D3.2 FIWARE-enabled application for Water Distribution

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Executive Summary

Deliverable 3.2 technically describes the efforts and developments carried out in task T3.2 'Smart Applications for Water Distribution', in WP3 'Smart Applications and Devices' of the FIWARE4Water (F4W) project.

The objective of this task is to develop a set of smart applications that improve operational and tactical decision support and infrastructure management in the Urban Water Supply domain. In this scenario, four topics have been focused: i) forecasting water demand, ii) prediction of water resource availability, iii) the detection and location of water leakage events, and iv) the detection of water contamination events.

To demonstrate the advanced capabilities of the implemented applications, its development has been aligned with the integration of the FIWARE ecosystem in the so called FIWARE4Water architecture and deployed and validated into two different real Demo Cases (DCs). Mainly, the developments detailed in this document are demonstrated in the Cannes (France) DC, but the third topic (the detection and location of water leakage events) is also implemented in the Great Torrington (UK) DC, since both cases deal with the Water Supply complexities, either from cities, water utilities, water authorities, citizens, or consumers point of view. The innovative and advanced properties of the FIWARE4Water digital architecture are reported in the corresponding deliverables of WP2 'Architecture/Data/Ontology/API/Legacy links/Standards'. Furthermore, the deployment of the smart applications into the real systems, in the proposed DCs, is presented in deliverables D4.2 'FIWARE4 Leakage Management', D4.3 'FIWARE4 Water Quality Monitoring and Pollution Response' and D4.5 'FIWARE4 Smart Metering and Citizen Engagement', all being outcomes of the work done in the WP4 'Demonstrating FIWARE4Water in the Real (Water) World'.

Essentially, the applications are based on predictive models, which provide them with a kind of intelligence, thus generating novel, effective and efficient solutions to the proposed water domain issues. These predictive models are boosted principally by data-driven algorithms even though, in some cases, they are also combined with numerical mechanisms (e.g. hydrological or hydraulic models) in order to obtain advanced capabilities.

The main objective of this document is to provide a detailed explanation (at technical level) of how these predictive models are designed, implemented, developed, and evaluated, thus enabling reproductivity and upscaling to other cases of similar characteristics and challenges. To do so, the description of these phases follows the same process and methodology used during the same project development. This process is an adaptation of the CRISP-DM (Cross-industry standard process for data mining), an open standard and data science methodology, which defines six sequential and iterative steps focused on the development of data mining projects: i) Business understanding, ii) Data understanding, iii) Data preparation, iv) Modelling, v) Evaluation, and vi) Deployment.

Five partners have contributed to this task to the development of the proposed smart models by demonstrating different innovative properties and characteristics, addressing different requirements, using different technologies, and demonstrating the FIWARE integration and interoperability capabilities (e.g. external sensors, legacy systems, different technologies, etc), as shown below:

I. Water demand forecasting:
   a. AI & ML: A semi-supervised approach for water demand forecast. Algorithms are implemented through MATLAB technology.
   b. Big Data: Regressive algorithms for water demand forecast implemented through Python technology with horizontal scalability and high-performance properties.

II. Prediction of water resource availability:
   a. AI & ML: long-term forecasting of water resource availabilities. Algorithms are implemented through MATLAB technology.
   b. Hybrid approach: a combination of data-driven & hydrological models. Real-time, continuous water availability forecast.

III. Water leaks detection:
   a. AI & ML: A supervised classification problem implemented through MATLAB technology.
   b. Big Data: A supervised classification algorithm for water leaks detection implemented through Python technology with horizontal scalability and high-performance properties.
   c. Hydraulic models: A model-driven methodology that relies on the EPANET model of the water distribution for leak detection.
   d. Workforce tool: A planner responsible for finding the optimal scheduling of workforces based on resources optimization.

IV. Detection of water contamination events:
   a. AI & ML: drinking water quality events detection through an unsupervised approach. Algorithms are implemented through MATLAB technology.
   b. AI & ML: A prediction-based approach combining Univariate Signal Evaluation and Forecasting-based Detector methodologies for water quality data.

As a result, four smart applications have been developed, one for each Water Supply topic, which combine the aforementioned capabilities in an ensembled solutions with the aim to provide the involved water utilities with an advanced Decision Support Systems for improved decision making, and resources and infrastructure management.

Finally, the EU added value and policies recommendations related to this document are detailed in the Conclusion sections.

Related Deliverables

D1.1 - "Requirements from Demo Cases" and D1.2 – "Requirements from end-users", which describe the requirements of the smart solutions developed in WP3.

D4.2 – "FIWARE4_Leakage Management", where the deployment and end-testing of the developed smart solutions for the French demo case are described.

D4.3 – "FIWARE4_Water Quality Monitoring and Pollution Response", where some of the anomaly detection algorithms are tested under practical conditions.

D4.5 – "FIWARE4_Smart Metering and Citizen Engagement", where the deployment and end-testing of the smart solutions for the United Kingdom demo case are described.

Document Information

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2.0	22/04/2022	Panagiotis Kossieris (NTUA)	Internal review of the document
3.0	29/04/2022	Lluis Echeverria (EUT), Marc Ribalta (EUT), Danillo Lange (EUT)	Final version of the document

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List of Acronyms/Glossary

AI Artificial Intelligence

ACF Autocorrelation Function

CRISP-DM Cross-industry standard process for data mining

DM Demo Case

DMA District Metered Areas

DMS District Metered Sector

DOC Dissolved Organic Matter

EWMA Exponential Weighted Moving Average

F4W FIWARE4Water project

FPR False Positive Rate

GBT Gradient Boost Tree

k-NN k Nearest Neighbours

LSTM Long short-term memory

MAE Mean Absolute Error

MAD Median Absolute Deviation

MCLP Maximum Coverage Location Problem

ML Machine Learning

MSE Mean Squared Error

NGI Next Generation Internet
The Next Generation Internet (NGI) initiative, launched by the European Commission in the autumn of 2016, aims to shape the future internet as an interoperable platform ecosystem that embodies the values that Europe holds dear: openness, inclusivity, transparency, privacy, cooperation, and protection of data.

NRMSE Normalized Root Mean Squared Error

PACF Partial Autocorrelation Function

PI Performance Indicator

RMSPE Root Mean Squared Percentage Error Loss

SLA Service Level Agreement

SVM Support Vector Machine

TOC Total Organic Carbon

UV	Ultraviolet
WDS	Water Distribution System
WO	Work Order
WP	Work Package
WPL	Work Packages Leaders