# HydroSys - An online platform for remote monitoring of water distribution networks


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## Abstract

Water distribution networks have a water loss rate that exceeds 40% in some Brazilian regions. Most current leak detection methods in Brazilian water distribution systems rely on inspections scheduled by water companies to ensure proper conditions of the pipes and to investigate leakage complaints. These manual reviews require displacement from the distribution company employees, which costs time. The proposed system HydroSys measures flow water data in the water pipes and analyzes the data collected, monitoring the leakage occurrence and the network distribution infrastructure remotely from an online platform. Fastening the detection of water loss can decrease the high waste of potable water, contributing to a sustainable world.



***Keywords:*** Water Distribution Networks, Water Leak Detection, Remote Monitoring, Internet of Things


## 1 Introduction

One of the biggest challenges facing water distribution is the high level of water loss in distribution networks. Part of the water leaving the treatment station, ready for consumption, does not reach the consumers, and part of the consumed water is not billed by the water company. If a large proportion of water that is supplied is lost, meeting consumer demands is much more challenging. Since this water yields no revenue, heavy losses also make it more difficult to keep water tariffs at a reasonable and affordable level. [3] Therefore, the adoption of technologies to control losses in water distribution systems is a necessity for the water companies. [6] The average water loss rate in the European Union (EU) countries is about 20 %, whereas several countries have water loss rates lower than 10 % [7]. According to the National System of Sanitation Information (SNIS) from Brazil, the Brazilian estimated rate of water loss is 37%, but in some regions, like the north and northeast, exceeds 40%. The rate of COMPESA (Companhia Pernambucana de Abastecimento) was 57% in 2010 [5]

A big challenge is to provide a scalable system, one which can be replicated to monitor several different district meter areas (DMA). A DMA is a discrete area of distribution caused by the closure of valves, in which the quantity of water entering and leaving the area is metered. A permanently monitored DMA is considered to be the most effective tool for reducing the duration of unreported leakage. Monitored DMAs must not be too large to maintain the water data variation within a tolerable range [4].

Most of the methods which detect leaks in Brazil rely on scheduled inspections by the water company. The priority of inspections is in areas of leakage complaints, made by phone calls from the population. In these inspections, the water operators verify the condition of the pipes and leakage complaints and carry out the necessary repairs. In contrast, there has not been much development of monitoring systems capable of detecting unusual events based on water data analysis, like flow and pressure. It is necessary that there is a development of a wireless sensor network and a data analysis mechanism of the water data distribution collected by these sensors for remote monitoring of the infrastructure of the water distribution system [2]. The main objective of our proposed system project, HydroSys, is to provide online monitoring of pipes from a water distribution network, fastening the detection of water loss and, therefore, decreasing the waste of potable water.

HydroSys is a system to be installed on pipes, which measures water flow. The sensor nodes send data to a gateway capable of analyzing the data and learning a pattern and then detecting anomalies which indicate a water leak. The gateway sends the result of the data analysis to a web page. In this page, it is possible to visualize the location of all sensor nodes and the pipes on a city map and the analysis results for each area, helping the water operators to guarantee the consumers right conditions of the infrastructure of the distribution network.

Similar works have been developed in the United States (US) such as Pipenet, a system also based on wireless sensor leaks networks which perform water data analysis for leak detection [1].

## 2 HydroSys Description

### 2.1 Overview

HydroSys is composed of three main modules (Fig. 1): The data capture modules, which are the sensor nodes, the leaks predictor modules (gateways), which are responsible for controlling a group of nodes and analyzing water data, and the online monitoring platform, in which is possible to visualize the location in a city map of the gateways and its nodes, the measured flow data by the nodes and the data analysis of the gateways.

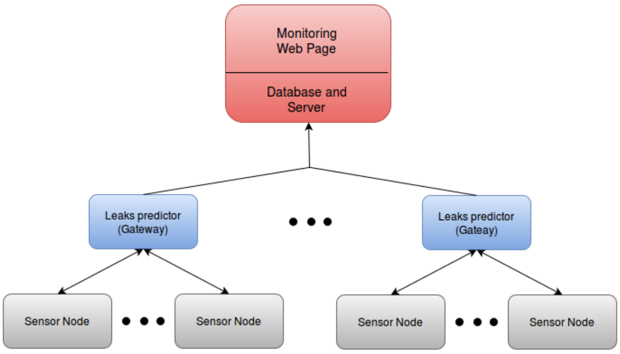


Figure 1: The HydroSys system architecture. Leaks predictor module communicates by radio frequency (RF) with a group of sensor nodes requiring flow data. After data analysis, it communicates with a server by GPRS, sending a sample of the received data from the nodes and the result of the analysis. If a leak is detected, a push notification alerts the water operator of the event.

The leaks predictor module reduces the quantity of information to be sent to the internet, lowering the communication cost and not overloading the server.

### 2.2 Data Capture Module

Measuring the water flow in the pipe during a period of water less demand allows a better statistical analysis due to less data variation. This period is called the minimum night flow period (MNF). To estimate real losses, MNF can be an indicator of distribution leakage and consumer wastage. MNF is the water flow into a DMA of a network during the period of minimum demand, that is, between 1:00 am and 4:00 am. The analysis of DMA flows allows estimation of leakage when the flow into the DMA is at its minimum value, which occurs at night when customer demand is at its lowest level, and therefore, leakage component is at its highest value. [4] When a new request is received, the sensor node sends the data by radio frequency (RF) to the leak predictor. While does not measure flow, the sensor is on standby operation mode to save power (Fig. 2).

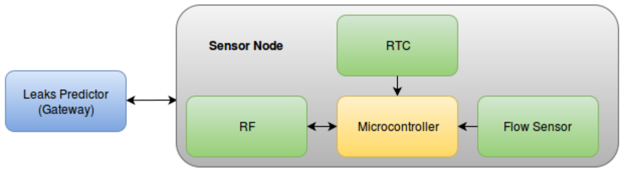


Figure 2: Each sensor node is a microcontroller which controls a radio frequency module and a flow sensor connected to the pipe. When a new request from the leak predictor arrives, the node sends the collected flow data by RF. The RTC generates an alarm interruption to awake the module from standby.

The microcontroller we used to implement the sensor nodes was the Arduino Uno. It controls the flow sensor, the wireless transceiver, and the RTC module. The Arduino sends to the gateway the data flow it reads from the flow sensor whenever it receives a data solicitation from the gateway. Because of the standby mode, the microcontroller can only be woken up by an external interrupt, for this purpose we used an RTC module. The RTC generates an alarm interruption to wake up the Arduino from standby for the configured night period. Figure 3 describes the state diagram of the data capture module.
We used the wireless RF transceiver module nRF24L01+ to implement the communication between sensor nodes and the gateway. The transceiver operates in 2.4Ghz ISM band, and the data transmission frequency is 250Kps. In case the packets delivery fails, the module has up to 15 tries to resend the data.

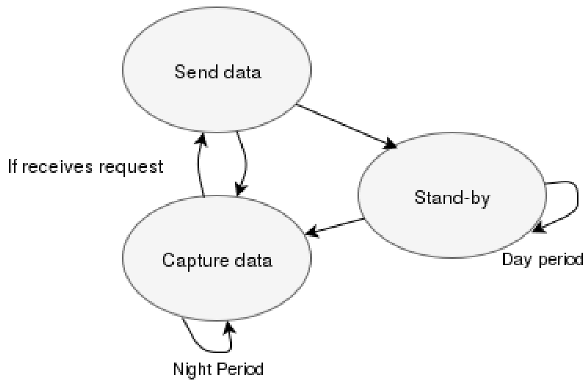


Figure 3: Microcontroller state machine. Arduino waits until receives a request from Galileo. When it receives, reads data from the flow sensor and sends them to Galileo for leak analysis.

### 2.3 Leak Predictor Module (Gateway)

This module controls the sensor nodes, requesting water flow data periodically. For each group of collected data of each sensor, the module performs a statistical analysis of training data and test data, detecting if there is a leak for each sensor. Then, the gateway

sends a sample of the data and the analysis result to the web server by GPRS. This technology was chosen so the system may work in locations which do not have an internet connection by Wifi (Fig. 3).
The problem of finding leaks using flow values was approached in this work as novelty detection, aiming one-class classification. In this type of classification, one class (the specified normal, "no leakage") has to be distinguished from all other possibilities. The goal is to learn a model of normality from a set of data that is considered "normal", the training set, and the decision process on test data is based on the use of this model [8]. We chose this approach because leakage data is not available initially and may have unpredictable patterns. Therefore we only collect training data from pipes that are not leaking.
The algorithm compares the training distribution with test distribution (data collected every night) to see if they are similar or different. If they are different, a leakage is occurring. If they are similar, then there should be no significant difference between the means from the collected training and test samples. Thus a leakage is not occurring.
The board used for the gateway was the Intel Galileo Gen 2. It controls the GPRS shield SIM900 from Geeetech to communicate with the web server via posts and gets, and the radio-frequency module nRF24L01+ to report with the sensor nodes.

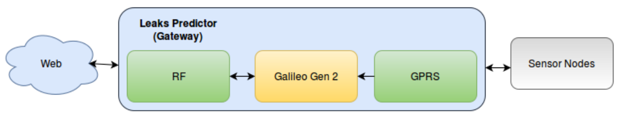


Figure 4: Gateway requests data to sensor nodes. The module recognizes if the test data differ in some respect from the training data. The leak predictor sends those results and sample of the received data to server

### 2.4 Online Monitoring Platform

We designed a website for easy monitoring of a water distribution infrastructure and water data visualization. It is an interface that allows the administration of all working sensors and stations and the visualization of the data analysis. For system administration purposes, the website allows registering leak predictor modules and its nodes.

It is possible to visualize in a map points indicating the gateways, and when a gateway is selected, another map opens showing all the nodes a selected gateway is responsible for, also indicated as points, and the pipeline infrastructure (Fig. 4).

The website allows the user to be notified as fast as possible of a leakage occurrence. If a leakage is detected, the gateway and the node that detected the leak turn red and a push notification is generated. It

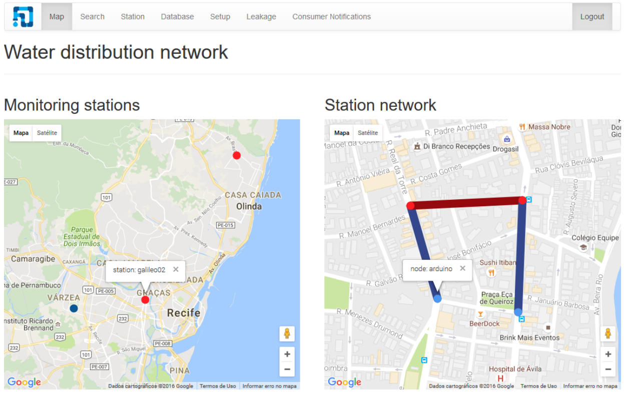


Figure 5: Map tab from HydroSys website. The first map shows points, which represent all the gateways registered on the site. The second map shows all the nodes the selected gateway is responsible for, also represented as points. The pipelines are the connection between the nodes, represented in the map as lines.

is possible to visualize the training and test flow data set for each node when clicking on the node.

A priority for each leakage was calculated for allowing comparison of all occurred leakages by ordering them in a priority list. One of the water distribution operators problems is which leak repair first when there are many leak reports. The objective of the priority list of leaks is to solve the problem by providing the user an estimation of the leakage aggravation and a fast way to visualize it.

## 3 Experiments

A prototype of a piping network was built o evaluate the proposed system, (Fig. 6). A water pump continuously pumps from an open container and delivers the water back to it. The pipe used has 1.875 cm in diameter. We installed two sensor nodes in the tube, which monitor the water flow continuously. The pipe between the two nodes represents the monitored pipe in our system. A tap was positioned between the nodes to simulate a leak, to deviate the path of water flow and generate a water flow variation. The amount of leaked water increases with the tap opening degree.

Fig. 7 shows the two nodes and the gateway, which is the Intel Galileo Board. An LCD (Liquid Crystal Display) was placed in Galileo for debugging purposes, showing the system state (training, testing, sleeping or sending data).

The board sends a command to the nodes to enter into a standby state. This way it is possible to save energy, during the period that the Gateway is not analyzing data. The sensor nodes only awake again when the night period begins. Running on 5V through the +5V pin, the microcontroller draws about 49 mA. On the standby mode, it draws 34.5 mA, a savings of approximately 30%.

Figure 6: Prototype.

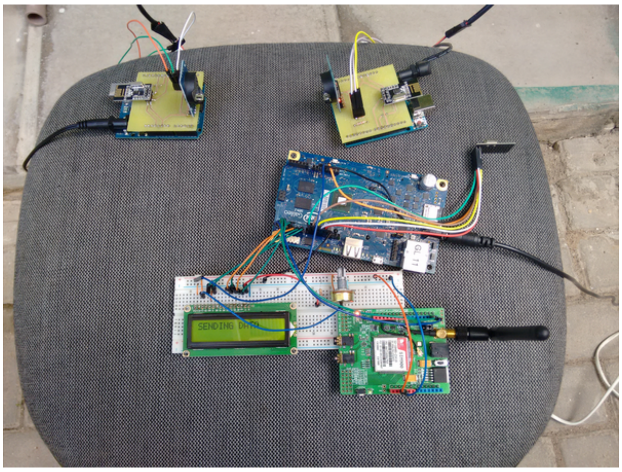

Figure 7: Two nodes and the Gateway.

# 4 Conclusion

Water distribution networks maintenance presents many challenges because of networks complexity. It is necessary then that water companies have mechanisms to control their infrastructure to perform faster maintenance and repairs, decreasing the water wastage in the network, which is very high in many places.

The HydroSys is a project of an original platform of distribution networks management which aims to help to detect leaks to reduce water losses and mapping pipelines to facilitate the infrastructure maintenance. Among the challenges, the system must be scalable, covering the most of the city with a low cost.

to improve the mapping of infrastructure, the website provides other relevant information about the node as brand pipe, material, diameter, and supported pressure by the tubes.

The problem of water losses in the distribution networks and poor management of the network infrastructure is severe in Brazil, and the HydroSys becomes then very relevant in this scenario.

# 5 Future Works

For future works, other methods of novelty detection could be used further to improve the performance of data analysis. Furthermore, a hydraulic simulator program, such as EPANET [9], can assist the construction of the normality model used in the novelty detection, improving the accuracy of the distribution used to represent the training data set.

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