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Adrijana Vrsalović
University of Split

Ivo Andrić
University of Split

Toni Perković
University of Split

Marin Aglić
University of Split

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Adrijana Vrsalović[*], Ivo Andrić[*], Toni Perković[†], Marin Aglić Čuvić and Petar Šolić[†‡]
[*]*Faculty of Civil Engineering, Architecture and Geodesy*, *University of Split*, Split, Croatia
[†]*FESB*, *University of Split*, Split, Croatia
[‡]*waveform j.d.o.o.*, Split, Croatia

***Abstract*—This paper presents architectural design and on-site implementation of smart building for purposes of building parameters monitoring, involving both required hardware and related software. For the purposes of implementation, the paper focuses on the technical description of required steps needed for successful implementation of used IoT architecture, while providing use cases on smart water meters implementation and given data analysis. The implementation of such a system is linked to the need to reduce costs and aims at more efficient spending by providing users with transparent data in real-time. In this way, smart water distribution is achieved through better distribution efficiency and sustainability of resources. The importance of consumption awareness of users is not to be ignored, since the graphical and numerical presentation of water consumption over time, available on different platforms for visitors and users of the building can lead to change in water consumption habits and patterns, therefore reduce the overall operating cost of the system.**

***Index Terms*—smart building, smart water meters, LoRaWAN, IoT Wallet**

I. Introduction

The responsibility of water utilization has significantly increased in recent years targeting to ensure sustainable water management in urban areas [1]. To manage water consumption, loss control and demand, meters have been utilized to measure water consumption. Usually, water meters are Manual Meter Reading (MMR) that require end operators to periodically travel and read water consumption, making water reading quite expensive and complicated [2]. However, recent advancements of communication technologies allowed the expansion of IoT ecosystem in which a large number of devices are connected and exchange sensor data [3]. This allowed the development of Automated Meter Reading (AMR) devices enabling the communication of recorded data in real time [4], [5]. These technologies range from Low power wide area network, GSM-GPRS, WiFi, Zigbee-3G and 4G Long Term Evolution (LTE) [6].

Such a metering technology allows the expansion of water consumption awareness aimed at minimizing cost, raising awareness, and creating transparency regarding consumption [7]. The collected data, integrated into the computer platform, provide real-time information on water consumption, detect losses in the distribution system, and the presence of possible breaks, which, if detected in time, can be repaired easily and quickly. Monitoring water consumption also has mutual benefits for the water user and the distributor. By implementing such a system, consumers can monitor consumption at any time, are more aware of their consumption, and seek to reduce it to reduce financial allocation for water consumption. At the same time, distributors have visibility into consumption trends as well as detection of potential interruptions in the system and do not need to hire a meter reader due to automatic meter reading [8]. Furthermore, when humans are working in the process, there is always the possibility of human error, i.e. an incorrect reading of the scale, which is not the case with an automatic reading. By identifying deficiencies, it is possible to address them, and by implementing new technologies and investing in infrastructure, it is possible to improve the distribution system for sustainable development and better service to consumers [9].

Fig. 1: Location of LoRaWAN-based watermeters from Axioma placed at University building with a high-rate daily-based change in the number of people.

In this paper, three smart water meters have been deployed

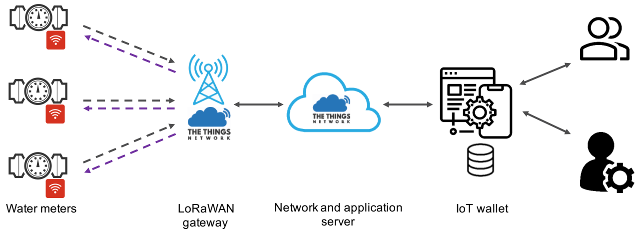

Fig. 2: High level overview of architecture of the proposed solution.

on an University building that has high-rate of daily-based change in the number of people. Every water meter measures the waterflow of a separate building block, i.e. the first water meter measures the overall waterflow, while two others measure waterflow of two building blocks (Block B and C in Fig. 1). These water meters are employed with LoRaWAN radio technology transceivers allowing them to convey information from electromagnetically harsh environments (e.g. in a parking lot, under a metallic plate) to a centralized system in a timely manner. Water consumption analysis was performed from the collected hourly water consumption values in each building block. It was shown that the largest consumption occurs between 9 and 12 a.m. for the complete building. Moreover, during the night hours, it was shown a constant loss of water of about 0.3 m^3/h giving insights into slow but continuous water loss. Such a form of information regarding water consumption, especially placed in a publicly available spot, or available at a glance of a hand of end user, in an IoT-wallet like application, can lead to a change in water consumption habits and patterns, therefore reducing the overall operating cost of the system.

II. IoT Technology for Smart Buildings

To enpower the concept of Smart buildings, future IoT systems will have to comprise of a great number of sensor devices that will measure changes in the environment and adequately inform the end user or other systems of such changes. From the perspective of smart buildings, one of the most important elements that makes smart buildings is smart water consumption management, timely and fast detection of pipe cracks as well as control of water consumption and loss in individual segments of the building. In order to collect information on water consumption in a timely manner, traditional meters require users to regularly inspect and read the status of the meters. On the other hand, in today era of smart buildings, water meters convey data to a centralized system that stores information on water consumption, draw conclusions about possible water leakage, send alarms to the user or a system about potential water leakage via smartphone web application, implement machine learning algorithms with the aim of possible savings, detection of smaller and / or consumption trends.

To envision the concept of smart buildings from the perspective of water consumption analysis, water that flows

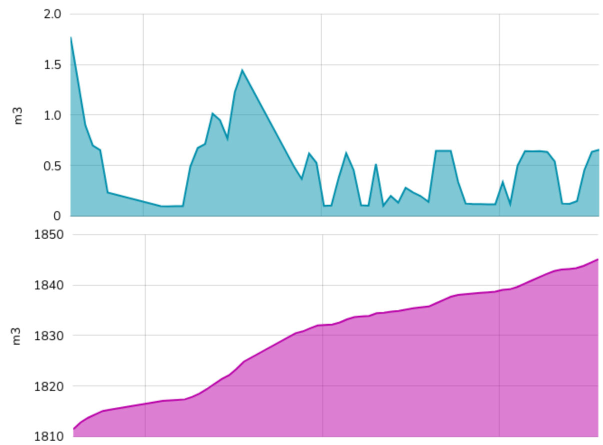

Fig. 3: Water consumption measurements collected by Axioma water meter device placed at one location - location A. Blue graph depicts delta volumes on an hour basis, while purple denotes overall water consumption.

through the pipes of University building was collected with Axioma Qalcosonic water metering devices placed in three positions, as depicted in Fig. 1. The first device (placed at the position A in Fig. 1) measured the water consumption of the complete building, while devices B and C measured water consumption of the two building blocks. Modern water meters employ new methods for measuring water flow, one of which are electromagnetic [10], fluidic and ultrasonic [11]. To measure water dataflow, Qalcosonic devices utilize ultrasonic technology as one of the most widely used methods that ensure high measuring accuracy, which can also identify small changes in the water network[1]. To convey the collected data from water measurement devices, Axioma Qalcosonic devices are equipped with LoRaWAN radio technology, as described below.

A. IoT Radio

To convey information from water meter devices to a centralized system and provide user information about water consumption, numerous technologies could be employed. Note that water meter devices are placed below the floor level, and usually some form of wireless interface should be deployed for the delivery of waterflow data. Omnipresent wireless technologies, either used for high-throughput data such as 3G, WiFi, and LTE or low-throughput data such as ZigBee, Bluetooth Low Energy (BLE) are limited in coverage and not suitable for such operation. Low power wide area networks (LPWA), and their representative technologies, LoRa [12], Sigfox [13], and NB-IoT [14], [15], allow battery-operated devices to convey data over large distances, making them suitable for the implementation of smart buildings. For water consumption analysis LoRaWAN as a LPWA technology was used over NB-IoT and Sigfox as it was shown to provide

[1] https://www.axiomametering.com/en/products/water-metering-devices/ultrasonic/qalcosonic-f1-ip68-ultrasonic-flow-meter

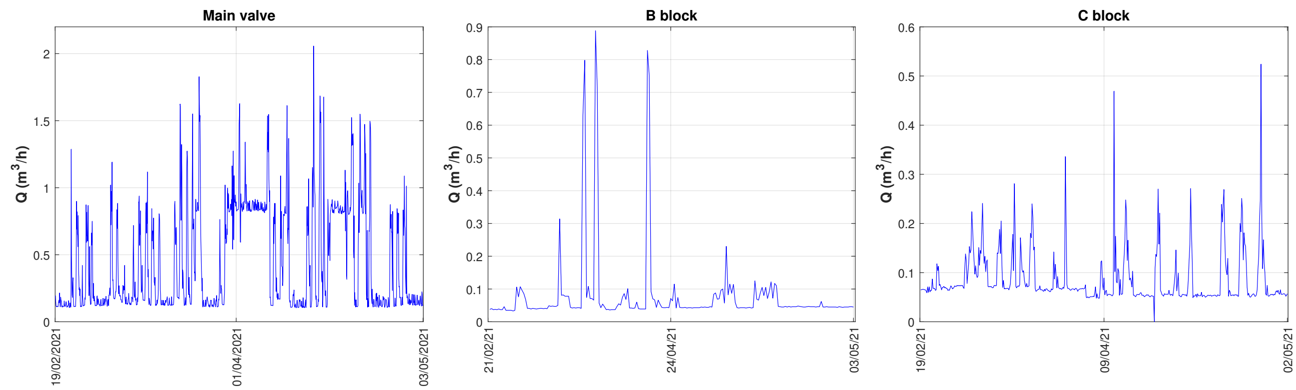

Fig. 4: Trend of water consumption at the main valve and in blocks B and C.

packet delivery to gateways without any error rate, which is especially important given that water meters transmit data in an electromagnetically harsh environment (water meter 1 in Fig. 1 is placed under the ground below a metallic hydrant cap at the parking lot).

Axioma Qalcosonic is equipped with LoRaWAN radio module that periodically sends sensor data to the gateway. Since Axioma Qalcosonic is battery operated device, to conserve energy and increase battery lifetime, the radio module sends a message every 6 hours. The payload part of the message contains information regarding the current volume, log date and time, volume at the moment of log date and time, but most importantly, 15 delta volumes corresponding to the last 15 hours of measurements. In addition, payload contains status code information such as dry, burst, water leakage, etc. Fig. 2 shows architecture of the proposed solution.

As a LoRaWAN gateway, Sentrius RG191 Gateway concentrator was employed that forwards messages from Axioma Qalcosonic sensor devices to The Things Network (TTN) cloud infrastructure. Our gateway is and indoor gateway based on Semtech SX1301/1257 LoRaWAN technology, equipped with 2.0 dBi gain RP-SMA antenna vertically polarized, omnidirectional antenna placed near Axioma Qalcosonic watermeter devices.

B. Software to use Data

Once the message from watermeter device is received by the gateway it is forwarded to the TTN cloud infrastructure that is equipped with Network and Application servers. TTN cloud infrastructure is equipped with numerous integrations such as MQTT, webhooks that allow message forwarding to our dedicated IoT wallet server equipped with database and visualization platform. Figure 3 shows a snapshot of the overall water volume as well as the hourly delta volume using one watermeter device, visualized by IoT wallet application. Such information can be interesting to give insight into possible slow water leakage of even send alarms if pipe rupture occurs.

III. Water consumption analysis

The analysis of water consumption was performed based on the collected data at the hourly level at the main valve and B and C building blocks. The values of the average hourly water consumption for the complete building and blocks A, B, and C were determined by averaging the available measurement data. The average consumption in block A is equal to the difference between the total consumption and the consumption in blocks B and C.

A graphical representation of the movement of average hourly water consumption for the entire building as well as for a single block shows the uneven water consumption over the course of the day (Fig. 4). The peak of consumption is therefore between 9 a.m. and 12 p.m., or more precisely between 9 a.m. and 11 a.m. in the whole building, at 9 a.m. in block A, at 11 a.m. in block B, and between 11 a.m. and 12 p.m. in block C. Considering that each block has a different purpose, block A has classrooms and a restaurant, block B has offices and a laboratory, and block C has classrooms, a different distribution of consumption during the day was to be expected. The variability of water consumption is expressed by the coefficient of non-uniformity, which indicates a deviation from the mean. The largest deviation from the mean was observed in block B at 11 a.m. (Fig. 5)

In addition to uneven consumption, the finding of water consumption at times when no consumption is expected indicates the presence of losses in the system. If we consider the consumption at the main valve, we see a relatively constant value of losses of about 0.3 m^3/h, while in block A they are 0.2 m^3/h, and blocks B and C have much lower losses in the range of 0.05 to 0.06 m^3/h. The lower value of losses in blocks B and C is due to the fact that they are newer buildings with recently installed pipes and valves with better quality, unlike block A.

The histogram shows the frequency of occurrence of the consumption of a particular value (Fig. 6). For example, the main valve records the highest consumption in the range of 0.27 to 0.37 m^3/h, block A in the range of 0.16 to 0.25 m^3/h, block B to 0.1 m^3/h, and block C in the range of

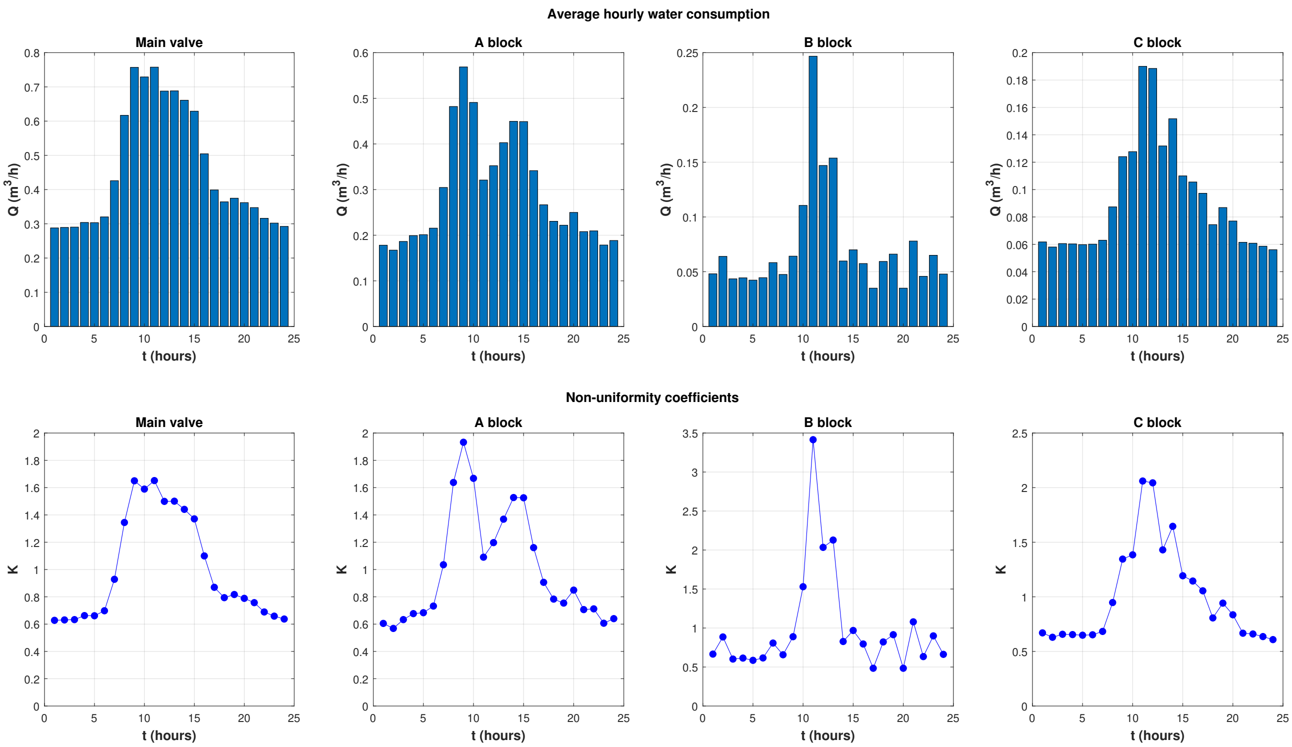

Fig. 5: Overview of the average hourly water consumption and non-uniformity coefficients in the entire building and for blocks A, B and C individually.

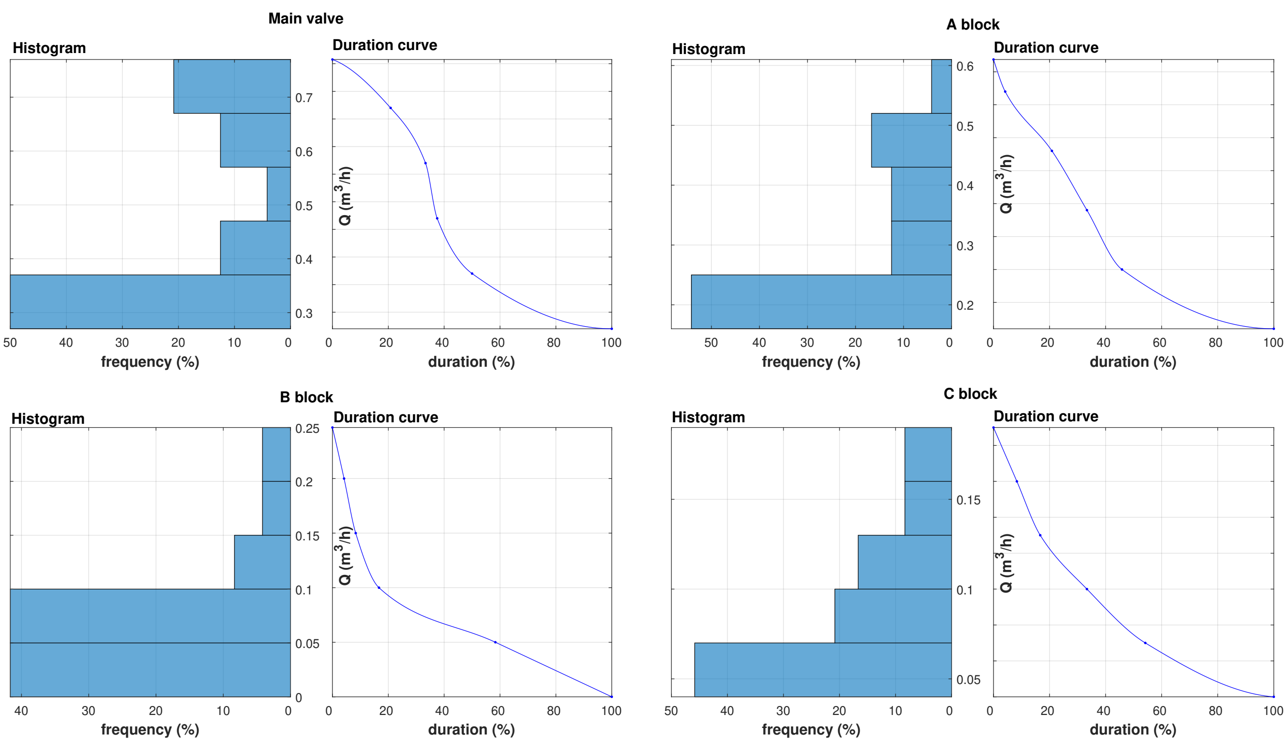

Fig. 6: Histograms and duration curves of average hourly water consumption at the main valve and individually in blocks A, B, and C.

0.04 to 0.07 m^3/h. The duration curves capture the highest duration, i.e., the cumulative frequency of consumption of the highest occurrences. Both views confirm the presence of losses in the system, whose values contribute to a higher occurrence of consumption equal to the value of losses. Leak detection is one of the main benefits of smart water monitoring, which allows timely detection of leaks due to a sudden change in the amount of water detected by a smart water meter. Rapid leak detection contributes to faster troubleshooting by saving time and money and avoiding excessive water consumption. The application of smart metering in water distribution systems can be used for better management using the collected data in analysis and prediction by implementing different modelling techniques.

IV. Conclusion

This paper describes steps needed for successful implementation of the smart water meter IoT architecture while providing use cases on smart water meters implementation and given data analysis. The motivation for implementing such a system is linked with reducing costs while enabling at the same time more efficient spending by providing users with transparent and real-time data.

As a use case scenario three LoRaWAN-based smart water meters were deployed at the University building aimed at tracking the water consumption of three building blocks. Preliminary analysis gave indications on peak hours of water consumption, as well as leakings in every building block. It was shown that building blocks B and C have smaller losses due to newer installed pipes with better quality.

For future work, insights into consumption trends could be extended to forecast future consumption and planned maintenance by applying machine learning techniques to avoid costly repairs or downtime in the system later. Using the available data, it is possible to develop savings concepts and implement sustainability measures.

Acknowledgment

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https://www.interreg-central.eu/Content.Node/CWC.html

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