshad,[4]M. Jhansi

[1]Assist Prof, ECE Department, ALIET, JNTUK, Vijayawada, Andhra Pradesh, India

[2,3,4]Student, ECE Department, ALIET, JNTUK Vijayawada, Andhra Pradesh, India

Abstract: Water leakage poses significant challenges in various settings, from residential to industrial, leading to property damage, financial losses, and environmental concerns. This paper presents an intelligent Internet of Things (IoT) and Machine Learning (ML)--based solution designed to detect and localize leaks early, thereby mitigating their adverse impacts. Our proposed system utilizes IoT-enabled water level sensor and rain sensor strategically placed throughout the infrastructure to continuously monitor water flow, transmitting real-time data wirelessly to a central processing unit. At the heart of the system lies a machine learning algorithm trained to analyze sensor data and discern patterns indicative of potential leaks. Employing supervised learning techniques, the algorithm classifies normal and abnormal water flow behaviors and employs anomaly detection algorithms to identify subtle deviations suggestive of leaks. Upon detecting a potential leak, the system triggers alerts via SMS, email, or mobile application, furnishing stakeholders with location and severity details to facilitate prompt intervention. Real-world experiments were conducted to validate the system's effectiveness, assessing detection accuracy, false alarm rates, and response times across various leak scenarios. Results underscore the system's reliability, efficiency, and cost-effectiveness in early leak detection and mitigation, thereby curtailing water wastage, property damage, and associated expenses.

***Index Terms*- Water leakage detection, Internet of Things (IOT), Machine Learning (ML), rain sensor, water level sensor, GSM Module**

I.INTRODUCTION:

Water is a precious resource. The world's freshwater resources are finite, necessitating careful management to sustainably meet human needs. The United States Geological Survey highlights that only a small fraction of the Earth's total water - 2.5% - is freshwater. Further, a mere 0.75% of this freshwater is stored in groundwater reservoirs, while surface water bodies like lakes, rivers, and swamps hold a minuscule 0.0072%. The data underscores the critical importance of conserving and managing freshwater sources to ensure their availability for future generation. While water is abundant, only a small fraction is suitable for human use, with the majority existing as saline water in oceans. Freshwater, essential for life, is mainly locked in ice, glaciers, and underground reservoirs. Although surface freshwater sources like rivers and lakes represent a small portion of the total volume, they are crucial for human consumption. It is important to understand water distribution for managing water resources sustainably and highlights the significance of surface freshwater sources, despite their relatively small volume compared to the total water supply. [1] The application of wireless sensor networks for leakage detection in water pipes is to overcome the problem of water dispersion in water distribution networks. Leakage prevention and break identification in water distribution networks are fundamental for the adequate use of natural resources. [2] To address this problem, and simply the leakage identification process, the authors have designed a wireless network system making use of mobile wireless sensors able to detect breaks and save energy, time, and cost by having an IOT-based water leakage detection using machine learning approach in pipelines, measure water level in tank and control in pump to turn it on when water level is low. The main part is an alarm based on the Global System for Mobile Technology (GSM) to send Short Message Service (SMS) to the owner. It also additionally sends Telegram messages to notify the user. The system is made up of basic components: water level sensor, rain sensor, a GSM module, Raspberry Pi, buzzer, and LCD. The result of using the proposed system is improving the efficiency of operation, reducing delay time and cost of maintenance pipelines after leakage detection. [3]

II.LITERATURE SURVEY:

Table1: Comparison and shortcoming of previous research

Ref no	Sensor data	Feature vector	ML model	Shortcoming
[4]	Piezo electric acceleration	Kurtosis and entropy	SVM	As water flowing through a valve is considered a "leakage signal", there is a chance of misclassification when people use a valve to control or use water.
[5]	Acceleration	Scalogram	KNN, CNN and AlexNet.	The dataset is very small, consisting of only 250 samples.
[6]	MEMS hydrophone	Spectral centroids	-	The signal processing does not happen onsite. Localization accuracy in within 5meters.
[7]	Acoustic sensor	IMF, approximate entropy, and PCA	SVM	Only 100 samples. High chance of model over fitting. The dataset needs variations.
[8]	Acceleration	Mel spectrogram	VGG	Signals were captured once a day. It is required to transfer larger audio files to a central server.
[9]	Vibration signal	Seven time-frequency domain feature vectors.	RF	It is computationally expensive. Seven features' vectors require a lot of CPU power and RAM to calculate.
[10]	Piezoelectric acceleration	Spectrogram	KNN	The sampling frequency is very low, only 4800Hz. According to Nyquist's theorem, the highest observable frequency component is 2400Hz. The proposed CNN model is complicated and requires three inputs.
[11]	Acceleration	CNN on raw data	KNN-SVM	Limited frequency range 200-700Hz. Data is transmitted for offsite processing and requires 10 seconds of data for inference. The leakage signal was created with a valve, but the leakage signal is different. The model size is not stated.
[12]	Water flow	-	RF	The flow sensors have ±5% accuracy. The researchers have not shown how they have compensated for the flow sensor measurement variation in their model.
[13]	Acceleration	Monitoring index efficiency	DT	Valve is used as leakage source. Have considered low and narrow frequency range. The ML model does not run locally on the device.
[14]	Water volume	-	SVM	Based on average household water consumption. A very small dataset only considers 16 households. The impact of random water overuse is not indicated.
[15]	Water flow	-	SVM	Only 200 data points. The algorithm is based on an average normal distribution. Specifying how the model will account for the influence of random water overuse is crucial.

III.EXISTING WORK:

The paper introduces a solution to address water wastage caused by pipeline leakage through the development of an edge Machine Learning (ML)--based low-power Internet of Things (IoT) device. Traditional leakage detection methods are inefficient and lead to substantial water loss. [16] To overcome these challenges, the proposed device detects leaks in real time, reducing water loss and mitigating environmental and economic impacts. The development process involved three stages: capturing real-life audio data of leak and non-leak signals using a piezoelectric contact microphone, developing an ML model, and implementing a node with ML capabilities and radio communication. The ML model quantized and pruned, achieved 98.96% accuracy with a lightweight size of 11 KB. Upon detecting leakage, the device emits a beeping noise and broadcasts low-energy RF messages to alert users. With minimal power consumption, the device can run for over 25 days on a single 3500mAh battery, making it suitable for both home and industrial environments. [17].

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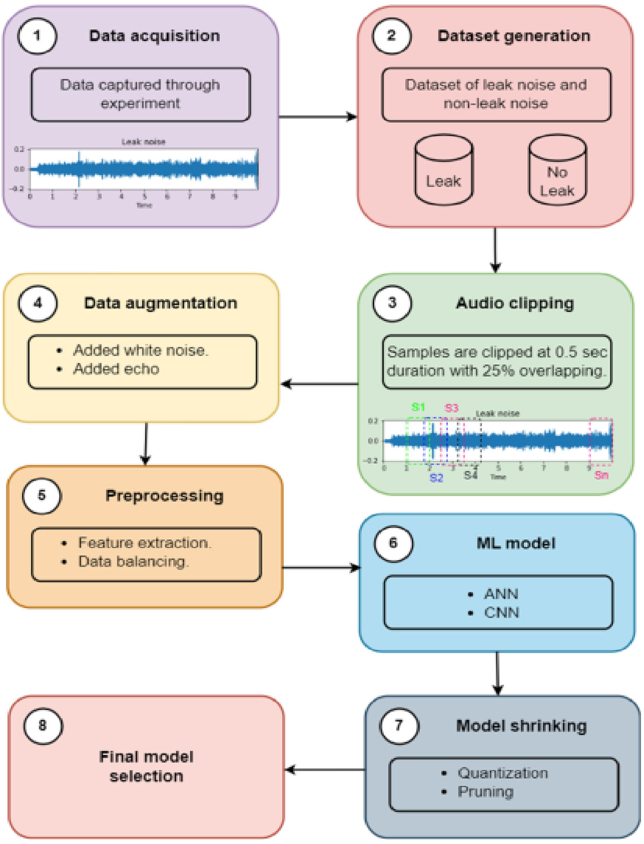

Fig1: Block Diagram for Existing Work

This is the existing work we have seen in the project to overcome and we have proposed some of the sensors which are used in the real life for the pipelines.

IV.PROBLEM STATEMENT:

The system should be able to collect data from water level sensor and rain sensor, then the collected data should be used for Machine Learning model training, and it should be capable of sending notifications via GSM module to alert users of any significant changes or issues detected. [18]

V. PROPOSED WORK:

The proposed methods for smart water leakage detection system typically involve a combination of sensors, Machine Learning model, and alerting mechanisms. Here an overview of the proposed methods that are commonly used in projects similar to the IOT based water leakage detection using Machine Learning approach.

Water Level Sensor: Water level sensors are commonly used in industrial and domestic settings to monitor water levels in tanks, reservoirs, and water treatment systems, ensuring efficient water management and preventing overflow or depletion.

Fig2: Water Level Sensor

Rain Sensor: Rain sensors integrated into pipelines monitoring systems can detect precipitation, alerting operators to potential leaks caused by external environmental factors such as heavy rainfall or flooding, allowing for timely intervention and maintenance to prevent water loss and damage.

Fig3: Rain Sensor

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GSM Module: Enables communication via SMS messages, allowing for remote alerting and notifications.

Fig4: GSM Module

IoT Protocols: MQTT, HTTP, or other IoT protocols are utilized for data transmission between sensors, microcontrollers, and cloud servers.

Data Storage: Cloud platforms like AWS IoT, Google Cloud IoT, or Azure IoT Hub are used to store sensor data securely.

Data Processing: Implementing cloud-based analytics and machine learning algorithms for data processing, anomaly detection, and predictive modelling**.**

Alerting Systems: Configuring alerting mechanisms within the cloud platform to trigger notifications based on predefined thresholds or anomaly detection.

Raspberry Pi: Raspberry Pi can be utilized in pipelines monitoring systems to collect and analyse sensor data, enabling real-time detection of leaks, anomalies, and environmental conditions, facilitating proactive maintenance and management of pipelines infrastructure.

Fig5: Raspberry Pi

Buzzer/Sounder: Audible alerts generated by buzzers or sounders placed in monitoring areas to notify individuals of detected anomalies.

Fig6: Buzzer

LCD: LCDs (Liquid Crystal Displays) are commonly used in pipeline monitoring systems to provide visual feedback on system status, displaying information such as sensor readings, alerts, and diagnostic messages, enabling operators to quick assess the condition of the pipeline network.

Fig7: LCD Display

VI.BLOCK DIAGRAM:

This Block diagram shows that what are the Input and Output sensors we have taken for the IOT-based Water Leakage Detection using Machine Learning Approach And outcomes that are present in this project by alerting mgs through the GSM module.

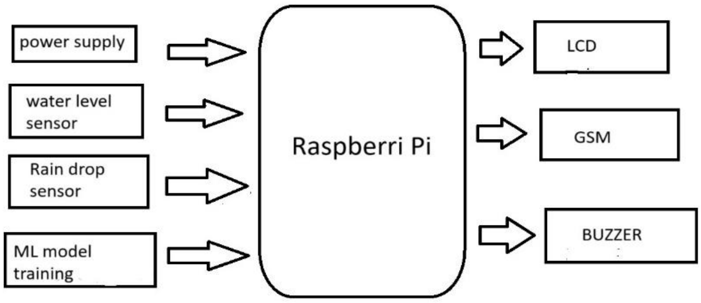


Fig8: Block Diagram for Proposed System

VII.METHODOLOGY:

1.Requirement Analysis: The main objective of "IOT based Water Leakage Detection using Machine Learning approach" is to detect water leaks effectively using IOT sensors and machine learning. The key requirements are Real-time alerts, SMS notifications, audible alarms, and Raspberry Pi integration.

2.Sensor Selection: Water level sensor and rain sensor are capable of detecting water presence or changes in water flow. These sensors are compatible with Raspberry Pi for seamless integration.

3.Hardware Setup: Configure Raspberry Pi as the central processing unit. Connect IOT sensors to Raspberry Pi for data acquisition. Set up communication modules such as GSM module for transmitting alerts and notifications.

4.Data Acquisition: Here code collects the data from IOT sensors. Implement mechanisms to capture real-time water-related data. Ensure data accuracy and reliability.

5.Machine Learning Model Development: Gather labelled data for training the machine learning model. The algorithms such as KNN, SVM and Random Forest Classifier Algorithm is used for detecting water leaks based on sensor data. Training the model using historical data and optimizing its performance.

6.Alert Generation: It triggers alerts based on machine learning model predictions. These algorithms are used to generated real-time alerts in case of water leakage detection. It is integrated with SMS notification and audible alarms such as buzzer for immediate response.

7.Testing and Validation: Conduct rigorous testing to verify the accuracy and reliability of water leakage detection. Validate the effectiveness of real-time alerts and response mechanisms. Address any issues or discrepancies identified during testing.

8.Deployment: Install the system in relevant locations prone to water leaks such as nodes. Configure the system settings and thresholds based on site-specific conditions. Train users on system operation and response protocols.

VIII. RESULTS:

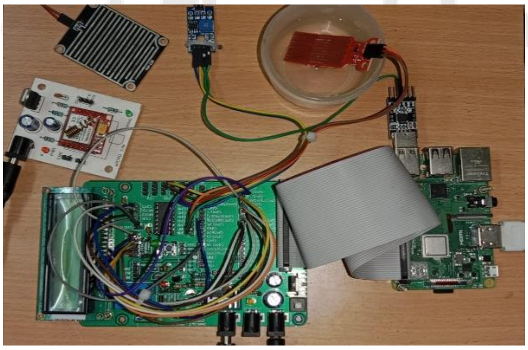
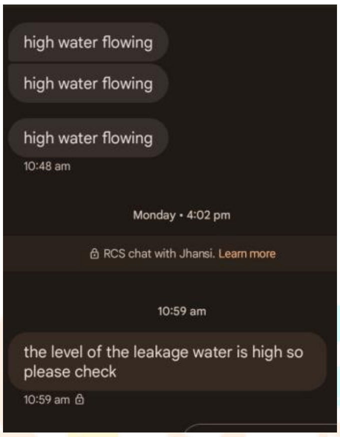


Fig9: Prototype for Water Leakage Detection System

The figure 9 shows the prototype of the project and dumping the code into raspberry pi and displaying the results in the form of LCD, SMS, and Telegram by step-by-step process.

Fig10: Alert Display on LCD

The above figure 10 shows the water leakage at nodes. This LCD displays if there is any leakage at the nodes.



high water flowing

high water flowing

high water flowing
10:48 am

Monday • 4:02 pm

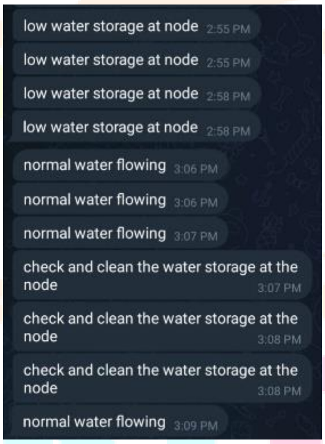
RCS chat with Jhansi. Learn more

10:59 am

the level of the leakage water is high so please check
10:59 am

Fig11: SMS Alert

In the above figure 11 shows the messages given by the GSM Module (SIM8001) to the mobile indication. It sends the information on the water levels at the nodes. If there is any water leakage the buzzer will alert the user.



low water storage at node 2:55 PM

low water storage at node 2:55 PM

low water storage at node 2:58 PM

low water storage at node 2:58 PM

normal water flowing 3:06 PM

normal water flowing 3:06 PM

normal water flowing 3:07 PM

check and clean the water storage at the node 3:07 PM

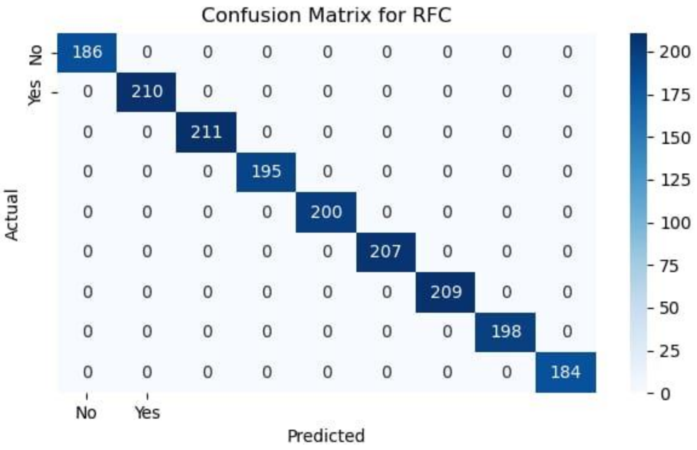
check and clean the water storage at the node 3:08 PM

check and clean the water storage at the node 3:08 PM

normal water flowing 3:09 PM

Fig12: Telegram Notification

In the above figure 12 shows the notifications received in Telegram about the water levels at the nodes.



Confusion Matrix for RFC

	No	Yes							
No	186	0	0	0	0	0	0	0	0
Yes	0	210	0	0	0	0	0	0	0
	0	0	211	0	0	0	0	0	0
	0	0	0	195	0	0	0	0	0
	0	0	0	0	200	0	0	0	0
	0	0	0	0	0	207	0	0	0
	0	0	0	0	0	0	209	0	0
	0	0	0	0	0	0	0	198	0
	0	0	0	0	0	0	0	0	184

Fig13: Confusion Matrix for RFC

A confusion matrix for a Random Forest Classifier (RFC) is a table that describes the performance of a classification model. It compares the actual values of the target variable with the values predicted by the model. The matrix typically includes four values: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). These values are then used to calculate various performance metrics like accuracy, precision, recall, and F1-score.

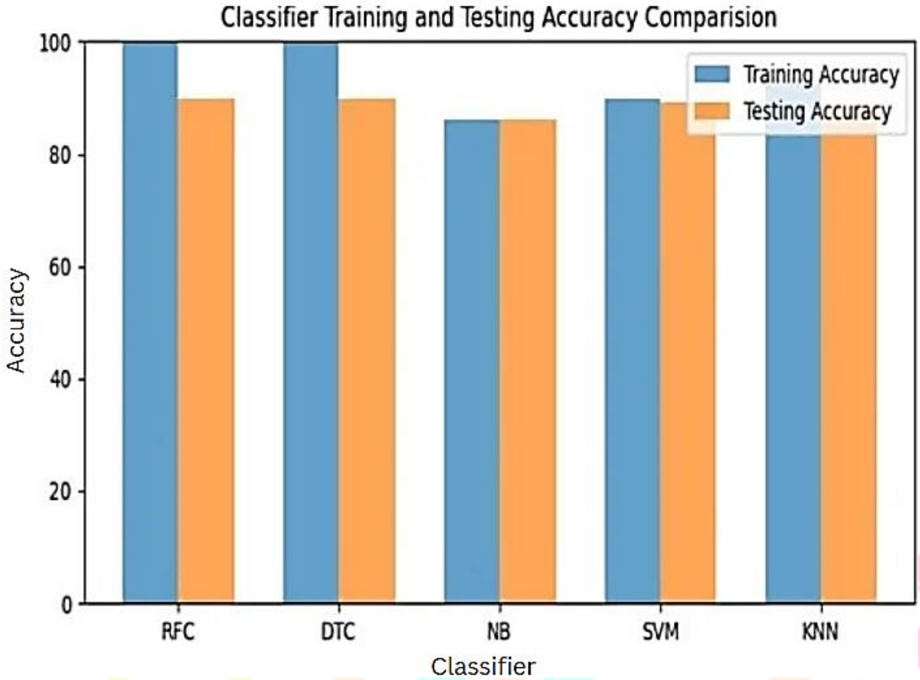


Fig14: Classifier Training and Testing Accuracy Comparison

Above graph shows the comparison of training and testing accuracy for a classifier involves plotting the accuracy scores on the y-axis against the number of training iterations or epochs on the x-axis. This helps visualize how well the model is learning from the training data and generalizing to unseen data. Typically, you'd expect training accuracy to increase over time, while testing accuracy might plateau or even decrease if the model starts overfitting. It's a useful tool for evaluating the performance and behaviour of a classifier during training.

IX.CONCLUSION:

In summary, the integration of machine learning and IoT in water leakage detection presents a transformative approach in modernizing infrastructure management. By harnessing the power of data analytics and sensor networks, this solution not only offers precise detection capabilities but also enables proactive maintenance and resource conservation. Moreover, it facilitates timely decision-making, enhances asset reliability, and minimizes downtime, ultimately fostering resilience in water distribution systems. Nevertheless, ongoing research, collaboration, and scalability considerations are essential for maximizing the long-term impact and ensuring widespread adoption of this innovative technology.

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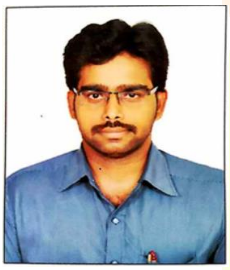

Mr. Y. PAVAN KUMAR received MTech degree from KL University. Present working as Assistant Professor in Andhra Loyola Institute of Engineering and Technology, ECE Department, Vijayawada, Andhra Pradesh, India.

R. Jhansi Pravachana Present pursuing BTech in the branch of Electronics and communication Engineering at Andhra Loyola Institute of Engineering and Technology, Vijayawada, Andhra Pradesh, India.

SK. Dilshad Present pursuing BTech in the branch of Electronics and communication Engineering at Andhra Loyola Institute of Engineering and Technology, Vijayawada, Andhra Pradesh, India.

M. Jhansi Present pursuing BTech in the branch of Electronics and communication Engineering at Andhra Loyola Institute of Engineering and Technology, Vijayawada, Andhra Pradesh, India.

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