

# A Conceptual Proposal for an Intelligent Water Management System for Household Use

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**Abstract:** Water scarcity is becoming an issue of more significant concern with a major impact on global sustainability. For it, new measures and approaches are urgently needed. Digital technologies and tools can play an important role in improving the effectiveness and efficiency of current water management approaches. Therefore, a solution is proposed and validated, given the limited presence of models or technological architectures in the literature to support intelligent water management systems for domestic use. It is based on a layered architecture, fully designed to meet the needs of households and to do so through the adoption of technologies such as Internet-of-Things and cloud computing. By developing a prototype and using it as a use case for testing purposes, we have concluded the positive impact of using such a solution. Being a first approach to the problem, some issues will be addressed in future work, namely, data and device security and energy and traffic optimization issues, among several others.

**Keywords:** Intelligent water management system; Internet-of-Things; household water management; leak detection; water metering.

## 1. Introduction

Domestic water waste is a significant issue that affects not only households but also the environment. Much water is wasted due to consumer behaviour and pipeline infrastructure issues. The issue of water wastage in domestic use is a reality, motivated either by unconscious actions on the part of consumers or due to ruptures and problems in the pipeline infrastructure. Furthermore, there is a consensus that there is still a need to create awareness of the issue that can lead to a more rational use of this resource, which is critical in reducing water waste [1].

Water consumption is likely to become more sustainable in the future as consumers become more aware of the problem of domestic water waste. Households will likely adopt more conscious, and responsible water usage habits as water conservation education and campaigns become widespread. As a result, water waste caused by consumers' unconscious actions will be reduced. Overall, the future of water consumption will see a shift toward more responsible water resource management and increased efforts to reduce water waste through individual behaviour changes and systemic infrastructure improvements [1]. Furthermore, more significant efforts will be made to improve pipeline infrastructure to prevent water leaks and reduce water loss. Those efforts will necessitate investments in cutting-edge technology and materials that are more durable and resistant

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to wear and tear. While it is possible to make some progress toward more sustainable water consumption without technology, significant reductions in domestic water waste are only possible with technological advancements [2].

While education and awareness campaigns can help reduce water waste caused by consumers' unconscious actions, they must address pipeline infrastructure issues or detect and prevent leaks with technology. Smart water meters and sensors, leak detection systems and automated shutoff valves are examples of advanced technologies that can significantly reduce the amount of water lost due to pipeline issues. As a result, while education and awareness campaigns are critical, technological advances will be vital in significantly reducing domestic water waste. Information Technologies (IT) like the Internet-of-Things (IoT) can help achieve sustainable water consumption. The IoT can monitor and manage water usage in real time, providing valuable data and insights that can help identify patterns of water waste and optimize water usage [3].

Taking this issue as a basis to state the problem under investigation, we can write the same as the need to respond simultaneously to intelligent water management in the domestic environment and the awareness of its use. Based on the Design Science Research methodology, we addressed the problem by conceptualizing one architecture in an initial phase and then conceiving, a cyber-physical artefact based on Internet-of-Things technologies, interconnecting several layers, physical and logical, from the hardware, communications and software platform, in the cloud and in a mobile environment, for each consumer. The software layer runs in cloud infrastructure, with Microsoft Azure being chosen because of its IoT framework. The layer is divided into three application groups: solution management, mobile user applications, and Azure IoT Hub. The management application controls overall device control and can detect water usage patterns for each user using machine learning. Users can interact with the control application via a web browser or mobile app, which includes a small local database for basic offline functionality. The solution employs the MQTT protocol, but other devices that support other protocols can be easily connected without requiring the solution to be recoded. Additionally, several other topics are intrinsically linked to the solution, specifically those related to data and device security, traffic and communication optimisation between the devices and the cloud application, the issue of the power required and the mechanisms that allow uninterrupted supply and the possibility of applying patches without the need to physically access the devices.

In this article, the entire process leading to the final solution is described, as well as proceed to carry out a validation of the same and its applicability.

The paper is organized as follows. In addition to this general outline section, section 2 presents the relevance and work highlighting the need to find effective and efficient solutions to the global water consumption crisis, exposing the benefits of using IoT technology. Section 3 characterizes the proposed architecture. In the 4th section, the system developed to support and validate the proposed artefact is detailed. Finally, section 5 presents research implications, the detected limitations, future work, and future considerations.

## 2. Water Management – Background Analysis

### 2.1. Water Security

From a conceptual perspective, water scarcity refers to a tri-partied view of water composed of water scarcity, pollution, and water-related hazards and vulnerability issues [4].

While planet Earth is easily distinguished from the remainder planets since approximately 71% of its surface is water-covered, water scarcity is indeed a real problem and, according to both the United Nations' Food and Agriculture Organization and the World Economy Forum, one of the main challenges of the 21<sup>st</sup> century [5,6]. Considering the

increase in water consumption registered in the last decade – whether from population growth or the ever-growing industrial and agrifood sectors – and the dynamics associated with the water (as a natural resource) itself, it is indeed critical to ensure that effective management of this natural resource is implemented [7].

Even though the current social uproar on water scarcity, a straightforward analysis of existing literature allows us to easily perceive that this issue has been the focus of many researchers and research projects since the beginning of the 21<sup>st</sup> century [9–11], the majority of which propose innovative approaches to addressing the issue, whether from a consumption optimization or a water management perspective. As a concept, water scarcity has been defined in multiple manners throughout the existing (scientific and grey) literature. Still, it can be consensually established as the condition where the available water fails to satisfy the existing demand [8].

Despite water scarcity being considered the most relevant issue surrounding the Water Management topic, as climate change becomes increasingly present, issues such as extreme flooding, over-exploitation of groundwater, and water pollution have also become one of the focus of scientists and government bodies, mainly due to the social and economic impacts that these catastrophic events tend to enforce and their impact towards local, regional and global sustainability [12].

Hence, the underlying argument is that to ensure long-term sustainability, we, as a community, need to advance our water security-related perspectives and initiatives further, mainly by doing more to address the problems of water shortages, water pollution, and water-related risks and vulnerabilities.

## 2.2. Water Management Digital Transition

As argued by Yu et al. [13] and Sapkota et al. [14], even though the water security issue is a global problem, it tends to pose different challenges for urban and rural areas. If, when focusing on rural territories, there is a tendency towards the deregulated use of water by the agrifood sector and the water scarcity issues, this paradigm tends to shift to the urban context where the topics of efficient and effective water and wastewater management, excessive consumption, water pollution, and over-waste of water are those who claim the podium of the most addressed.

Hence, when addressing current water management and drawing on Hoffmann et al. [15] and Wilderer [16] arguments, there is a clear tendency for the rise of systems and solutions that are typically classified as grid solutions, non-grid solutions or hybrid solutions. Grids are essential components of today's centralised systems, whose capital expenditure on pipes and sewers usually ranges from 70 to 80 per cent, creating effects of technological lock-in. Non-grid systems have plumbing inside individual structures and, on the grounds, no sewers or pipes connecting them. Hybrid systems incorporate both non-grid and (small) grid solutions into grid systems.

As the complexity of water management arises and digital technologies evolve and are adopted throughout societies and economies, one can easily perceive the potential of combining these two (conceptually) distinct contexts. The digital transition of water management and the inherent adoption of digital technologies such as sensors, the Internet of Things (IoT), digital ecosystems, big data, and artificial intelligence have the potential to trigger the development of more efficient water monitoring, control and forecasting solutions, and to foster more sustainable collection, storage and use of freshwater [17–19].

Indeed, as both cities and regions become increasingly digital – as the result of the massive development and application of the smart city and smart region concepts – and individuals and organizations become increasingly connected (to the internet), one can easily acknowledge that digital and smart technologies can not only improve citizens quality of life and the efficiency of local/regional/national government entities but also leverage the abovementioned territories sustainability [20,21].

Based on the active combination of IoT, sensors and artificial intelligence, smart water management solutions are currently understood by existing literature as the future of water management and as a decisive asset towards a continuous assurance of water security [22–25]. Several works can be found in the scientific literature, such as the ones shown in Table 1, but there are no concrete proposals of solutions and tools for the intelligent management of low-pressure water.

**Table 1** – Research on smart water management

Reference	Comments
(Khambati, 2021) (Rojek, 2014) (Xiang et. al., 2021) (Krishnan et. al., 2022)	Do not propose real working systems, but a data-based solution for consumption prediction over a certain number of households and for decision making on water distribution.
(Suciu et. al., 2017) (Savic et. al., 2013)	IoT solution but at distribution level (high pressure), not at consumer level (low pressure).
(Robles et. al., 2014)	Discussion about the lack of industrial standards for water management
(Sammaneh & Al-Jabi, 2019)	Water distribution management on a specific situation where every home possesses a tank.
(Abdeljebbar et. al., 2019)	Smart water management pillars in the context of smart cities.

Many other works can be found, going back in time, but which follow the same line as those summarised in the previous table.

### 3. Intelligent Water Monitoring System Proposal

As the existing literature highlights, the advent of digital water management systems and the majority of the history associated with this type of system has targeted city or industrial-level solutions that should be adopted by local governments or significant water distribution or water consumption companies [26,27]. Nevertheless, considering that the majority of modern households are becoming increasingly digital and "smart", it is highly relevant to understand how one can develop novel, more effective, more economical, more automated and more decision-support-oriented systems that might be easily installed in our typical houses and not only help to monitor (undesired) for water consumption events but also to trigger the arising of knowledge that foster the adoption of more sustainable water consumption patterns within the household [28,29].

#### 3.1. Solution Requirements

By analysing all the above-mentioned arguments, the following initial insights have been established:

- To the best of our knowledge, the existing literature needs to propose a water management solution that can give the consumer instantaneous feedback on water consumption. Some of the existing solutions can collect data concerning water usage but not to provide immediate feedback;
- Within the catalogue of analysed solutions and systems, there was no solution that allowed for the remote control of the water flow, as the majority of the analysed solutions only addressed the collection of data concerning data usage;
- Despite the goodness of the proposal, the majority of the revised models and architectures published in the existing literature were not implemented, so their use in a natural environment has yet to be proven.

Many initiatives have been developed in the last ten years, but none with practical results and a strong focus on water usage in agriculture [30–32]. Several problems have not been adequately addressed, including some problems with technology, due to the

need for multiple layers, as well as with the integration of it. Also, there seems to be some confusion about where to put the control: on high or low pressure. We also found some technology-related problems at this level, but the focus is on high pressure [12,33,34]. Recently, some companies started to apply some level of technology to domestic water consumption metering – mainly to collect consumption information or sensors able to detect a sudden leak at home, providing only an alert (home automation systems), based on LPWAN (Low-Power Wide Area Network) communication protocols like LoRa, or Narrowband-IoT (NB-IoT), and other licensed protocols like SigFox or even supported by PAN/Mesh Network technology like ZigBee.

In conclusion, no architecture and the respective implementation for an intelligent water management system was found, nor a feedback model that could lead to the creation of control and, at the same time, able to provide a more significant consumer awareness. The conclusion supported the writing of the research question about how to let individuals control the water they use while creating awareness of that consumption.

Besides the research question, two objectives have also been defined: 1) How to reduce house water waste? 2) How to create a more rational use of the resource?

Focusing on the answer to the research question while looking to reach the stated objectives, we started by defining a certain number of requirements for our proposal, namely:

- Every piece of the solution has to be as standard as possible;
- The solution will use only open and non-proprietary communication protocols;
- The solution must provide the ability to put the data/information in the hand of each user;
- The search for the solution has to take into consideration the transformation of the traditional water meter into an intelligent device;
- We may propose additional devices to complement the meter activity.

In table 2 we emphasize the requirements of the system and their impact on the water management.

**Table 2** – Impact of requirements on water management

Requirement	Impact on water management
Every piece of the solution has to be as standard as possible	Usage of standard elements will have an impact on the time to market of any developed solution, as well in the time to repair when needed. In this way, any problem caused by failure or lack of the device is minimised.
The solution will use only open and non-proprietary communication protocols	The use of non-proprietary protocols will facilitate network coverage and make the communication process cheaper, while minimising the risks of failure of connections and, as a consequence, the exchange of information and commands between devices and the cloud application.
The solution must provide the ability to put the data/information in the hand of each user	If each user, at any given moment, can understand their consumption, as well as having a solution that minimises losses through leakages and other problems of a similar nature, then we will have individual capacity to manage water.
The search for the solution has to take into consideration the transformation of the traditional water meter into an intelligent device	A smart meter will give each user the ability to carry out individual water management, providing them with data for decision-making, as well as the tools capable of independently acting in an emergency situation.
We may propose additional devices to complement the meter activity	Additional devices allow a greater granularity of information to the consumer, a superior protection of the installation and with greater precision.

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### 3.2. Solution Architecture

The Internet of Things aspires to create a pervasive computer environment in which ordinary objects allow interoperability in order to achieve a shared purpose (Gupta & Quamara, 2020). It may be considered as an interconnection between the physical world and the Internet. We can also control our physical environment using these applications.

A general architecture has been long discussed by several authors (Ray, 2018; Gupta & Quamara, 2020; Sethi & Sarangi, 2017; Choudhary & Jain, 2016). Based on the various generic architectures that can be found in the literature, we designed the one that we felt fitted the entirety of our situation. It is illustrated in Figure 1.

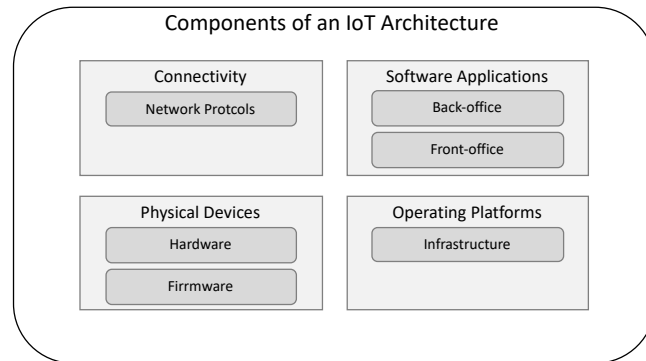


Figure 1. Components on a generic IoT architecture.

Considering the components detailed in the previous figure, we tried to simplify such a general architecture. This effort took us to a layered approach as final architecture, as illustrated in figure 2. From the requirements, we started to divide the possible solution into several different layers, approaching the partial solution on each layer and dealing with the integration later. Internet-of-Things solutions were found as the most suitable due to their characteristics [35,36]. Figure 2 depicts, on the left side, the layers typically found on any cyber-physical solution based on Internet-of-Things technologies.

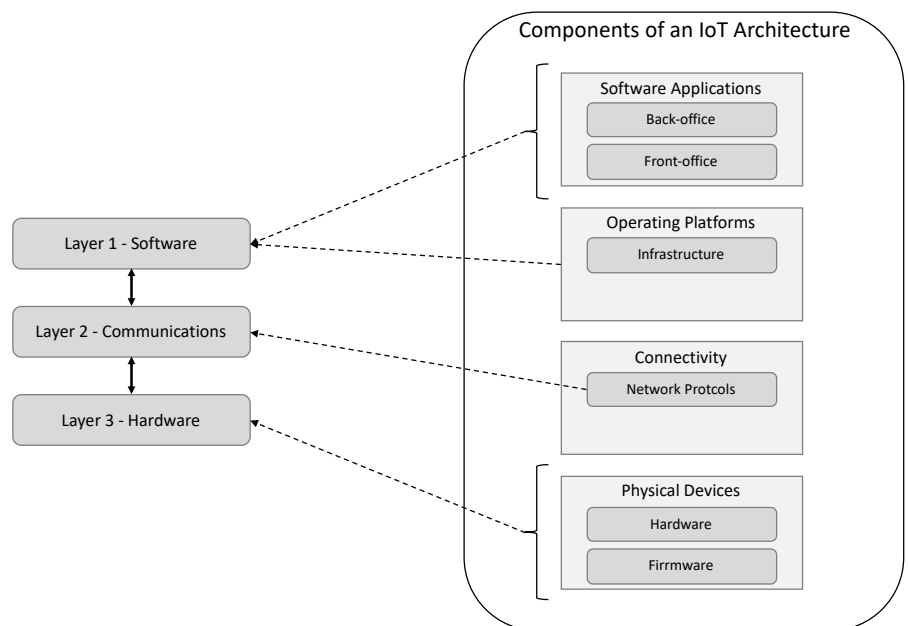


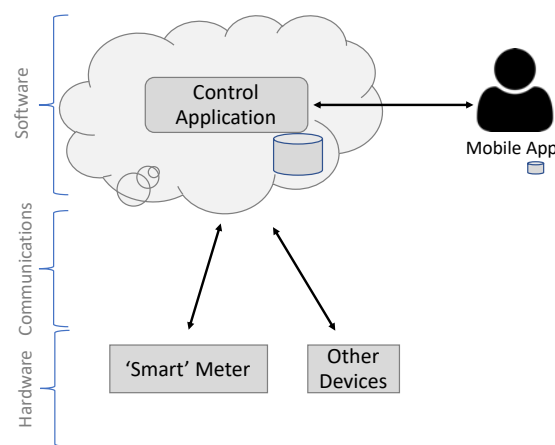
Figure 2. Components on a generic IoT architecture

This layered approach allows for an independent architecture and implementation within each layer, considering the communication processes among them. Also, it brings as an advantage the fact that we can easily change or update the technology in one layer without affecting the others.

We based our work on those three layers:

- Layer 1 – Software, considering the requirements for an end-user solution able to fulfil the objectives and comply with the requirements;
- Layer 2 – Communications, considering the usage of non-proprietary protocols and the need to support different approaches, thinking on a global perspective of later broad implementation;
- Layer 3 – Hardware, defining and engineering the needed hardware to support the solution's requirements.

The final architecture is represented in Figure 3.



**Figure 3.** Layered Solution Architecture.

Based on this layered approach, we will detail every aspect of the architecture.

### 3.1.1. Software Layer

The software layer is executed in cloud infrastructure, and we did choose Microsoft Azure due to a large number of accelerators already available through its IoT framework [37]. So, this layer can be divided into three groups of applications: (i) application developed for the management of the solution, filling the general requirements previously stated; (ii) mobile application for the user; (iii) Azure IoT Hub, supporting the interface through message queue management, supporting MQTT, AMQP, COAP and, even, webhooks, relieving us from the effort of coding and keep updated those protocols implementation [38]. Our solution uses MQTT protocol, but with the environment, we are using, connecting the future new devices supporting other protocols will be very easy and without recoding any part of the developed solution.

The application developed to manage the solution is responsible for the global control of all devices, providing all the functionalities to manage them (intelligent water meter and other devices). It can receive all incoming data from the devices, with information collected by all the sensors, and provide commands to the same devices. It also allows the provision of devices and customer accounts, linking both. As seen in Figure 4, this control application **Figure 4** has a machine learning engine that, acting on collected data, can detect the water usage patterns for each user, classifying it on a specific profile.

The user can interact directly with the control application through a web browser or use a mobile app developed for data consumption and alert management. This mobile app has a small local database to provide fundamental offline analysis and deal with performance when there are already many data collected for a user. From the mobile app, the user can consume its data and interact with devices, sending commands like water shutoff, total or partial, for example.

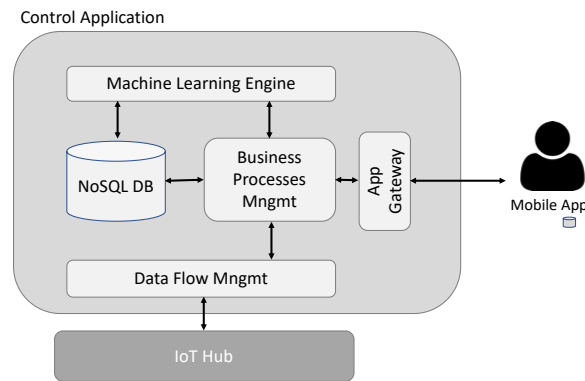


Figure 4. Software Layer components.

From an implementation point of view, this control application uses a specific IoT Hub from Microsoft, provided as an Azure service, that supports all the different communication processes, stripping and isolating the application from implementation details at that level. The IoT Hub delivers data directly into a module that deals with data flow or receives data (commands) to be sent to a specific device.

This option has been taken because it easily supports different data types (e.g., structured and non-structured) and provides low transaction latency. The business processes implemented and supported by a NoSQL Database, also from Azure, deal with the data. The data is also accessed by the machine learning engine, which looks for patterns and specific alerts from sensors and makes decisions about actions, transforms them into commands, and sent to devices.

There is also an application gateway to integrate with the mobile app, which can run either on iOS or Android systems.

This modular structure approach allows us to change or improve some application pieces without impacting others. At the same time, the used Azure services remove the complexity of dealing with some aspects that changes through time, namely communication processes.

### 3.3. Communications Layer

The devices need communication. Otherwise, they would not be able to send the sensor data to the control application, nor the control application would be able to send action commands.

However, we soon understood that we needed to solve problems like frequent loss of connectivity, fast battery drainage when there are no electricity and coverage problems. We started by engineering a solution based only on Wi-Fi standards (IEEE 802.11). From here, we decided to implement also support for GSM and LoRaWAN.

GSM is intended to be used when there is no other communication channel to be used since it imposes a particular cost in the communication process, as well as in battery drainage, but gives us an almost global-wide coverage area.

LoRaWAN is an LPWAN protocol (Low Power Wide Area Network), non-proprietary and working on open frequencies, developed precisely to support Internet-of-Things (IoT) communications [39,40]. Since there is growing coverage of LoRaWAN worldwide, it seemed a good decision [41]. We used a gateway from a vendor, which also provides its own Network Server.

For cost reasons, a device supports only one of those protocols, so there is a decision to be taken by the end user prior to the installation.

### 3.3. Hardware Layer

The hardware devices are not only sensors; we also use actuators. The water meter can efficiently measure the water flow due to high-resolution ultrasound sensors. It can be mounted on any position and measure the water flow in both directions. Water consumption also measures temperature, water pressure, and time.

This device can receive commands from the control application to close the water supply (total or partially). From the end user's point of view, there could be a feeling that the water meter is able to interact with other devices, like our leak detector, but it is done through the control application. In the same way, the water meter generates alerts and information that is sent to the control application. The actual "intelligence" of the device is provided by the control application, previously described, which executes in the cloud. A controller that includes LoRaWAN was chosen. The final schematic for the water meter device is illustrated in Figure 5.

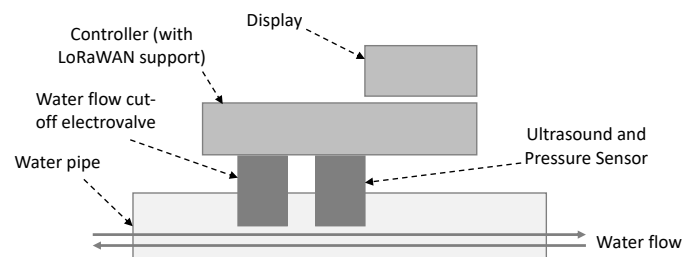


Figure 5. Hardware device schematics.

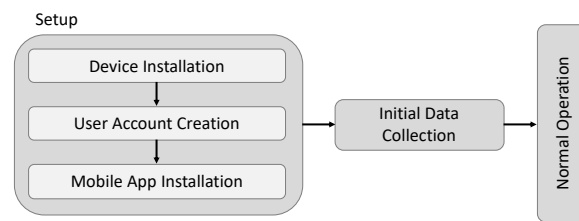
#### 4. Solution at Work

Bringing together the solution architecture with the initial requirements we can check they are all covered. Table 3 shows this verification.

Table 3 – Checking requirements and the solution

Requirement	Addressed by
Every piece of the solution has to be as standard as possible.	Software layer based on Microsoft IoT Framework; communications supported in LoRaWAN; hardware uses standard controller and devices from the market.
The solution will use only open and non-proprietary communication protocols.	Communications supported in LoRaWAN.
The solution must provide the ability to put the data/information in the hand of each user.	Mobile application that connects to Control Application, allowing the user to consume data and interact with devices.
The search for our solution has to take into consideration the transformation of the traditional water meter into an intelligent device	The device can shut down the water by itself; the control application provides data and recommendations for better usage of water.
We may propose additional devices to complement the meter activity.	For local leak detection, a small device has been developed, completing the whole solution.

This solution is different from a 'plug-and-play' solution. It requires specific initial steps to be performed to allow the regular operation, as represented in Figure 6.



**Figure 6.** Solution Setup.

First, there is a need for an initial setup, which is composed of three actions: 1) The intelligent water meter device is properly installed, put in place and working; 2) The customer installs the mobile app on his smartphone; and 3) The customer account has been created in the control application, and the device has been associated with it.

After this setup, the data incoming from the meter starts to be collected for a whole week (7 days) until it starts the regular operation.

The initial data collection is delivered to the Machine Learning engine through the Control Application. The result is profiling this installation so that the software can detect a leak from normal and regular water usage. Ultimately, the system can show the different profiles for all users or by city. Based on this data, the system uses gamification to create virtual rewards for users when their usage profile registers a lower water consumption. The virtual rewards are delivered through the mobile app.

There is also an "away mode", allowing the users to define a period of non-usage of water. This is particularly important during holidays or weekends.

When the meter detects that in a short time (one minute), there is a consumption equal to or bigger than 100 litres, it generates a 'slow leak alert' that is propagated to the user's mobile app; any other detection, if greater, generates a 'leak alert' and the Control Application can be configured to automatically close the water after some time, in case the user does make any action. Of course, we want to note this because the usage is profiled, so the meter can distinguish a leak from a regular use for that particular installation.

When unexpectedly water starts to run for some time (can be seconds), it starts by generating an alert informing that the water is going to be closed unless the user acts in the mobile app; in case there is no action, the meter shuts off the water, alerting the customer through email and SMS.

The water meter communicates every two hours, providing all the collected data, in regular operation. If a leak is detected, the water meter communicates immediately the event.

Note that, complementing the action of the water meter, we developed a small device for leak detection that should be disposed of where there is a more significant probability of a water leak. These devices operate independently, and they have communication capabilities. Placing examples are: below washing machines; in the back of toilets.

If the leak detector device detects the presence of water, it will enquire the meter in that installation, and if there is water passing by, then a leak is detected. The customer is alerted by email and SMS. The water supply is automatically shut off.

Of course, it is not the leak detector that inquires about the meter. The leak detector will send an alert to the control application, which, in turn, will send a command requesting the appropriate information from the meter in that installation.

Acting like this, if someone accidentally spills water in the device, it can differentiate from an actual water leak.

Two prototypes have been built. Those prototypes have been installed on two properties, in different regions, about 100km apart.

The installation went smoothly and as expected. This was despite the fact that the intervention of a plumber was necessary in both situations in order to ensure the most correct installation of the physical device. The installation went smoothly and as expected. A gateway from a vendor in the market was used and with no coverage problems due to

the distance between the physical device and the gateway (15 meters in one case; 25 on the other).

The collection of profiling data went as expected. After the seven days of data collection and the activation of all the solution's functionalities, after 2 months of use, only one false-positive was identified. This was due to the need for an intervention in the garden's irrigation system, whose test led to the closure of the system due to the detection of a large-scale leak and subsequent alert to the user, the property owner.

In figure 7, we illustrate the collected data for the initial 4 months of using the solution. Starting from an average (for the last 12 months) of water consumption, we can easily understand the importance of having the users to know how much water they are spending just a few moments after the event occurred.

	Characteristics	Number of Persons	Water Consumption (in Litres)				
			Last 12 Months (Monthly Average)	Month 1	Month 2	Month 3	Month 4
Property 1	Villa w/ garden	3	17600	15710	14860	14310	13770
Property 2	Villa w/ garden	4	23200	20265	19678	18678	18045

Figure 7. Collected data.

Interestingly, a 17% reduction was observed in the water consumption of the properties with the solution installed. When we went to analyse the reasons for this reduction, we realised that it was caused essentially by giving users the possibility of being able to see the water consumption values in the instant immediately after events such as, for example, a bath or washing the car.

We consider this result as unexpected, insofar as we anticipated that something in this context might happen, but never at such a significant level of consumption reduction.

On the other hand, some issues were identified that need some reflection and further development in order to be solved, such as: (i) when someone opens and then closes a tap, the infrastructure at home causes some water to return to the network, and this amount is incorrectly accounted for; (ii) it is necessary to develop a method to update the firmware of the meters supported in the communications network, so that corrections and updates can be applied without having to dismantle them and send them to the factory.

## 5. Conclusions

### 5.1. Research Implications

The proposed intelligent water management system represents, from our perspective, a valuable novelty as it not only advocates a more agile and efficient water management approach but also comprises a layered architecture composed of three distinct layers, each of them with a very individual and outlined set of functions but all-embracing the necessity of being interoperable with each other.

Hence, from a theoretical perspective, the establishment of novel layered architecture, supported by a very up-to-date literature background, that perceives the relevance of having a software layer aligned with the current software-as-a-service and infrastructure-as-a-service paradigms, combined with a communication layer that represents the necessity for ensuring wireless and low-power communications between the solution remote and central nodes, and a hardware layer that mimics the actual electronic and physical elements of the proposed water management system and their integration abilities, represents a valuable contribution for current and future researchers on the field of intelligent water management.

Concerning the more practical contributions of our research, they are related to the practical implementation of the proposed artefact. This new knowledge that was created during the referred implementation process, alongside the technical and functional details associated with each of the system layers, can be used by existing companies to further

develop their own water management solutions or as the baseline for the development of new commercial-graded solutions, they can market. At the same time, a contribution was made to the development of solutions capable of managing and minimising water consumption, an increasingly scarce resource, through individual awareness.

### 5.2. Limitations and Future Research

The main limitation is that we are still running a small number of installations (i.e., 15). Despite this, they are pretty spread, with some more than 200 km from the others, so they are settled in regions with very different characteristics concerning water availability. We need to understand if there is any correlation between those characteristics and the usage of our system.

In future work, we want to enhance the functionalities of this intelligent water management system while trying to adapt the solution to work with old and conventional water meters. Future work will be focused on data and device security, traffic and communication optimisation between the devices and the cloud application, the issue of the power required and the mechanisms that allow uninterrupted supply and the possibility of applying patches without the need to physically access the devices.

With the increase in the number of devices, we will face an increase in the amount of data collected by all sensors. We also look to edge computing models to keep the central solution manageable.

### 5.3. Final Considerations

We started with the question about letting individuals control their water while creating awareness of that consumption.

After researching the state-of-the-art, we found no solution to help provide a proper answer to that question.

From here, we engineered a solution based on Internet-of-Things technologies and, with a multi-level architecture, able to support us in the search for a proper answer. With the solution we developed, now every user can avoid water wastage, giving control to each individual (sometimes, taking control of the situation in case of an emergency). Also, we collect, process and deliver all the data related to that particular process. At the same time, we delivered an architecture able to support any IoT device independently of the message system it uses.

That means users can now create awareness about their water consumption – the data we have collected shows that everyone tends to reduce the amount of water consumed! And as soon as the first month after having the system.

As the main benefits of using this solution, we find remote access to each water installation; comparisons and insights; gamification; real water saving (17%); conservation of pipes infrastructure on each home; leak detection; alerts; real-time measurement; wireless communication; reports (real-time and analytics); dashboard for remote access; forecast/insight.

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