



# Internet of Things for Smart Management of Water Networks †

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**Abstract:** According to the Sustainable Development Goals included in the 2030 Agenda signed by 193 UN member countries, one of the expected targets is the improvement of Water Management through sustainable and efficient practices. Italy holds the record among the European Union countries for the highest withdrawal of water for drinking use per capita: in 2020, 9 billion cubic meters of water were supplied to users, corresponding to 152.4 m<sup>3</sup> per inhabitant per year, with a progressive worsening in the efficiency of the distribution systems. The modernization of poor infrastructure is, therefore, the main driver for reversing this negative trend in the Integrated Water Service. In the case of water, “Smart” consists of making water supply and distribution intelligent with Internet of Things (IoT) technologies so as to allow reciprocal connection and communication with other parts of the plant and city. Smart water systems use sensors activated by the IoT to collect data in real time and generate the so-called “Digital twin”, which is the digital twin of the physical infrastructures present in the area and allows a modern and optimized management. This allows optimization of water structures by detecting leaks in the network and by the users, flow rates, pressures or control of the distribution of water on the network and allows operators to make more informed decisions regarding the management of water resources, also with regard to qualitative parameters. The processes currently underway at many water managers of districting and modeling of water networks cannot ignore ever greater sensorization of the assets and ever more refined processing of the data generated by them. These structures, connected and integrated by means of native IoT communication networks, public and standard, will allow significant water savings, reducing losses due to malfunctions and breakdowns. Furthermore, they will allow savings on the bill for the private citizen and a reduction in waste, an absolutely fundamental issue in a world that is becoming more and more populated and which, up to now, has treated natural resources as if they were infinite and guaranteed.

**Keywords:** urban environment; water distribution networks; resources saving; adaptation measures



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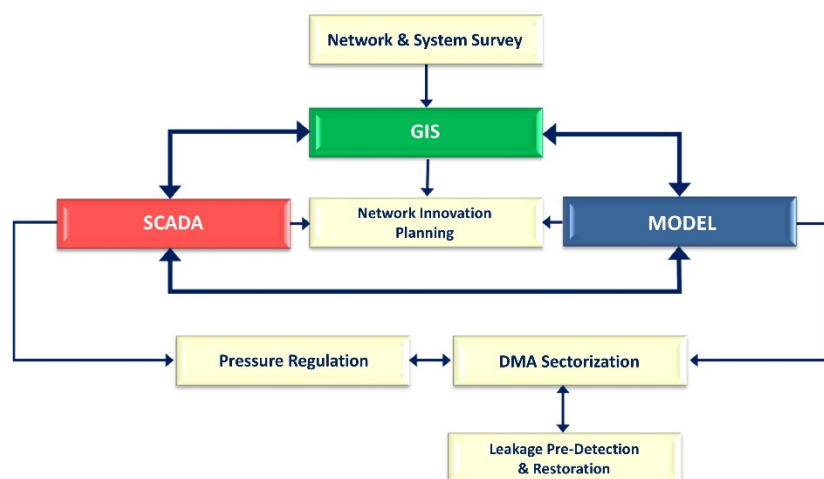


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## 1. Introduction

An articulated and organic methodology of a digital implementation process is proposed, as part of the process of digitization and development of monitoring, control and reduction systems for water losses in hydraulic infrastructures, in order to obtain an updated cartographic database integrated with a system of measures for the permanent monitoring of the fundamental hydraulic parameters [1]. This is to ensure the efficiency of the infrastructure managed over time after hydraulic validation and analysis of the system performance by means of numerical models and to allow a set of actions for the efficiency of the system by evaluating the costs and benefits of the proposed interventions.

The main macro activities and their interactions are schematically represented in the following layout (Figure 1):



**Figure 1.** Interactions between the Macro Activities of digitization and optimization of managed water systems.

## 2. Cartographic Database

### 2.1. Plants and Artifacts Relief

The works and artifacts that are important for the complete reproduction of the functioning of the system and the management are necessary to identify. The survey is also focused on elements whose complete functional definition may be necessary for design purposes in order to improve and optimize the system. For example, it will be defined whether to detect and represent only the pertinent area or an additional one if this is of interest for the design of future interventions for artifacts, that is, if expansion or enhancement works are planned.

### 2.2. Networks Relief

The purpose of the survey activity is to define all characteristic elements of the pipelines. The knowledge base obtained with the field survey will be placed in a cartographic system. So, it will be possible to get a general set of plants subjected to the survey, such as pipes (with material, nominal diameter and direction of flow), gauges (pressure, flow rate, chlorine, etc.), gate valves (type and status—open or closed), pumps, hydro valves, (with indication of the different types of regulation—pressure support, flow rate, level etc.), expansion vessels, anti-water hammer devices, etc. The symbology to be used is in line with that defined by the UNI 9511 standard.

## 3. GIS

Once the GIS (Geographic Information System) has been defined, the methods for publishing must be established, as well as relevant elements of the system: power plants, tanks, pipes, hydro valves, dividers, pumping systems, etc., with linear, punctual or polygonal layers.

Subsequently, it is necessary to define the reference system to be adopted, typically Gauss Boaga or WGS (World Geodetic System) on geographical coordinates or on a flat projection and the basic cartography, vectorial and Raster or WMS (Web Map Service, like Open Street Map, Google Maps Hybrid, etc.). The architecture of the cartographic database is then designed by defining formats, units of measurement and relational tables between the different elements.

## 4. Numerical Modeling

The calculation environment for numerical modeling to be used for network analysis and hydraulic checks is also defined. The calculation code to be used, among the most popular commercial software (Epanet, InfoWorks WS Mike + DHI etc.), is chosen, and,

consequently, the type of model is defined, preferably integrated with a modeling analysis of the quality parameters [2].

Furthermore, the functional hydraulic checks to be carried out as a model are defined, such as that of the hydraulic falls, showing the main hydraulic calculation parameters with a comparison with the field measurements and pumping operation (Figure 2).

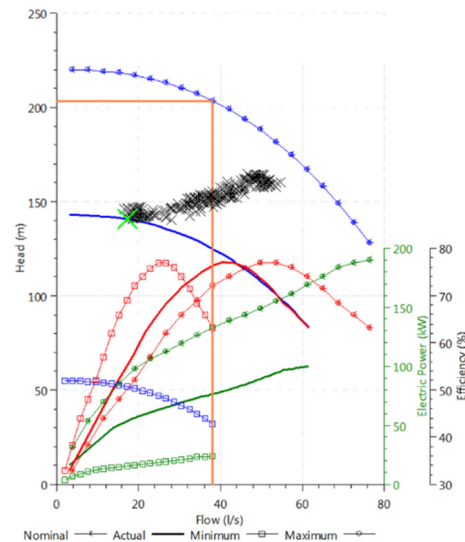


Figure 2. Pump check with inverter.

### 5. District Metering Sectorization

Since the research and localization of leaks alone do not allow the control of the leak phenomenon, it is possible to resort to Pressure Management techniques based on the active control of the pressure in the water system through the use of valves, regulation or district technique [3].

The district requires the installation of flow meters in strategic positions of the distribution system. They permanently record the flow rate connected with a mathematical model following a series of guiding criteria and seeking the solution that minimizes installation, operation and maintenance costs (Figure 3).

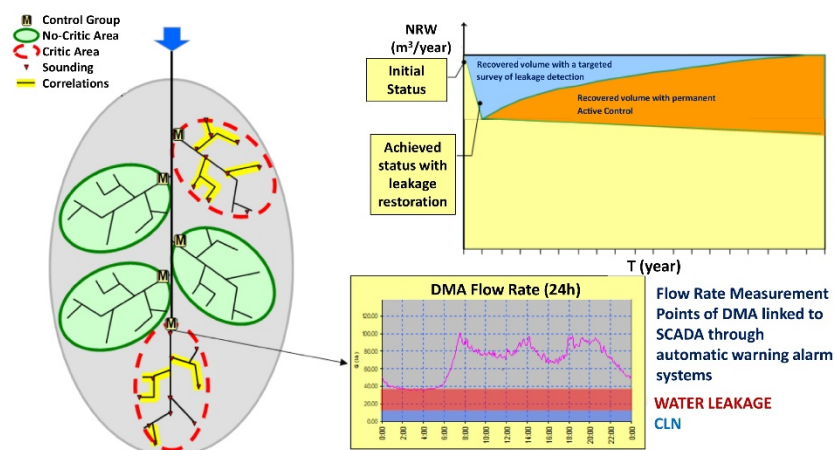
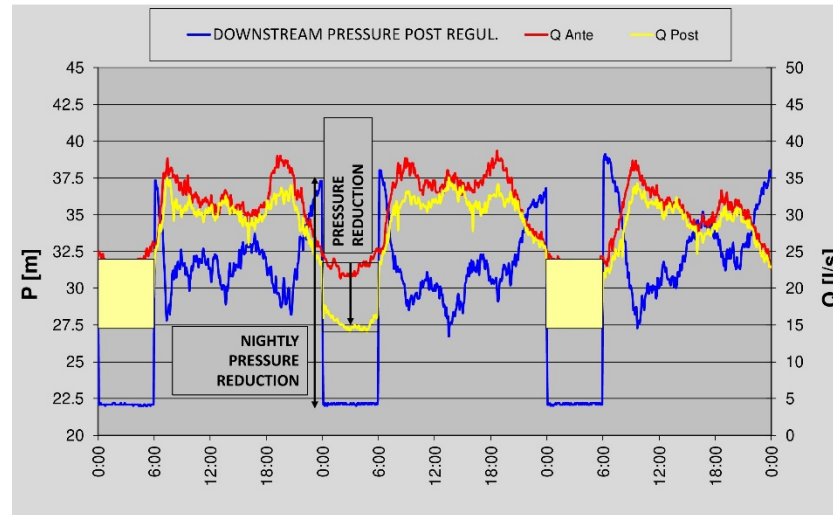


Figure 3. Conceptual scheme of controlling the level of loss by districting.

The interventions defined, with the aid of the aforementioned mathematical model, aim to obtain optimal pressure regulation. In this sense, it is well known the importance of correctly managing the pressure of a distribution network by means of hydro valves with different degrees of complexity, for example, single pilot, double pilot with timed

regulation day and night, remote control with communication and regulation pressure on the most critical point of the network. An example of regulation, in this case only at night, is shown in Figure 4.



**Figure 4.** Local point adjustment and night time delay.

Pump speed controllers (inverters) are installed (they normally have local automation based on maintaining the pressure on the delivery pipe) to increase the energy efficiency of distribution in water networks; this means that when the water demand decreases (for example, during the night), it is possible to keep the outgoing pressures constant, preserving the network from excessive pressures and at the same time reducing electricity consumption [4].

Technological evolution has also introduced more sophisticated controls based on the pressures recorded directly on remote points in the network (Figure 5). The advantage of these technologies is given by the fact that the regulation of the pump on a remote point takes into account the pressure drops in the network, which, as known, are very variable throughout the day; this allows to obtain the maximum efficiency in the regulation of the pump revolutions because it involves a reduction of the revolutions in the periods in which there are lower pressure drops.

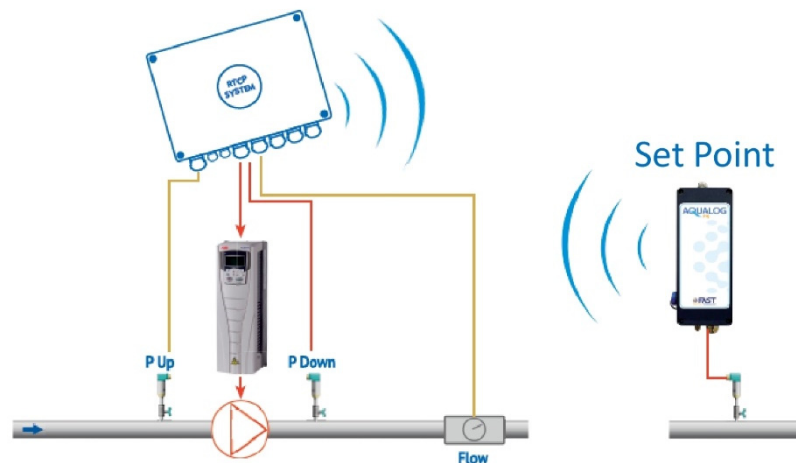
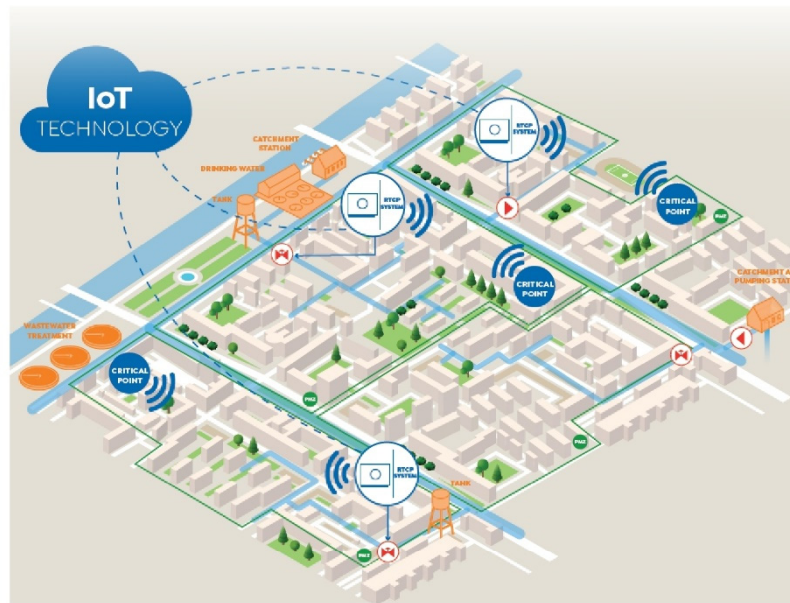


Figure 5. Remote point regulation systems.

### 6. Telemetry System for Measurement Processing

The type of pressure measurement in the network is also defined; it normally occurs with the installation of external pressure transducers in order to allow easy maintenance of the probe in case of malfunction without having to remove the data logger.

The instrumentation for measuring the flow rate may be of different types in relation to the location, the availability of sufficiently long straight sections, the need to operate in load without interrupting the flow, and the need to create temporary districts. In particular, insertion or ultrasonic flow meters can be used, depending on the type of pipe, dimensions, measurement accuracy, etc. All the instrumentation must be connected to the data logger for data logging, processing and sending them to the TLC/supervisor [5].

The flow transmitter must have two transducers that work both as generators and as receivers of ultrasound signals in acoustic communication between them: the second transducer is able to receive the ultrasound signals transmitted by the first, and vice versa. The clamp-on transducers offer maximum installation flexibility compared to traditional technologies for flow measurement and offer an accuracy better than 1% of the read value.

The new generation peripherals provide up to 3 levels of data management and analysis:

- Level 1: configuration of peripherals and connection with the server with data analysis and management interface capable of allowing the user to make assessments on the validity of the measures, consistency with the process, and transients.
- Level 2: management of systems distributed over large areas, ensuring real-time communications via data streams, with visualization of the network architecture and the location of the remotely managed systems throughout the territory. In particular, the system displays the process data by analyzing its progress and thus allowing assessments of the efficiency of the network. Different types of graphs represent the data in different contexts (area, plant, Remote Terminal Unit), and virtual instruments and process synoptics allow you to interact with the instrumentation.
- Level 3: assistance to the manager in immediately grasping the salient elements of the functioning of the network, from the creation of the districts to the in-depth investigation of losses. As the data is collected, they populate a database, which provides an authentic and timely scenario of the district's situation while at the same time making the modeling work more precise. In the areas served by the signal, it will be possible to download in real time the number and type of data required, such as the operating pressure, the night minimum, and the total flow rate introduced into a district or network.

### 7. Losses Search

The techniques usually applied are based on day or night hydraulic measurements and acoustic measurements. The latter makes use of electroacoustic technologies (stethoscope or listening rod, geophone, noise recorders) and correlative technologies (in-line or post-process correlators) [6].

Acoustic searches are the most commonly used in distribution networks (Figure 6). A leak that comes out of a pipe produces a noise that propagates along the walls and through the water carried by the pipeline but also through the ground. By exploiting the propagation of noise, it is possible to recognize the presence of a leak.

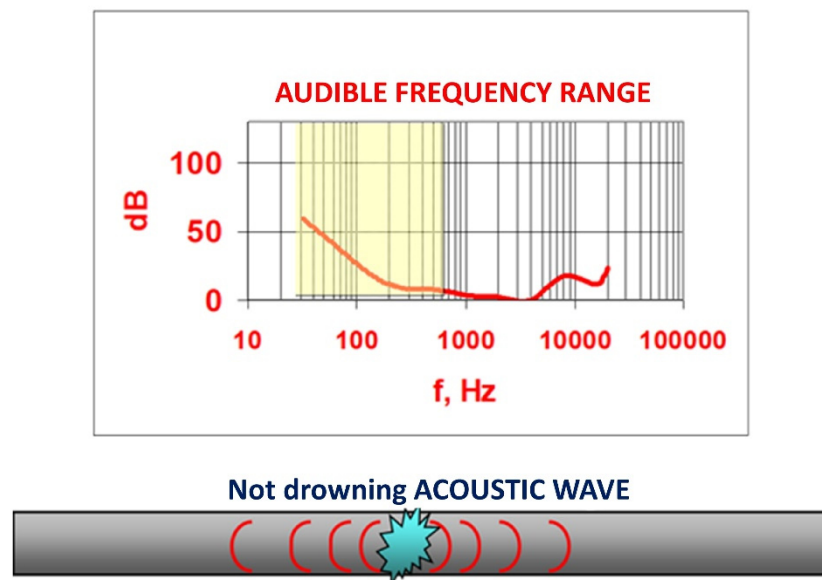


Figure 6. Frequency range produced by a non-drowned leak.

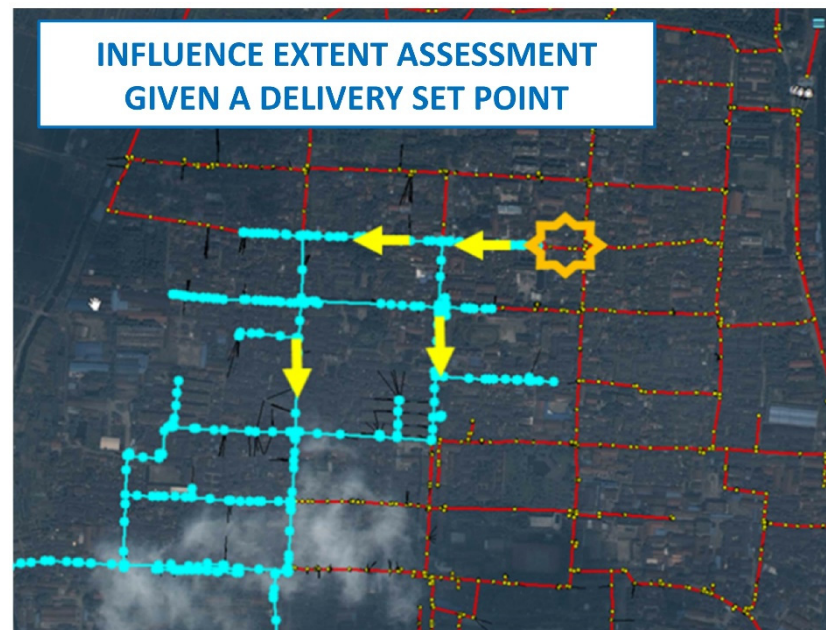
To achieve this, four methods are normally adopted:

- external electro-acoustic technique: direct listening to the tube;
- external electro-acoustic technique: indirect listening from the surface;
- correlative technique;
- internal electro-acoustic technique: listening in the flow.

The noise must be picked up either directly by contact with the accessible points of the network, which are the gate valves, hydrants, meters or directly on the surface.

## 8. Network Renewal

In order to get the maximum effectiveness in planning the renewal of the pipeline fleet, the digital technological system developed in the previous phases provides a tool capable of determining the criticality of specific objective parameters, which can be used to define a priority ranking for the renewal of the water network [7]. The system, therefore, provides useful data for the classification of intervention priorities directly inferable from the GIS, such as material, year of installation, degree of interference with traffic or number of failure events or obtained from specific model simulations (Figure 7).



**Figure 7.** Identification by model of the effects of the rupture of a pipeline.

The simulations can, for example, provide data on the number of users involved in the rupture of each pipeline and on the expected service interruptions or define the importance of the section in terms of flow rate with the calculation of the unit head loss for the identification of “packages of bottle” and under-sized pipes and therefore to be replaced in order to maximize energy efficiency [8].

## 9. Conclusions

The theme of the Smart City is now widespread, and, in the case of water, “Smart” consists in making the supply and distribution of water intelligent with the technologies of the Internet of Things (IoT) in order to allow mutual connection and communication with other parts of the plant and the city.

Smart water systems use sensors activated by the IoT to collect data in real time and generate the so-called “Digital twin”, which is the digital twin of the physical infrastructures present in the area and allows a modern and optimized management. This allows for the optimization of water structures by detecting network leaks, losses at utilities, flow rates, pressures or controlling the distribution of water on the network and allows operators to make more informed decisions regarding resource management water. The processes currently underway at many water managers of districting and modeling of water networks cannot ignore ever greater sensorization of the assets and ever more refined processing of the data generated by them.

These structures, connected and integrated by means of native IoT communication networks, public and standard, will allow significant water savings, reducing losses due to malfunctions and breakdowns. Furthermore, they will allow savings on the bill for the private citizen and a reduction in waste, an absolutely fundamental issue in a world that is becoming more and more populated and which, up to now, has treated natural resources as if they were infinite and guaranteed.

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