Advanced IoT Techniques for Detecting Water Leaks in Supply Networks with LoRaWAN

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***Abstract*—Water leaks are a common problem when water flows through pipes, causing significant losses of this valuable resource. Our solution uses the Internet of Things (IoT) to address these losses. We employ LoRaWAN (Long Range Wide Area Network) technology to collect data from sensors, allowing real-time monitoring of pipelines and the detection of leaks and bursts as soon as they occur. Our goal is to contribute to the preservation of available water resources. We propose non-destructive ultrasonic level sensors to mitigate this issue, thereby avoiding water supply interruptions. These sensors are easy to install and maintain, with a cost that is affordable compared to other existing solutions. Our work aims to gather as much information as possible from water pipelines to ensure rapid leak detection. By using IoT and the LoRaWAN communication protocol, we automate the management of water supply facilities, enhancing efficiency and reducing wastage of this precious resource. We achieved satisfactory results using this solution on our test water pipe.**

Keywords—Internet of things; LoRaWAN; leak detection; pipeline monitoring; ultrasonic liquid level sensor

I. INTRODUCTION

This Water resource management faces increasingly complex global challenges, exacerbated by rising demand, the effects of climate change, such as intensifying extreme weather events, and the deterioration of aging infrastructure. Faced with these challenges, early detection of leaks and bursts in water supply systems is crucial to minimise water losses [1] and optimise the distribution of this vital resource. Despite the existence of various leak detection methods, their applications are often limited by prohibitive costs, technical complexity, and reduced efficiency in real-world conditions. The rise of Internet of Things technologies and long-range networks, combined with the innovative use of water level sensors in pipelines, opens new pathways to address this issue. These technologies enable real-time, remote monitoring, providing a potentially more efficient and cost-effective alternative for leak detection. However, the application and effectiveness of these innovations in the specific context of water leak detection remain largely unexplored.

Our research aims to fill this gap by proposing a LoRaWAN-based IoT application for real-time monitoring of water supply, as well as for detecting leaks and bursts in water pipelines. By utilising non-invasive water level sensors, which are rarely used for this purpose but potentially complement other types of sensors, along with LoRaWAN communication that offers long-range and low data rate and energy consumption [2], Our approach aims to provide a scalable, economical, and reliable solution. It would enable the rapid detection of leaks and bursts in water pipelines, thereby contributing to the reduction of water losses and improving the management of water resources. The innovative approach in our study, combining water level sensors with LoRaWAN technology, promises to offer valuable insights for both the scientific community and industry professionals, marking a significant step forward in monitoring and managing water supply pipelines.

II. RELATED WORKS

The literature review reveals several studies in the field of leak detection. As identified by [3], leak detection methods can be broadly divided into three main categories: software-based solutions, non-technical approaches, and methods relying on specific hardware components, such as ultrasonic flowmeters. Moreover, the emergence of new methods leveraging wireless sensor networks across various fields, such as the biomedical domain and fire detection ([4], [5], [6], [7]) and also in leak detection and localisation, marks a significant evolution, combining software and hardware approaches. These systems often rely on data collected by sensors measuring sound, vibration, flow, or pressure, illustrating the diversity and complexity of strategies used to address the issue of water leaks. Moreover, the adoption of Internet of Things technologies in water resource management represents a revolution in how water networks are monitored. As noted by [8], the use of IoT sensors allows for comprehensive monitoring of water supply systems, both above and below ground. Certain sensors require direct contact with water, which can be invasive and thus increase installation costs [9]. Moreover, wireless communication and recharging buried sensors present significant technical challenges. The works of ([10], [11], [12]) examine how the Internet of Things can be used to monitor water quality and detect leaks. Their approach is based on analysing the difference between distributed water and those actually used, relying on flow and pressure sensors to identify leaks. Their strategy is primarily suited for small-diameter pipelines, highlighting a potential limitation in applying these techniques to larger and more complex systems. The same principle was applied by [13] using invasive flow meters suitable for larger pipelines. They implemented an automated system incorporating electronic valves to identify issues in water supply systems, enhance the management of these systems, and combat losses in the water supply chain. The author in [14] developed a leakage monitoring system using the LoRaWAN communication protocol and ultrasonic flow sensors compatible with LoRa. Their approach focuses on detecting leaks by measuring the flow variation between two points, A and B, with a detection threshold set at 500 ml to trigger automatic alerts. The system uses the MongoDB platform to structure a database from the information transmitted by the flow sensors. However, it is noted that the flow sensor is designed for small-diameter pipelines, which restricts its integration into pre-existing pipeline networks.

The author in [15] used an invasive ultrasonic hydrophone sensor manufactured using micro-electromechanical system (MEMS) technologies for identifying leaks in water pipelines. The examination of transient signals and spectrograms demonstrates that the MEMS hydrophone is capable of locate the leak position in terms of sound sensitivity and energy consumption compared to commercial hydrophones. However, it is crucial to mention that in order for the leak to be detected, it needs to be located between two hydrophones. Furthermore, transmission loss, related to signal attenuation depending on the material type of the pipelines and the length of sensor placement, can potentially trigger false alarms. The author in [16] presented a technique for identifying multiple leaks in fluid pipelines. This technique utilises the velocity of ultrasonic waves, dependent on the mathematical correlation between ultrasonic speed and internal pressure. This enables non-invasive determination of the leak's location, which is calculated using a simulated annealing grey wolf optimisation (SAGWO) algorithm.

Other ultrasonic methods were identified by [17] Bulk waves: These waves are used to inspect pipes using single or multiple transducers affixed to the outside of the structure. They are generated by ultrasonic waves. However, ultrasonic inspection of pipe materials poses challenges due to their high attenuation. Guided ultrasonic wave techniques: These techniques involve the propagation of waves in waveguides, such as pipes. These waves can travel long distances, but their effectiveness is limited when inspecting water-filled buried pipes. This limitation is due to the significant attenuation of guided waves, caused by losses in the pipe material and energy leakage into the surrounding soil, which reduces the testing range. Guided wave ultrasonic (GWU) monitoring relies on acoustic waves to inspect water pipes over long distances. This method is based on torsional waves propagated by two transducers, which calculate the distance of anomalies and estimate their significance based on the amplitude. This technique shows potential for detecting small leaks, although its range may be influenced by the pipe's geometry and other structural characteristics [8].

Research by various authors has explored the use of impedance detection to identify leaks. The author in [18] introduced a pipe sheath designed to monitor water leaks, conductivity, and temperature in small-diameter pipelines. This sheath utilises non-contact impedance measurements, enabling the detection of even very small water leaks over long pipe distances. Consequently, it is necessary to install thin metallic electrodes along the pipe. The author in [19] developed a compact modular electronic unit that employs ultrasonic techniques with four copper electrodes for scalable impedance detection to detect leaks and monitor water in plastic pipes. However, this equipment is considered complex, rendering it impractical for real-world applications. The author in [20] conducted a study aimed at monitoring plastic water pipes using non-contact sensors such as strip electrodes and piezoelectric transducers. This method enables the measurement of several parameters, including flow rate, fill level, temperature, and leaks, which can be installed in existing manholes. The flow rate is determined by the Time of Flight (ToF) difference of two ultrasonic waves propagating in opposite directions within the fluid. Furthermore, ultrasonics can be used to transmit both energy and data over short distances along pipes. It is important to note that integrating electrodes into existing potable water pipelines is costly due to the extensive length of these pipelines.

Robots have also been used, such as the ultrasonic thickness measuring robot designed by [21]. This robot assesses the polymer coatings used in drinking water pipeline infrastructures to extend their lifespan. While it may be effective for its specific purpose, this robot has limitations in terms of size, range, target materials, cost, and broader inspection capabilities. This requires careful evaluation of its relevance for each application case. Another technique is based on vibratory signals [22], which involves placing sensors on the pipes of the network to detect and locate water leaks in distribution systems. This method relies on measuring the radial vibratory state of the pipes to detect energy variations transmitted to the walls of the pipe, which can be linked to a leakage flow. However, it is important to note that the sensors in this case must be very close to the leak to detect it.

Recent studies, such as those conducted by [23], have introduced an IoT-based system for detecting leaks in underground pipelines, utilising a moisture sensor and a wireless NodeMCU. This technique allows for leak detection while reducing the time needed to identify leaks by 70% and the system's hardware costs by 83% compared to previous work. Additionally, their strategy aims to avoid water waste by redirecting it to replacement reservoirs in case of a leak. However, the practical application of this system faces obstacles. The design relies on a shielded pipeline, a configuration not commonly seen in typical pipelines made of PVC, polyethylene, or asbestos cement. This characteristic makes the system potentially expensive and complex to implement in existing pipeline infrastructures. According to the article by [24], an integrated approach using Geographic Information Systems (GIS) and remote sensing techniques, including infrared imaging, is presented for detecting leaks in water distribution networks. This method, applied particularly to the network of the Sharjah Electricity, Water, and Gas Authority, utilises variations in flow, pressure, and chlorine residue to identify leaks, which are then confirmed with infrared cameras. The main advantages of this method lie in its use of GIS and infrared technologies, its integration of various data sources, and its ability to offer real-time monitoring for leak identification. However, this technique requires specific expertise and resources for the integration of GIS and infrared imaging. In the research carried out by [25], the researchers introduced a monitoring system based on IoT, utilising LoRaWAN to profile pressure rates in water pipelines. Designed to improve pressure monitoring across water distribution networks, the system employs a pressure sensor and a GSM module for real-time collection and transmission of pressure data to a cloud-based data management system. Experimental results confirmed the system’s leak detection capabilities, revealing an average pressure variation of 7.7 kPa, indicating high consistency in measurements. However, the installation and maintenance of the system could present challenges, especially regarding the integration of the technology into existing infrastructures without causing major disruptions. The article by [26] explores the implementation of software and hardware technologies for detecting leaks and bursts in water distribution systems. This study explores a variety of methods, including acoustic-based detection systems, pressure, flow, as well as advanced approaches such as Artificial Intelligence. In the methodology they propose, the IoT framework consists of multiple layers, including a sensor layer, a communication layer, a water system layer, an exploitation layer, and an application and prediction layer. Data on flow characteristics, pressure, and water quality, along with information from the water demand model and AI models, are collected by the Supervisory Control and Data Acquisition (SCADA) system from sensors. While acknowledging that further progress is needed to align current technological capabilities with industry needs. However, non-destructive solutions such as using level sensors, accelerometers, and moisture sensors, among others, remain a viable alternative to bridge the divide between the ideal system and current capabilities. The study by [27], The authors examine approaches based on models, data, or mixed methods that combine both. Model-based methods use hydraulic simulations to detect and locate leaks, relying on the availability of a calibrated hydraulic model and water demand measurements. However, data-based approaches primarily focus on one of these two tasks, using techniques such as machine learning to analyse sensor data without requiring a deep understanding of the network. Mixed approaches focus on locating leaks; therefore, their extension to detection poses challenges when identifying low leak rates. The authors emphasize the importance of covering the entire distribution network with sensors, both for detection and for multiple-localisation. According to their recommendations, leak management methods must be designed. This highlights the usefulness of non-destructive sensors, also known for their low cost and easy installation, as complements to existing sensors to address this constraint. These sensors allow the application of information fusion techniques, combining data from different sensors, each suited to various areas and conditions of water pipelines, such as diameter, location, whether it's crowded or not, accessibility, and so on. In their article, [28] examines the use of high-frequency pressure and acoustic sensors within smart water networks (SWNs). Their study highlights the advantages of these technologies in optimising the management of urban water distribution networks by enabling leak detection and localisation, asset management (pipe failures), and online hydraulic modelling. The study included an experimental setup that simulates a pipeline network with ultrasonic flow sensors and pressure sensors. The collected data is transmitted to a cloud server for analysis. However, it was found that the pressure readings were not sufficiently reliable to detect leaks due to the relatively short length of the experimental pipeline network, which led to a significant pressure loss between successive nodes.

In summary, our exploration of various methods for detecting leaks in water pipelines has revealed that every approach has its unique strengths and constraints. The choice of the ideal method largely depends on factors such as pipeline dimensions, the scope of the inspection, the available sensor technology, and other specificities inherent to each application context. This article explores advanced techniques for leak detection and water management, initially describing the structure and operation of our IoT sensor system. We then discuss the communication protocols used, detail our methodological approach, and present the results of practical tests. We conclude with the implications of our findings for future water management.

III. STRUCTURE OF THE PROPOSED SOLUTION

The general structure of our solution is illustrated in (Fig. 1). It consists of sensor nodes that continuously and in real-time acquire water level measurements. These measurements are then transmitted to the gateway via the LoRa communication protocol. The primary role of the gateway is to manage communications according to a unified standard. Subsequently, the data are forwarded to the server for processing, monitoring, and decision-making. Additionally, the gateway is capable of sending data back to the sensors. Our main contribution in this article is based on the use of distance-measuring sensors to determine the water level in pipelines, a use not yet reported in existing literature. While these types of sensors are typically used in reservoirs, their adoption for water pipelines represents a novel approach. Additionally, the integration with the LoRaWAN communication protocol helps overcome issues related to sensor range and autonomy, while remaining non-destructive. This solution is ready to be deployed either alone or in conjunction with other sensor technologies. Furthermore, the existing manholes in current infrastructure make this solution applicable to a wide range of pipelines, whether buried or not. This monitoring capability significantly enhances the efficiency of teams responsible for pipeline maintenance and inspection by precisely identifying the suspect section of the pipeline.

A. Methodology

The occurrence of leaks is a significant problem for operators in water production and distribution. Repairing leaks requires significant human and material resources, and any disruption in the drinking water supply is not tolerated by residents. The idea is to continuously monitor the water pipes through alerts on a smartphone or computer, this is achieved by relying on the water level in various the water pipes sections. The water level can vary over time due to several factors such as overconsumption, anomalies in a water pipeline, or a malfunction in hydroelectric equipment. In practice, when the water level drops for an extended period, this indicates that there is a leak to be detected and monitored. Our task in this case is to determine the leak location by installing sensors in the water pipes, specifically in already-existing manholes. Given that water supply networks extend over kilometres and encompass various techniques and structures for water transport, such as buried pipes, necessary manholes for emptying, and those containing air valves to release air from the pipes we have the advantage of accessing the pipes through the doors of the manholes, which allows us to easily install our sensors.

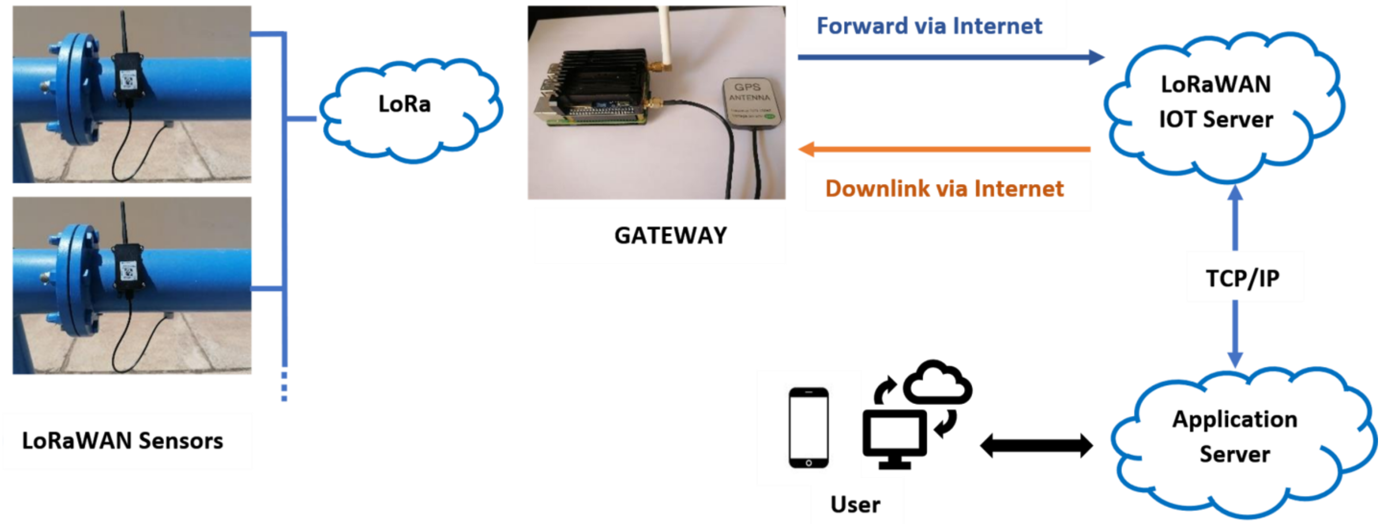


Fig. 1. System architecture of the LoRaWAN-based leak detection system

The level sensors (Fig. 2) continuously perform real-time measurements and transmit these readings to a remote monitoring centre. This centre then compares the gathered data with readings taken under equilibrium conditions. If, in the second phase of the process, a deviation exceeds a predefined threshold, an alarm is automatically triggered, prompting verification of conditions upstream, such as checking the filling status of reservoirs and valve positions, to prevent false alarms. Subsequently, the centre observes the level sensors along the suspected area for a certain period. During the third phase, an analysis of adjacent measurements along the concerned segment is conducted to determine if there's a leak and pinpoint its location. The results of this analysis are then relayed to the operations staff for further action.

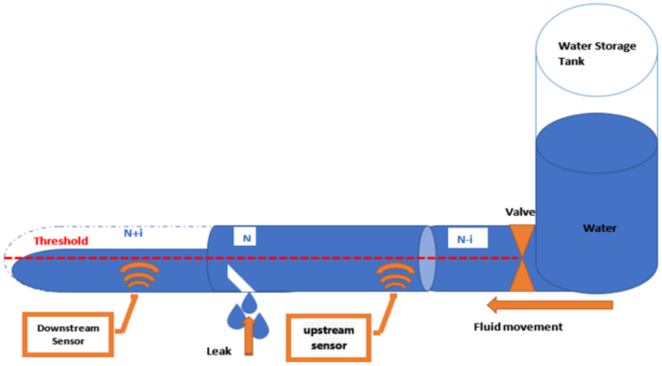


Fig. 2. Leak detection approach

Eq. (1) illustrates the principle of calculating the liquid level relative to a predefined threshold. In these equations, $\boldsymbol{L}$ represents the liquid level measured in each pipe segment. $\boldsymbol{k}$ denotes the number of sensors on each side of segment $\boldsymbol{N}$, which is the segment suspected to be affected by the leak. $\boldsymbol{L_0}$ is the reference liquid level, representing the expected or initial water level in the absence of a leak. $\boldsymbol{T}$ is the predefined level threshold. This threshold $\boldsymbol{T}$ is determined through experimentation and depends on the pipe's diameter as well as the upstream and downstream conditions of each section.

$$\sum_{i=1}^{k}(L_0 - L_{N-i}) < T \;\&\; \sum_{i=1}^{k}(L_0 - L_{N+i}) > T \quad (1)$$

B. Mathematical Relationship of Flow Rate as a Function of Level

To establish a mathematical relationship between the drop in flow rate (ΔQ) in a water pipe and the drop in water level (Δh) in that pipe, we can use the continuity equation, which expresses the conservation of mass in a fluid flow. The continuity equation states that the mass flow rate of a fluid remains constant along a pipe, provided that losses are negligible. We can mathematically relate the drop in flow rate to the drop in water level.

1) The continuity equation is as follows

$$A1.V1 = A2.V2 \quad (2)$$

Where:

- $A1$ and $A2$ are the cross-sectional areas of the pipe at two given points (usually in square meters).
- $V1$ and $V2$ are the fluid velocities corresponding to these points (usually in meters per second).

However, we have a water pipe in which the water level decreases by a certain amount Δh over a certain pipe length Δx. We can define the drop in water level Δh as the difference in height between the inlet and outlet points of this pipe section.

2) Relationship between fluid velocity and water level height: We use Torricelli's law to relate the fluid velocity (v) to the water level height (h) in the pipe. This law is formulated as follows:

$$v = \sqrt{2 \cdot g \cdot h} \tag{3}$$

where:

- v is the fluid velocity in the pipe (in meters per second).
- g is the acceleration due to gravity, approximately 9.81 m/s² at Earth's surface.
- h represents the height or water level (in meters).

3) Calculation of velocity variation ($\boldsymbol{\Delta v}$): The velocity variation (Δv) between the inlet point 1 and the outlet point 2 of the pipes can be calculated by subtracting the velocity at the outlet ($v2$) from the velocity at the inlet ($v1$):

$$\Delta v = v1 - v2 \tag{4}$$

By using Torricelli's law for $v2$ and $v1$, we get:

$$\Delta v \ = \sqrt{2 \cdot g \cdot (h1 - h2)} \tag{5}$$

4) Calculation of flow rate variation (ΔQ): The flow rate variation (ΔQ) between the inlet and outlet points of the pipe can be calculated by multiplying the cross-sectional area at the inlet ($A1$) by the velocity variation (Δv):

$$\Delta Q = \ A1 \cdot \Delta v \tag{6}$$

Using the previous expression for Δv, we get:

$$\Delta Q \ = A1.\sqrt{2 \cdot g \cdot (h1 - h2)} \tag{7}$$

This is the mathematical equation that relates the drop in flow rate ΔQ in the pipe to the drop in water level Δh between the inlet and outlet points of the pipe, based on the cross-sectional area of the pipe $A1$ and the acceleration due to gravity (g).

IV. IOT COMMUNICATION PROTOCOL

There are different communication protocols in which IoT modules operate. This difference has consequences on the range, the speed, the frequency, the connection quality and the messages volume to be transmitted. (Fig. 3) shows some communication protocols examples distributed according to their data rate and distance. In our case, we favour the large distance over the data rate, the choice is therefore focused on the LoRa (Long Range) because it is adapted to our needs.

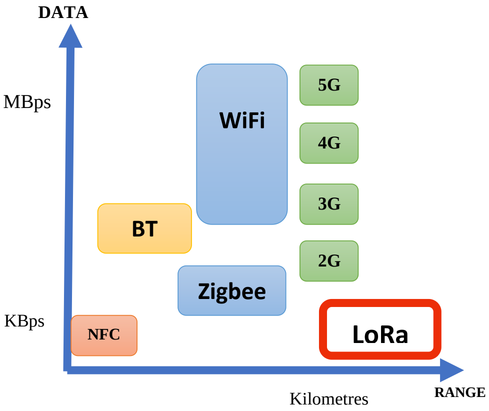


Fig. 3. IoT communication protocol

V. MATERIALS AND METHODS

In this section, we outline the essential steps undertaken to conduct our practical experiments, facilitating data acquisition for the purpose of early leak detection.

A. The Things Network (TTN)

This is an open and decentralised network infrastructure for Internet of Things devices. It allows devices to communicate with each other and with the internet. TTN uses LoRaWAN technology, our connected objects must operate in remote or hard-to-reach areas, and it has three clusters and depends on the geographic location of each user. In our case, we are using the frequency of 868 MHz designed for Europe. This frequency is crucial for equipment certification and proper operation, so it is essential that all equipment uses the same frequency. In our practical test, we manage the acquisition and processing of information from the gateway and sensors, while the rest of the infrastructure is managed by the TTN server.

B. Gateway

The gateway (Fig. 4) used for our test comprises two main components: a Raspberry Pi board and an integrated LoRa module, the PJ1301 from DRAGINO. This module allows us to manage various devices using the LoRaWAN communication protocol. It is a high-performance multichannel concentrator designed to receive multiple LoRa packets simultaneously. The goal is to establish a robust connection between a central data concentrator and wireless terminals spread across a wide area. Internet of Things applications can support up to 5000 nodes per km² in moderately disturbed areas. The gateway's integrated GPS (Global Positioning System) module provides precise synchronization and geographical coordinates to the Raspberry Pi. After adding and activating our gateway, TTN displays the connected status, The received messages contain the information sent by all sensors around the gateway with a timestamp, the bandwidth of 125 KHz, the spreading factor, as well as the RSSI (Received Signal Strength Indication), etc.

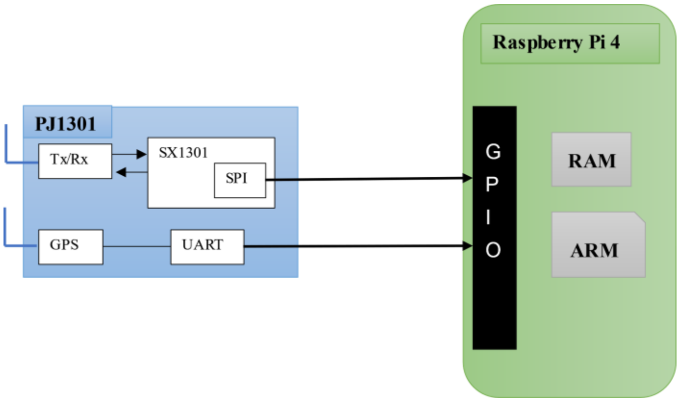


Fig. 4. Gateway structure

C. Sensors

We employed the DRAGINO LDDS20, an ultrasonic LoRaWAN liquid level sensor designed for IoT applications (Fig. 5). This sensor measures liquid levels in containers or water pipes non-invasively and transmits the data to the IoT server via the LoRaWAN network. Positioned directly beneath the water pipeline, the sensor is engineered to detect liquid levels efficiently, offering extensive-range spread spectrum communication, robust interference resistance, and minimal power usage.

1) Equation for measuring water level using the ultrasonic sensor: The LDDS20 calculates the distance to an object by measuring the time it takes for an ultrasonic wave to travel to the object and return. The fundamental equation for this calculation is:

$$\text{Distance} = \frac{\text{Speed of Sound} \times \text{Time}}{2} \quad (8)$$

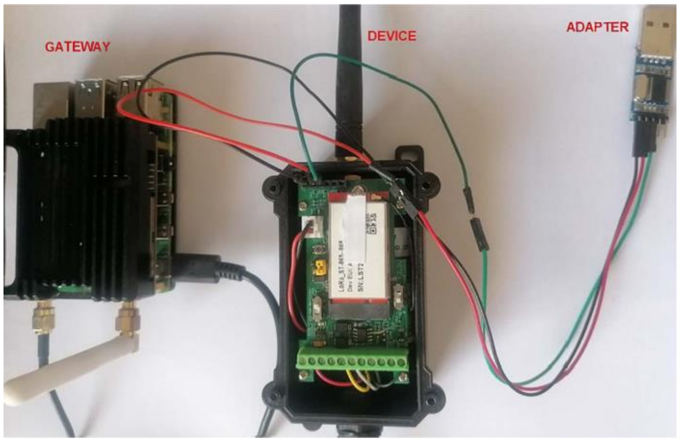


Fig. 5. The gateway, sensor device, and adapter for AT command

Where:

- Distance: Represents the distance to the liquid interface.
- Speed of Sound: The speed at which sound waves propagate in the medium, in pure water at 20 °C, this speed is approximately 1 482,343 m/s (5 336,435 km/h).
- Time: The duration for the ultrasonic wave to travel to the interface and return, in microseconds (µs).

The sensor emits an ultrasonic wave, a high-frequency sound wave, toward the target (e.g., the liquid interface). This wave propagates through the water in the pipe at the speed of sound. Upon reaching the liquid interface, it is reflected back to the sensor. The sensor measures the time taken for the ultrasonic wave to travel from the sensor to the liquid interface and then return. Using (8), the sensor calculates the distance to the liquid interface. The division by 2 is necessary because the ultrasonic wave makes a round trip. The calculated distance is then provided as an output, which is used to determine the liquid level in the pipe.

D. Datacake

Is an IoT development platform that allows users to connect, monitor, and remotely control devices via the internet. The platform provides a variety of tools for developers, including real-time data collection, customizable dashboard creation, user management, integration with third-party services, and automated notifications. Initially, we activated the integration at the TTN level to retrieve data. After activating the integration, we registered the sensors on the Datacake platform.

VI. CONDUCTING A PRACTICAL TEST

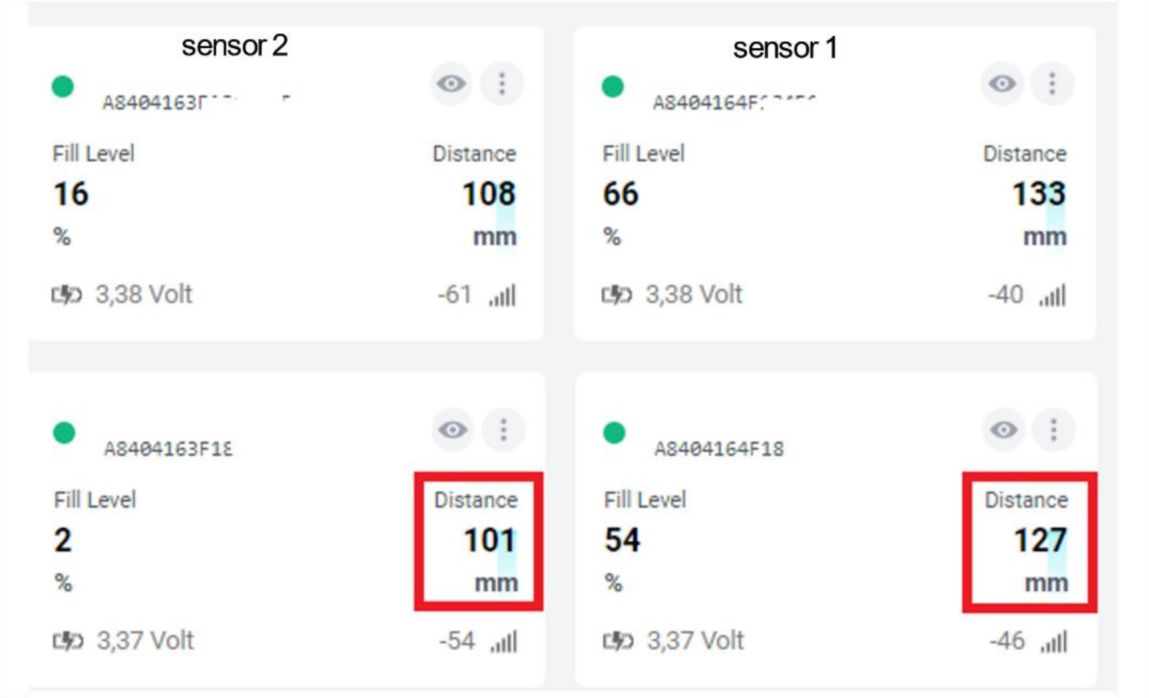
The process involves applying the prototype to a PVC water pipe, similar to those used in actual drinking water transport. The pipe is filled with water to test the sensors and evaluate their effectiveness. The level sensor provides measurements on the rate of filling, then controlled leaks are induced to observe changes in the water level. The initial step involves installing two sections of pipes, totalling 6 meters in length. The selected diameter is 160 mm, with a cap for sealing and an elbow for filling at both ends, as shown in (Fig. 6).

Fig. 6. Test prototype with sensors installed in the pipe

VII. RESULTS

Following the preparation of the prototype and the installation of the sensors, we commenced the testing process. The initial step involved connecting the gateway to the TTN server. The next step was to verify the uplink connections, where the packets sent by the sensors contained data regarding the detected liquid levels. Our experimental approach consists of three main phases. The first involves filling the pipeline, followed by initial water level measurements at the sensor placement points. However, it is crucial to continue testing to evaluate the sensors' capacity to detect rapid changes in water levels. After progressively inducing a leak, the continuity test for water level sensor detection shows a progression of measurements over time, as illustrated in (Fig. 7). It provides an overview of the various measurements obtained from the sensors, indicating distance, sensor voltage, and signal quality. Additionally, the system sends automatic email alerts based on predefined thresholds. The results suggest a good capacity for the system to detect changes in water levels, which is crucial for effective leak monitoring.

Fig. 8 shows that our solution successfully identifies a 74 mm drop in water level, a crucial parameter for detecting potential water leaks, or which can indicate various real-world situations, such as a pump equipment failure or an upstream reservoir is empty. The system's ability to track these changes in real-time, with a granularity that allows for detecting shifts of just a few millimetres, is significant is essential for identifying not only major leaks but also minor anomalies, which could indicate emerging issues within the water pipelines. Additionally, our system includes a sensor box consisting of nodes that continuously capture accurate real-time measurements in the pipes. However, for more robust monitoring and management of the water network, integrating other types of sensors, such as accelerometers, hydrophones, etc., would be beneficial. These enhancements would offer a more comprehensive perspective on network conditions and enable improved water resource management.



sensor 2
A8404163
Fill Level 16 %
Distance 108 mm
3,38 Volt
-61

sensor 1
A8404164F
Fill Level 66 %
Distance 133 mm
3,38 Volt
-40

A8404163F18
Fill Level 2 %
Distance 101 mm
3,37 Volt
-54

A8404164F18
Fill Level 54 %
Distance 127 mm
3,37 Volt
-46

Fig. 7. Monitoring of water level

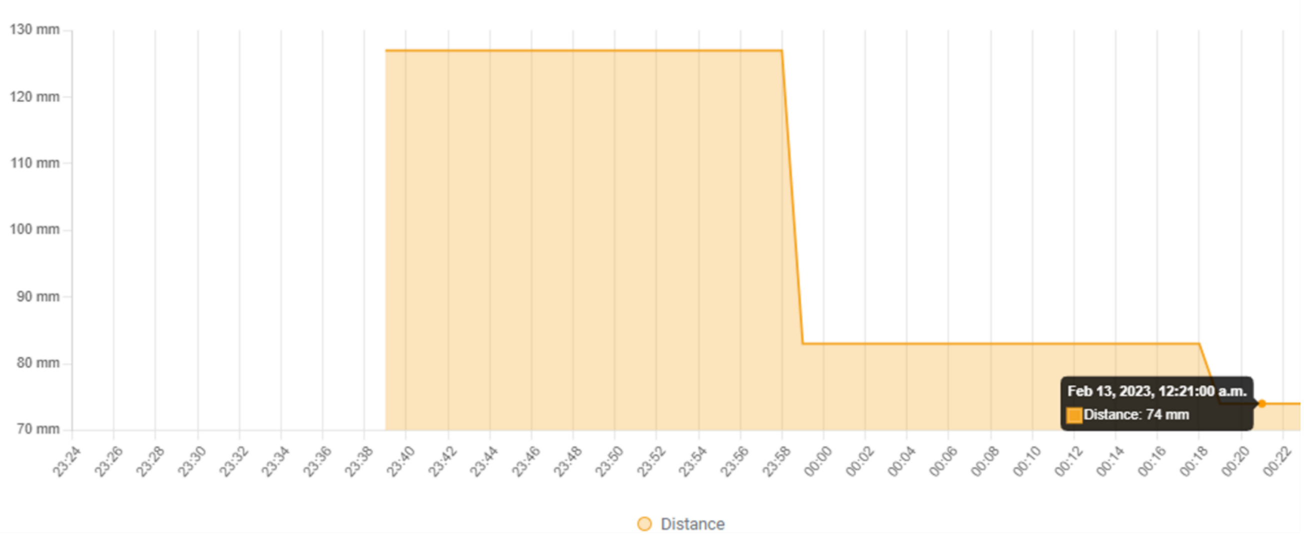


Fig. 8. Water level drop during continuous monitoring

VIII. DISCUSSION

This article proposes an innovative IoT application for leak detection in pipelines. Our system, based on LoRaWAN technology, allows for real-time data collection and transmission from sensors, providing continuous and precise monitoring of water pipelines. The originality of our approach lies in the integration of standard sensors into an IoT architecture optimised for water transport environments. This approach offers a cost-effective and practical solution for water management, which could generate significant interest from the scientific and technical community.

Compared to existing systems, our solution offers increased applicability across various types and diameters of pipes. For instance, unlike systems that utilise flow sensors primarily suited for small-diameter pipelines, as described by ([10], [11], [12], [14]), our method operates effectively across a broad range of diameters. Moreover, the reduced cost of non-destructive sensors, combined with their multi-year autonomy, represents a significant advancement in terms of cost-effectiveness and durability compared to systems that require invasive sensors, such as pipeline flow meters [13] or hydrophones [15]. Real-time and remote monitoring via mobile devices, and the capability to automatically send email alerts, offer improvements over methods that require more intensive human interaction for leak detection, such as the thickness measuring robots [21].

IX. CONCLUSION

Our research demonstrates that ultrasonic level sensors are a highly effective method for the early detection of water leaks. These sensors successfully identified variations in liquid levels within materials typically used for pipeline construction, underpinning their utility in real-world applications. More than just detecting leaks, our approach integrates these sensors within an IoT framework, utilising LoRaWAN technology to offer a scalable, robust solution for the proactive management of water distribution systems.

This integrated method enhances the efficiency of water resource management by enabling automated monitoring and rapid response capabilities, significantly reducing water losses. Our solution stands out due to its non-destructive nature, ease of installation, and cost-effectiveness compared to traditional methods.

Significantly, our findings contribute to the scientific community and operational management by demonstrating a viable, innovative strategy for water conservation. These contributions are particularly relevant in the context of global challenges such as increasing demand and the impacts of climate change on water resources.

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