Work-In-Progress: SMART-WATER, a Novel Telemetry and Remote Control System Infrastructure for the Management of Water Consumption in Thessaloniki

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Abstract. Water scarcity and water stress issues pose a serious threat to the global population. Climate change, drought, population growth and consolidation in urban centres have all been increasing the pressure on water service providers to deploy more sustainable approaches in urban water management. Real-time monitoring and control of water consumption are key ingredients for a smart water management system which will raise consumers' environmental awareness and reduce costs. This paper introduces a smart infrastructure system which enables remote telemetry and control of water consumption via a web application. The bidirectional and reliable communication between terminal devices (smart meters and valves) and the end-user (consumers and water utility operators) is realized through a fixed hybrid network which uses multiple telecommunication protocols. The metering data is collected and further processed through modern data analytics tools to give a deeper insight on water consumption and behavioral patterns.

Keywords: Internet of Things, Smart Cities, Smart Metering, telemetry, actuation, LPWAN, Predictive Big Data Analytics

1 Introduction

According to the United Nations Department of Economic and Social Affairs, 1.8 billion people will be living in countries or regions with absolute water scarcity by

2025, and two thirds of the world's population could be living under water stressed conditions [1]. Water utility companies are increasingly investing in automated water consumption telemetry infrastructures to create new enhanced services. These technological infrastructures are also known as Advanced Metering Infrastructures (AMI) [2,3] and have evolved out of Automated Metering Reading (AMR) technologies [4,5] which first appeared in the 1980s. AMR involves the automated transmission of recorded consumption data, typically via public (e.g. GSM) or private radio systems, to servers for storage and further processing by the utility company and/or third parties [6]. Usually, this involves the use of existing compatible "dumb" meters [7], which are modified/upgraded resulting in "smart enabled meters". AMR technologies result in improved accuracy and proliferation of metering data but only offer a slight increase in data density, e.g., one read per month, although higher frequencies have been used [8].

In addition to what is offered by AMR technologies, AMI also allows for continuous bidirectional communication between the meter and the end-user (utility or consumer) and significantly higher data density. AMI offers a vast volume of data that enables real-time monitoring and data analysis. When applied in water management systems, AMI technologies enable near real-time monitoring of water consumption, immediate detection of water loss which may be due to leakages or unauthorized usage, environmental protection via water resources' splurge reduction and the potential for significantly improved customer service.

Water management infrastructures typically utilize wireless data collection methods commonly known as "walk-by" and "drive-by" [9,10]. These methods allow for wireless collection of metering data from water meters through a portable short-range radio frequency reader carried by the staff in charge. The water metering staff will approach the point of installation of the meter at close distance (tens of meters), either on foot ('walk-by') or on a vehicle ('drive-by'), in order to be within range of reception. Obviously, these methods do not allow for frequent data reception and therefore cannot constitute the foundation of intelligent infrastructures which collect and process the measured data in near real time. Furthermore, these technologies cannot support bidirectional communication between terminal devices and a water management infrastructure enabling remote control exercise. For the aforementioned reasons, research on smart water management systems has turned to the development of fixed communication networks, which allow bidirectional connectivity of terminal meter devices to a remote server in real-time.

Recent research in Greece has revealed that the wireless reception of metering data from water meters which are located inside buildings and underground installation points comes with high risk of data loss and important reliability issues [11,12]. The challenges involved in radio transmission of water metering data in Greek cities are attributed to the dense urban environment, the reinforced structural materials and the limitations of legacy RF technologies. Nevertheless, a new generation of Machine to Machine communication (M2M) technologies, commonly referred to as Low Power Wide Area Network (LPWAN) technologies [13,14], promise to alleviate current challenges in water meter device connectivity.

2 Related Work

The introduction of modern Information & Communication Technology in water supply management systems aims to create new solutions for measuring water consumption and reducing unnecessary wastage, contributing to raising water consumption awareness among consumers and promoting sustainable use of natural resources.

One such example is the 2015 pilot project i-WIDGET (Improved Water Efficiency through ICT Technologies for Integrated Supply-Demand Management). This was a pilot project emphasizing the design and development of a web-based platform under the collaboration of Southern Water (UK), the water company of Barcelos (Portugal) and a number of other specialists [15,16]. Another significant pilot project is "SmartH2O", which focused on water demand and how it is affected by the use of smart meters. The application of the methodology developed by the project was shown to have achieved a consumption reduction of 10% in the pilot area tested in Switzerland and 20% in Spain [17].

Studies have also been conducted to visualize household consumption data and to develop a platform for mobile phones, including digital educational games [18]. Other examples of pilot projects are “WATERNOMICS” [19] and “WISDOM” [20], which focused on the use of ICT technologies to improve water resource management.

3 Purpose

SMART-WATER is a collaborative pilot project run by the Thessaloniki Water Supply and Sewerage Company S.A. (EYATH); APIFON Telecommunications; and the Information Technology Institute (ITI) of the Centre of Research and Technology Hellas (CERTH). The project puts forward a novel design of an infrastructure that utilises modern telemetry and remote-control technologies to provide innovative services to consumers and water utility operators. The end-user web applications that are part of the smart water management infrastructure deliver novel services to consumers while raising environmental awareness. The integrated system infrastructure will be tested in the urban area of Thessaloniki, the second largest city in Greece.

4 Approach

4.1 Gateways

As mentioned earlier, the key to an intelligent water metering infrastructure is the deployment of a fixed telecommunication network comprising of wireless communication gateways deployed across locations within a coverage area. The gateway installation locations need to be selected on the basis of telecommunication range requirements and cost constraints. In the case of SMART-WATER the gateways are hybrid telecommunication network nodes allowing for bidirectional connectivity via multiple telecommunication protocols (LoRaWAN, wM-bus, GSM, NB-IoT) between terminal devices and a protocol-agnostic network server. Their use is crucial since none of the terminal devices use wireless internet protocols to communicate directly with the central server where device and data management takes place. The key role of the gateways is data transmission from wireless terminal devices, via an Internet protocol, to the central server as well as routing of downlink commands in the opposite direction (from the server to the terminal devices).

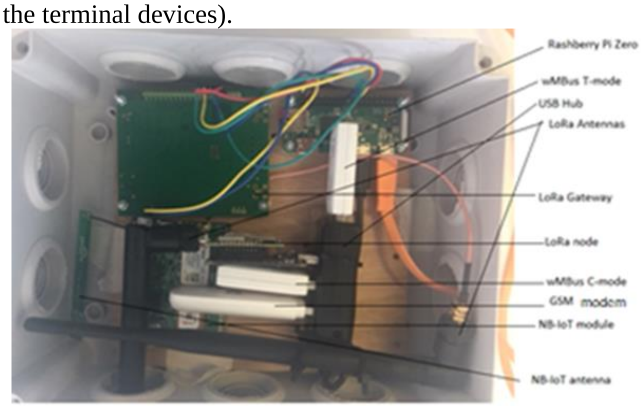

Fig. 1. Custom gateway and its electronic components

The hybrid gateway is a special-purpose electronic device developed to communicate with the terminal devices through the LoRa and wM-Bus wireless protocols and connect them to the cloud-based server over NB-IoT and GSM cellular protocols. The gateway device uses a Raspberry Pi Zero (1GHz, single-core CPU, 512MB RAM) as a host computer power unit and peripheral components for the wireless interfaces.

The components are: iC880A IMST LoRaWAN Concentrator, iM871A IMST wM-Bus adapter, SODAQ SARA N211 NB-IoT node, MultiConnect mDot LoRa node and Huawei E3372 4G (Fig.1). The host system operates several packet forwarding algorithms developed using Python, Go and C++ programming languages to establish the bidirectional connection between the terminal devices and the server.

Given that gateways serve as the main building block of the proposed system, they must be controlled and managed remotely so that the network administrators can have full-scale network supervision and monitoring. All gateways run a software enabling remote control and actions like SVN repository updates and firmware upgrade over the air, log extraction, configuration, etc., at any time, via a cloud-based network management platform which provides a graphical user interface environment. The communication between the gateways and the platform is achieved through the MQTT (Message Queuing Telemetry Transport) messaging protocol. A messaging broker service (MQTT broker) runs at both sides (gateways and platform) to create communication channels (‘topics’) and route requests and responses between them.

4.2 Field Testing

Based on the RF technologies (LoRa, WM-bus, GSM, NB-IoT) used by the terminal devices and the custom gateways, field tests in real conditions were realized inside the building blocks of the candidate consumers at the urban area of Thessaloniki to draw conclusions on the practical capabilities and limitations of the above technologies as well as the possible solutions for the implementation of the fixed wireless network. The testing procedure was realized through a custom ‘tester’ device which executed consecutive field tests on wM-Bus, LoRa, NB-IoT and GSM coverage at specific locations. The results of the tests are projected in a HTML-based GUI where the user added metadata such as the exact location and address where the test took place. The metadata of the test campaigns were locally saved and then forwarded and stored to a cloud-based database (InfluxDB) for further processing.

5 SMART-WATER Architecture

The SMART-WATER novel system is analyzed into 5 interactive layers that encompass the basic system processes (Fig.2) and specified as follows:

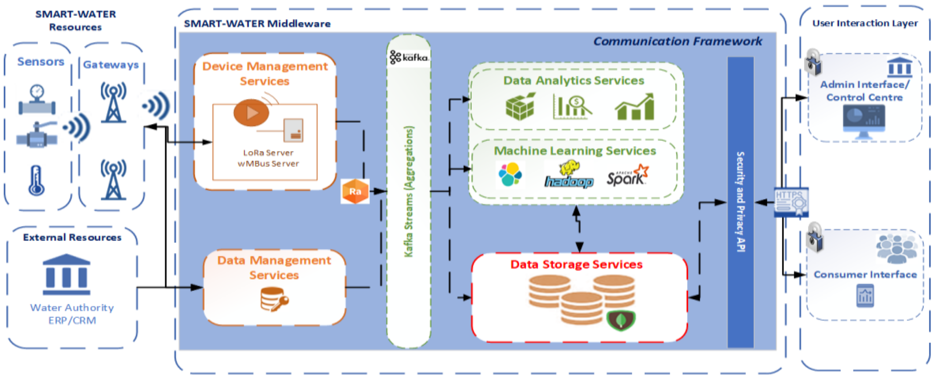

Fig. 2. Basic components of SMART-WATER system architecture

1. **End Device Layer:** SMART-WATER metering data sources are divided into two categories, namely the endogenous sources of terminal devices (smart meters, smart valves) and external resources which consist of other interacting systems with the SMART-WATER ecosystem environment, for example the ERP / CRM systems of the Water Utility company (e.g. EYATH S.A.).
2. **Device Connectivity Layer:** The key role of this layer is the bidirectional transmission of the metering data, from the smart terminal devices to the central server using wireless telecommunication protocols, as well as the forwarding of commands in the opposite direction. The bidirectional hybrid fixed network is deployed via special-purpose multi-protocol indoor/outdoor gateways which operate as intermediate telecommunication nodes.
3. **Device and Data Management Layer**: The *Data Management Services* component receives, decodes, decrypts and stores the data sent by the smart meters. Furthermore, it manages the actuation commands from the control center to the smart valves. The *Device Management Services* component is responsible for the status of terminal devices and their remote control as well as for the supervision of telecommunication nodes. Storing and sharing the vast amount of data which flows from smart terminal devices to the system is made possible through the Apache Kafka platform, which provides high-performance solutions for data storage and distribution.

4. **Data processing and analytics layer**: The purpose of this layer is to directly process and analyze the metering data as well as to forward the data and analysis results for storage into the Data Storage Services component. Specifically, tailored state-of-the-art methods and techniques from the field of statistics, predictive data analytics and Machine Learning are applied. Initially, the streaming data passes through a pre-processing step using Kafka Streams.
5. **User Interaction Layer**: SMART-WATER end-users are water utility company operators and consumers. Each group has different needs, requirements and perspectives using the system. Specifically, the User Interface of the water utility company encompasses functionalities for direct monitoring of water consumption of all or selected consumers, advanced reporting and comparative spatio-temporal analysis of the obtained consumption streaming data. Furthermore, it enables EYATH's personnel to control the status of all telemetering and remote-control devices installed in the field, as well as to manage the devices (Fig.3, Fig.4). Similarly, the consumer's web interface will provide consumers with tools to monitor their water consumption, to benchmark their consumption levels against the average consumption in their area and to control the flow of water by sending actuation commands to the water valve installed on their premises, in near real-time.

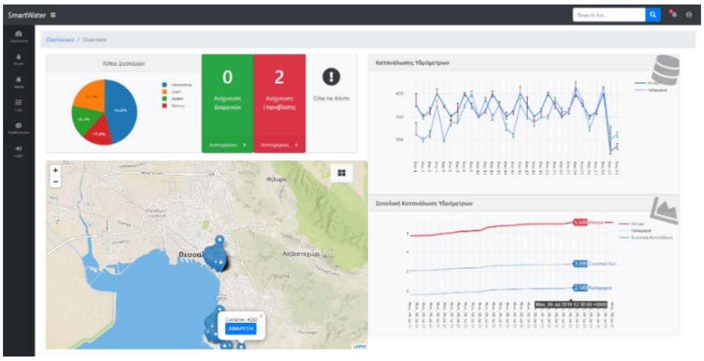

Fig. 3. SMART-WATER's dashboard – Overview picture of water consumption

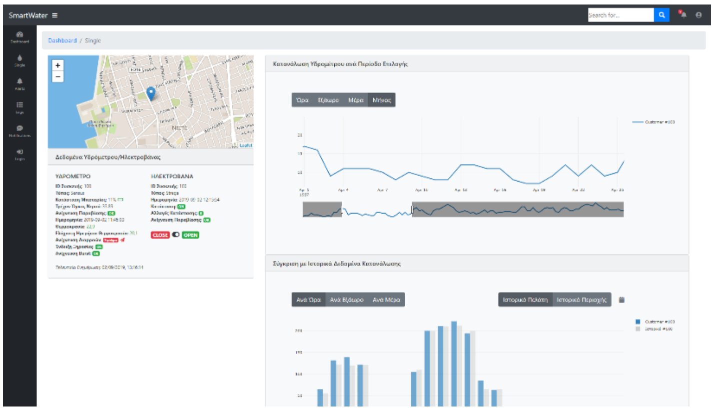

Fig. 4. SMART-WATER's dashboard – Picture of a single water meter (customer)

6. Conclusions

The research being conducted as part of the SMART-WATER project will give the water utility company of Thessaloniki (EYATH) a sound understanding of consumers' behavioural patterns rendering cost reduction, better resource allocation and modernization of consumer services a viable option. Telecommunication-wise, evidence from field tests suggests that reliable and uninterrupted bidirectional data transmission can only be feasible via a hybrid fixed communication network utilizing modern IoT and conventional RF protocols to achieve wide area coverage and deep in-building penetration.

The comparison between LoRaWAN and wM-Bus technologies, both in laboratory testing conditions and in real field test conditions, has shown that LoRaWAN significantly outperforms wM-Bus technology in terms of coverage and penetration. However most renowned water meter manufacturers prefer the mature and widely tested wM-Bus technology.

In addition, the fact that terminal devices (water meters, valves) use more than one communication protocol (LoRaWAN and wM-Bus) makes it necessary to create a hybrid multi-protocol network that will provide bidirectional connectivity between terminal devices and the central server. Implementing such a network that reliably support many different connectivity scenarios requiring the use of multi-protocol gateways. Given the limited range of the wM-Bus terminal devices, the gateways must be located close to them and at the same time remain connected to the central infrastructure via GSM or NB-IoT.

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