Wireless Sensor Network to Create a Water Quality Observatory in Coastal Areas

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Abstract. Water is a natural resource necessary for life that must be taken care of. In coastal areas with near agricultural activity, it is very common to detect spills of chemical products that affect water quality of rivers and beaches. This water usually reaches the sea with bad consequences for nature and, therefore, it is important to detect where possible spills are taking place and water does not have enough quality to be used. This paper presents the development of a LoRa (Long Range) based wireless sensor network to create an observatory of water quality in coastal areas. This network consists of wireless nodes endowed with several sensors that allow measuring physical parameters of water quality, such as turbidity, temperature, etc. The data collected by the sensors will be sent to a gateway that will redirect them to a database. The database creates an observatory that will allow monitoring the environment where the network is deployed in real time. Finally, the developed system will be tested in a real environment for its correct start-up. Two different tests will be performed. The first one will check the correct operation of sensors and network architecture; the second test will check the network coverage of the commercial devices.

Keywords: Wireless sensor network · The Things Network (TTN) · Long Range (LoRa) · LoRaWAN · Water quality · Monitoring · Observatory

1 Introduction

Spain has approximately 8,000 kms of coastline. Along its entire coast, multiple areas classified as protected natural spaces can be found, as well as other areas which, despite not being classified as such, have a high ecological value due to their biodiversity; giving rise to one of the greater riches in landscape and coastal features of Europe. A large part of the Spanish population depends economically on coastal areas due to the presence of tourism and the productive activities carried out there, with more than 600 facilities,

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which include marinas, yacht clubs, and nautical and sport stations. Moreover, activities such as aquaculture and fishing, have also been an important source of income for the Spanish population [1].

Recently, different press publications highlighted problems in the quality of bathing water in coastal areas. In Oliva (Valencia-Spain) [2], for example, some bathing areas had to close because the water did not reach the required quality levels. Likewise, in Murcia (Spain) [3], the critical state of the Mar Menor where, in addition to chemical products such as zinc, a cloudy and greenish appearance of the waters can be found, as well as the increase in temperature of its waters. Another worrying case worth mentioning is the port activity, which can generate both atmospheric pollution (due to gas and CO_2 emissions, etc.) and water pollution (presence of hydrocarbons, suspended elements, etc.) [4]. Given the current situation and the constant publications of news regarding the poor quality of certain waters, we can deduce that it is necessary to apply corrective measures to try to solve and minimize the environmental impact that we are observing.

In order to apply corrective measures, the first essential point is to be able to detect, quantify and qualify any type of anomalies in our waters and environments that worsen their quality. This can be solved by using strategically located wireless sensor networks (WSNs) that continuously monitor water and atmospheric quality [5, 6]. WSNs are composed by a group of electronic devices with sensors and wireless communication capabilities that collaborate in a common task to detect a series of events or situations [7]. Their field of application is extremely wide, and it can be used in industrial environments, home automation, military environments, environmental detection, etc.

Nowadays, WSNs for marine monitoring systems [8] that store the collected information in a database and generate alarms are easily found. In this paper, we aim to go a step further from the simple generation of alarms. As summarized by G. Xu et al. in their review on the use of the Internet of Things (IoT) for environmental monitoring [9], the evolution of these networks must necessarily go through the application of novel data processing techniques and decision-making algorithms that allow the generation of intelligent actions to not only detect, but also solve unwanted situations.

For this reason, this paper presents the design, development, and start-up of a WSN based on LoRa (Long Range) technology for the creation of a water quality observatory in coastal areas. LoRa/LoRaWAN is a relatively new wireless technology that offers several important improvements over classic WiFi-based networks. LoRa/LoRaWAN is an LPWAN (Low Power Wide Area Network) technology that meets all the requirements of any IoT project. On the one hand, it offers us long-distance connectivity that ensures connections through triple encryption. It also allows the bidirectional sending of small data packets, which is more than enough for the purpose of this project. In addition, it has very low energy consumption, making it very suitable for the deployment of monitoring networks. Finally, it should be noted that LoRa is currently the only low-power technology capable of accurately geolocating outdoor and indoor locations and works on a free frequency band (making connectivity costs considerably lower than with any other methods). Our LoRa network will consist of a set of wireless nodes that will incorporate low-cost sensors to measure environmental parameters. The nodes will be in charge of monitoring water quality levels in terms of turbidity, temperature, salinity levels [10], and the presence of fuels and oils on the water [6]. The nodes will also be in charge of measuring meteorological parameters such as temperature, humidity, etc. [5]. These nodes will be located in the final sections of ditches/streams that flow into our beaches, ports and bathing areas, to collect environmental information. The collected data will be sent through a gateway to a database from which an Observatory will be created to enable real-time monitoring of data and allow the analysis of the evolution of the environment over time.

The creation of these observatories is extremely useful for the application of Big Data techniques and artificial intelligence algorithms to improve the sustainability of a productive area or sector. These decisions will be directly related to the adequacy of the recommendations for the quality of coastal waters in port areas [11]. The developed system will be deployed in a controlled environment for its testing and proper commissioning. The infrastructure proposed in this paper has many extensions and applications such as aquaculture [12], agriculture, and port activities management, among others. In addition, it can help promote the tourist activity in an area, bringing what is known as "blue tourism" and ensuring that aquatic activities are carried out in excellent quality waters. Finally, it should be noted that all the collected data can be displayed through a web portal, so that citizens have real-time access to the state of the waters and feel part of this project, to help preventing the pollution of our natural spaces.

The rest of the paper is organized as follows. Section 2 presents the related work on other existing water quality monitoring systems. Section 3 describes the developed system as well as the hardware and software resources used to implement the nodes. Tests and results are explained in Sect. 4. Finally, the conclusion and future work are presented in Sect. 5.

2 Related Work

In this section, some related works associated to our proposal are presented and analysed.

In 2017, Pule et al. performed a survey on the application of WSN to monitor water quality comparing and evaluating sensor node architectures in terms of monitored parameters, wireless communication standards, power supply architectures, and autonomy, among others [13]. Given the high rate of worldwide deaths caused by water borne diseases, ensuring water quality has become a major challenge. Depending on its application, the suitability of water relies upon its physical, chemical, and biological characteristics. Therefore, the acceptability of water requires collecting a large number of samples to compare its characteristic parameters with standards and guidelines and ensure a correct analysis. The use of WSNs allows real-time monitoring with relatively low maintenance costs, though this type of networks often lack processing power, energy, memory, and communication bandwidth if not addressed properly. Moreover, the use of repeaters might be necessary in order to improve their range capabilities.

Geetha et al. designed a power-efficient solution for in-pipe water quality monitoring based on IoT that analyses water samples and alerts remote users if water quality parameters suffer any deviations from standard values [14]. The proposed system monitors parameters such as turbidity, conductivity, pH, and water levels at a domestic level with sensors being directly interfaced to the controller unit. In this case, the collected data is displayed on an LCD screen and sent to the cloud through the controller. Moreover, a mobile application was implemented so that users can visualize real-time data and receive messages from the sensing device. Though an extensive research on techniques and tools used on pre-existing systems was performed, the lack of algorithms to detect anomalies in water quality parameters might prevent this approach from being applied on field environments.

In [15], Chen et al. presented a multi-parameter water quality monitoring system to collect real-time high-frequency data of Bristol Floating Harbour and display it online. In this case, researchers used the smart city infrastructure as a plug & play platform for wireless communication, data processing, storage, and redistribution. The designed system comprises several modules for data acquisition, data transmission, data storage and redistribution, as well as a power supply. This water quality monitoring probe is connected to a subnetwork using a serial to Wi-Fi server solution, and a software defined network and cloud computing for a fast and cost-effective deployment of the system. This project demonstrated how IoT can be used in environmental monitoring systems to provide details of water quality variations that can be useful for further evaluating water quality parameters.

Ngom et al. depicted a LoRa-based measurement station to monitor water quality parameters at the Botanical Garden pool of UCAD's Faculty of Science in Canada [16]. This low-cost system is composed of a remote station that uses a LoRa module, powered by a solar power source, and a web-platform for data visualization. The remote measurement station involves an acquisition node with a micro-controller and four sensors to monitor pH, conductivity, water temperature, and oxidation/reduction potential, and transmit the data to a gateway. In this case, it was decided to send structured frames to the gateway through a LoRa network and store them in a database of the local server using the Ethernet interface of the gateway. If the internet connection is available, the collected data will also be stored in a cloud database to enable direct access to the data and have a backup system. Although the designed system allows to effectively monitor some water quality parameters, the lack of physicochemical and bacteriological parameters prevents this system from surveying possible water borne diseases.

In [17], Simitha et al. developed a monitoring system based on IoT and WSN to collect real-time water quality data to better preserve and manage water resources. The proposed approach aims to achieve a low cost and low power consumption system using LoRa modules and LoRaWAN communication protocol to transmit sensor values to the ThinkSpeak platform and perform further analysis. However, this system is divided into two phases: water quality monitoring, and air quality monitoring together with streetlight energy saving. Among the water quality parameters monitored in the first phase of this project, we encountered that only temperature, pH and turbidity are being monitored whereas the dissolved oxygen (DO) is calculated using the temperature-DO dependency equation. As a result, researchers designed a long-range communication system capable of successfully monitor the established water quality parameters.

In 2019, Wu et al. proposed a mobile water quality monitoring system based on LoRa and IoT that uses unmanned surface vehicles (USVs) to monitor several water parameters in Lake Dardanelle, Arkansas [18]. Although this lake is a major destination for tourist activities and game fishing, it also includes areas with intensive crop agriculture, timberlands, and industrial units. However, it lacks monitoring systems to ensure that water quality parameters obey the necessary health standards. By integrating a set of sensors on a mobile platform that will pass the collected data to a LoRa transceiver module, researchers designed a low-cost long-range system that communicates with the LoRa gateway to send data to The Things Network (TTN) cloud.

In [19], Jia introduced a real-time monitoring system based on a multi-sensor combination to monitor water and air quality in wetlands. The water sensor combination uses six types of sensors to monitor temperature, pH, conductivity, turbidity, water levels, and DO. The collected data is sent to the base station using a LoRa module; thus, allowing a high speed and wide coverage system. Although LoRaWAN protocol is used to communicate acquisition nodes and sink, a data fusion algorithm was implemented on the acquisition nodes to reduce the amount of data being sent, improving the network throughput, and reducing power consumption. However, since this system was not tested in site-specific environments, its robustness needs to be verified. Moreover, no solution was provided for data management and analysis.

Unlike existing works, this paper shows the design, development, and implementation of a wireless sensor network in a real environment for water quality monitoring. In addition, a web-based user interface has been developed. This user interface made citizens part of this project to see and know the quality of water in rivers and, thus, make them aware of the importance of keeping rivers clean and avoiding uncontrolled discharges.

3 System Description

This section describes the developed system as well as the hardware and software resources used to implement it.

3.1 System Overview

The developed network is based on LoRa technology, which is a widely used wireless technology for monitoring tasks, and it is included into the category of a low-power wide-area networks (LPWAN) [20]. It is characterized to be a low power technology able to transmit up to hundreds of kilometres with adequate and unobstructed direct vision in the Fresnel area between the devices [21, 22]. The range for rural surroundings is around 20 km. However, in urban surroundings, it is reduced to 5 km due to the high dependence on the environment and the building materials. Additionally, it is possible to send small packets of data between 0.3 kbps and 5.5 kbps.

The network topology used is an infrastructure architecture where a LoRa Gateway will be in charge of collecting data from LoRa nodes and forward it to a server to store and/or process the data from the sensors. The collected data will be stored in a network storage server. In this case, the Data Storage integration service provided by The Things Network (TTN) [23] was used. It offers the necessary tools to collect and store the data in a database (DB) at a minimum cost for a period of 7 days. On the other hand, we can easily visualize the data in real time using Ubidots Platform.

Finally, a dashboard through a web application has been developed to allow users to see the monitored parameters. Figure 1 shows the network architecture of our system.

The dashboard takes the data from the different nodes and sensors and presents it as a graph. Furthermore, the position of nodes is displayed in a map.

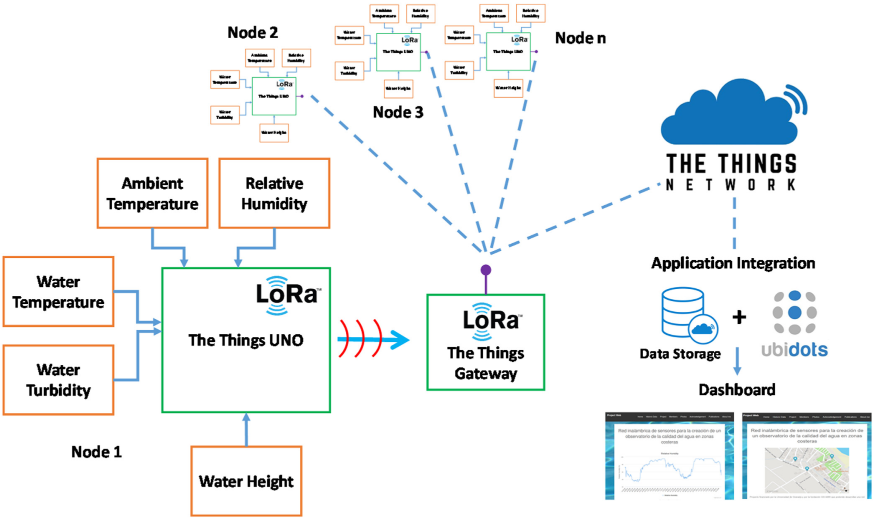

Fig. 1. Proposed system

3.2 Hardware

This subsection exposes the main features of the different devices and elements used to deploy our nodes.

Network Devices. The Things Gateway [24] is a LoRaWAN base station that permits connecting LoRa devices, such as sensors and embedded computers, to grant them access to the internet. It is based on open source hardware and software standards and operates at 868 MHz for use in the EU and 915 MHz for use in US. This model uses an antenna of 14 dB gain. The Things Gateway implements its own security systems through https connections and embedded mechanisms in the LoRaWAN protocol. According to the manufacturer indications, a single device can serve thousands of nodes inside a coverage wireless range of up to 10 km (6 miles).

The Things Uno module [25] is based on the Arduino Leonardo board with a Microchip LoRaWAN RN2483 module and on-board antenna. It is fully compatible with the Arduino IDE and existing shields. The Arduino Leonardo is a board with an ATmega32U4 microcontroller that allows IoT designs. It has native USB by hardware and therefore does not need any serial-USB conversion. It has 20 digital input/output pins (with a maximum current of 40 mA per pin) of which 7 of them can be used as PWM outputs and 12 as analog inputs. The clock speed is 16 MHz. It contains 32 KB Flash Memory (4 KB used for the bootloader), 2.5 KB SRAM and 1 KB internal EEPROM. A supply voltage between 7–12 V is recommended.

Combining The Things Gateways and The Things UNO nodes, it is possible to deploy IoT networks for embedded, sensing and connected city applications, with up to 10 km range coverage. Figure 2 shows the network devices used in this system.

Analog Turbidity Sensor. The turbidity sensor detects the water quality by measuring the level of turbidity. It is capable of detecting suspended particles in water by measuring the speed of light transmission and scattering that changes with the amount of total suspended solids (TSS) in water. As the TTS increases, the liquid turbidity level increases. This turbidity sensor has both analog and digital signal output modes. Sensor operating voltage is 5 VDC with a maximum current of 40 mA. Sensor response time is lower than 500 ms. The analog output value is between 0 and 4.5 V with an operating temperature between 5 °C and 90 °C. As we can see in [26], the water turbidity is dependent on water temperature, i.e., if the sensor is left in the pure water, it will read an NTU < 0.5. However, this value will be 4.1 ± 0.3 V when temperature is between 10 °C and 50 °C.

Fig. 2. LoRa Gateway and Nodes used to deploy our network

DHT11 Temperature and Humidity Sensor. In order to measure the environmental temperature and relative humidity, the system includes a DHT11 sensor [27]. This sensor offers a digital output due to a small 8-bit microcontroller that is already calibrated by the factory. The DHT11 sensor is able to measure temperature in the range of 0 °C to 50 °C with an error of ±2 °C and relative humidity in the range of 20% to 90% with an error of ±5%.

3 Wire PT100 Temperature Sensor. This sensor is a 3-wire RTD resistance thermometer. The sensor is made up of a stainless-steel housing that provides great robustness to the sensor. Its size is 50 mm long and has a diameter of 6 mm with a cable length of 2 m. The working range of this sensor is from −50 °C to +300 ºC. The temperature measurement is based on the common characteristic of all conductors and semiconductors, i.e., the electrical resistance is modified itself when temperature varies. The PT100 sensor has an ohmic value of 100 Ω at a temperature of 0 °C and its coefficient of variation is 0.00385 Ω/°C.

Infrared Distance SHARP GP2Y0A21 Sensor. The Sharp GP2Y0A41SK0F [28] distance sensor allows obtaining the distance between the sensor and some object within the range of 4 to 30 cm. It integrates three devices: An infrared emitting diode (IRED), a sensitive position detector (PSD) and a signal processor circuit. The device delivers a voltage output proportional to the sensed distance. The difference in the reflectivity of the materials, as well as the operating temperature, does not greatly affect the operation of this sensor due to the detection method used based on triangulation.

After analysing the features and working ranges of each sensor, they were combined and mounted to perform the tests. Figure 3 shows a diagram of the deployed node while Fig. 4 shows a picture of the sensor node in a plastic drum with real river water sample.

3.3 The Things Network Platform

The Things Network (TTN) [23] is an organization/community that has created a distributed and decentralized network of LoRa Gateways for the Internet of Things with open source hardware and software philosophy. The particularity of this scenario is that the network is created from the collaboration of citizens who install gateways that provide coverage and allow communications between the nodes and the Internet. Currently the TTN community is made up of more than 12,800 gateways and more than 117,000 across 150 countries.

The LoRaWAN [29] network architecture is based on a star topology. The main component of this topology is a gateway that forwards messages between an end device and the network server. The network server forwards the packets of each device in the network to an application server. The security of the network is provided by a symmetric model of session keys derived from keys associated with each device. The gateways are connected to the Internet through the conventional TCP/IP network protocol, while the end devices are connected to the Internet using LoRaWAN and communicate with one or more gateways. The Gateway's function is collecting data from the different nodes included in the network and connecting them to the rest of the network. Finally, the users can access the data by using the TTN supported protocols such as HTTP or MQTT (Message Queuing Telemetry Transport).

3.4 Web-Based User Interface

Web-based user interfaces allow users to interact with the content stored on remote or cloud servers through web browsers. In this acquisition method, the web browser acts as a client and, therefore, it is in charge of downloading the stored data to present it to the user. As it is said before, in this case, Ubidots platform was used as it allows

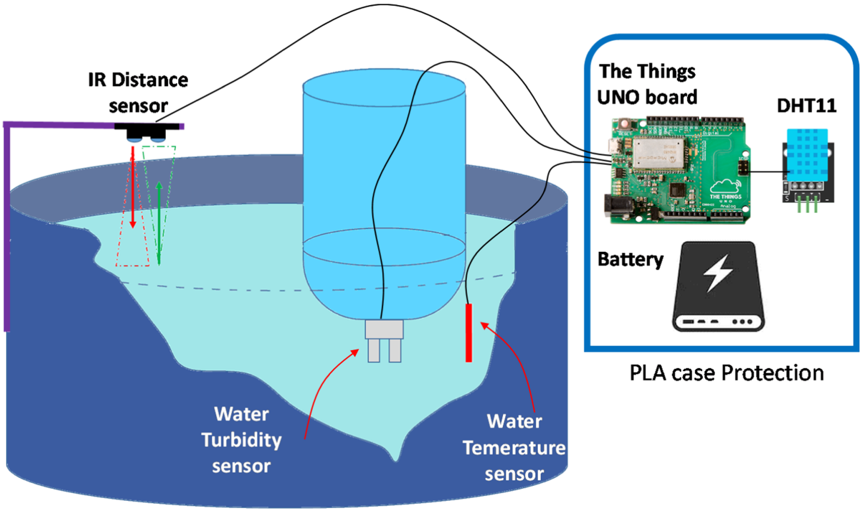

Fig. 3. Diagram of the designed LoRa node

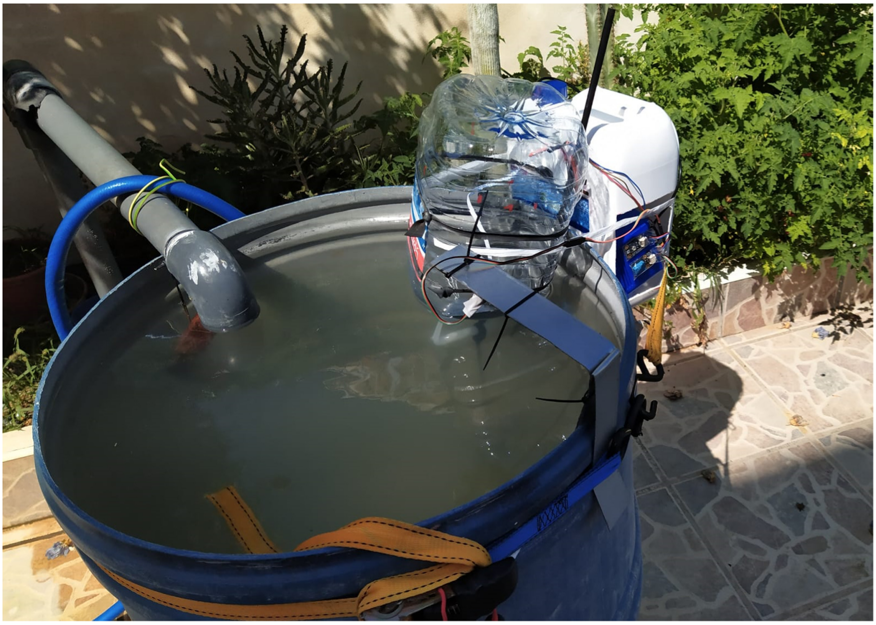

Fig. 4. Sensor node in a plastic drum with real river water sample.

affordable and reliable end-to-end IoT solutions through HTTP, MQTT, TCP and UDP protocols [30]. Figure 5 presents the developed website. As the figure shows, the main page displays the position of the nodes in a map. These nodes are clickable and they allow the user to have an overview of the sensed data in the form of a small pop-up window that exhibits real time data of the sensors connected to that node.

In this project, the collected data is retrieved from the server using HTTP protocol and Node.js JSON parser to execute request methods for real time asynchronous events. Figure 6 displays the flow diagram of the web application. Although the web browser executes HTTP methods to retrieve information from the server, the solicited data is sent to the TTN storage site in the form of a JavaScript Object Notation (JSON) file, which is the format type that Ubidots platform manages. To effectively connect TTN and Ubidots platforms, TTN payload formats need to be configured in our application console to decode this type of messages. After integrating Ubidots to TTN, we will be able to retrieve data from the database and display it in the dashboard. Furthermore, this setup allows the nodes to push information over the LoRa network up to the TTN server, and from the TTN server to Ubidots. Since the main page will display de position of the nodes, this data will be converted into a csv file that includes name, geolocation, id, and the token of each device. In order for the user to enter the dashboard and visualize real time data of each node, the selected node needs to be clicked. This action will open a pop-up window with real time values of the monitored parameters and a button to access the dashboard and observe the historical data of the sensors plotted in different graphs to see their evolution over time.

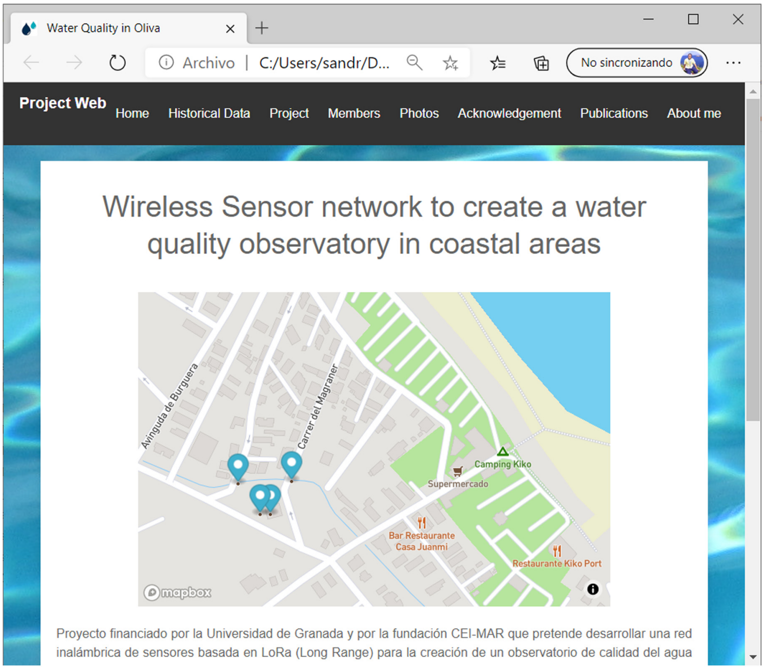

Fig. 5. HTTP-based dashboard.

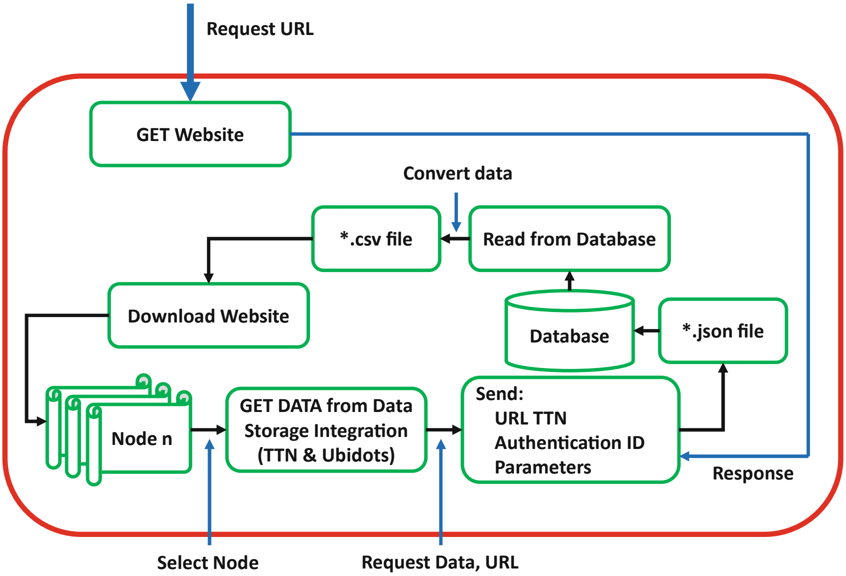

Fig. 6. Scheme of the developed website.

4 Results

This section presents the test performed and the results obtained by the developed network. The tests have been performed in a semi-urban scenario, in Oliva Beach (Valencia-Spain). In this scenario, single-family semi-detached houses are predominant.

In order to carry out the measurements, we used three different nodes placed on the green points of Fig. 7. Two of these nodes were placed directly in the river while the other one was placed in a swimming pool. The LoRa gateway (identified by the red point in Fig. 7) was placed inside a building. Moreover, each node was configured to send data every 5 min. The rest of time, the node is in sleep mode. Figure 7 shows the placement of nodes and gateway and Fig. 8 shows a node in the river during the tests.

In the following figures, we will display the monitored parameters to compare the results of two scenarios: cloudy pool water (Node 1), and ditch water (Node 2 and Node 3).

Figure 9 displays the relative humidity sensed by the nodes in pool water and real river water. As this graph shows, the relative humidity levels sensed by Node 1 (pool water) are considerably lower than the ones measured by Node 2 and Node 3 (ditch water). The reason for these differences is the location of each node during the testing process as well as the amount of sun exposure. Furthermore, the humidity sensor has a working range of 20% to 90% with a ±5% error, which is the reason why relative humidity levels saturate at 95%.

Additionally, DHT11 sensor also measures environmental temperature in the range of 0 °C to 50 °C with a ±2 °C error. Figure 10 shows the sensed ambient temperature in pool water (Node 1) and real river water (Node 2 and Node 3). As the figure shows,

Fig. 7. Position of nodes and gateway.

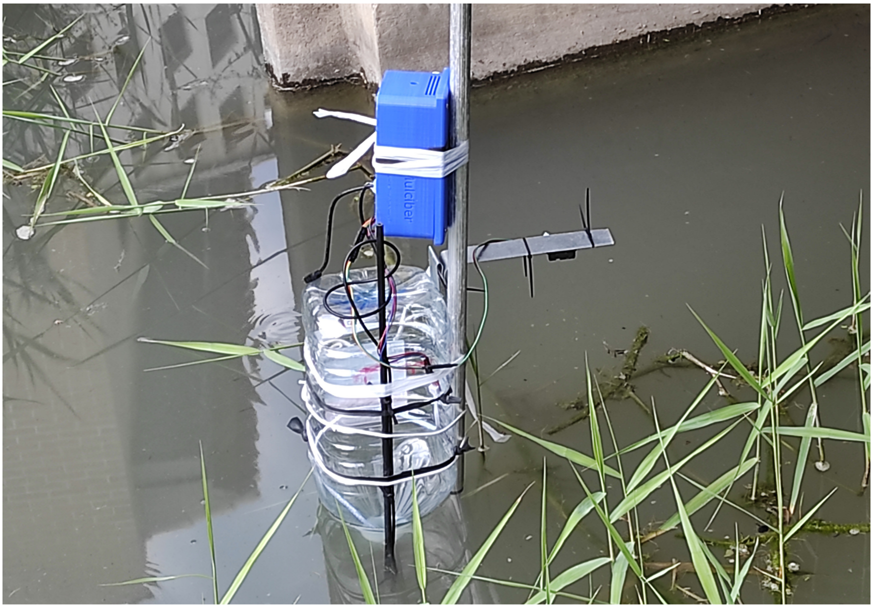

Fig. 8. Sensor node in the river to perform the tests.

ambient temperature of Node 2 and Node 3 are practically the same. However, the sensed ambient temperature is sometimes higher than in the rest of cases. This was caused by the location of the water samples during the tests.

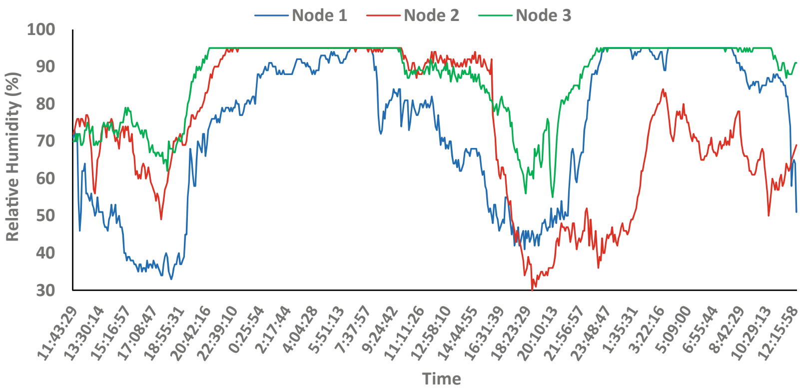

Fig. 9. Relative humidity in %.

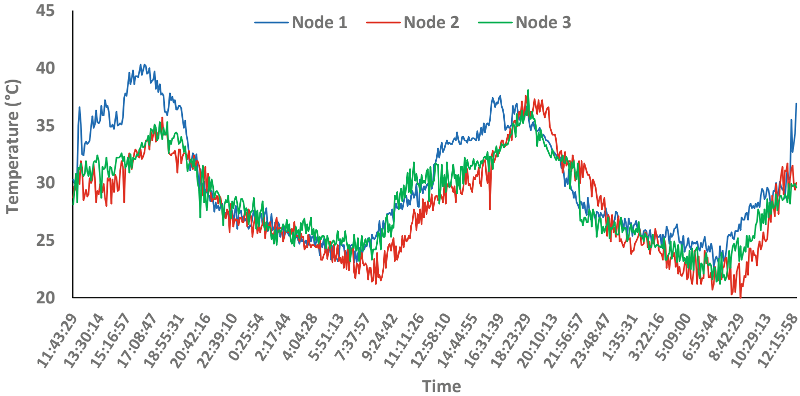

Fig. 10. Ambient temperature in °C.

Water levels were measured using Sharp GP2Y0A41SK0F analog distance sensor that features a detection range of 4 cm to 30 cm, indicated by the output voltage. Though in this case water levels in pool water and ditch water are not significant for the sake of this study, Fig. 11 helps demonstrate the functioning of this sensor. As it can be seen, water levels measured by Node 1 (pool water) are much lower than the ones measured by Node 2 and Node 3 (real river water). The reason for this is that the buckets used in each test were different. However, this graph shows some fluctuations of water levels that can be explained by the sensor's sampling rate.

Water temperature was measured using PT100 3-wire sensor that allows a reading range from −25 °C to +250 °C. Figure 12 displays water temperature of pool water (Node

1) and real river water (Node 2 and Node 3). As the figure shows, water temperature in ditch water is generally higher than in pool water. The reason for this is that real river water contains a full biodiversity of aquatic invertebrates and particles that contribute to the increase of temperature, while pool water is often cleaner.

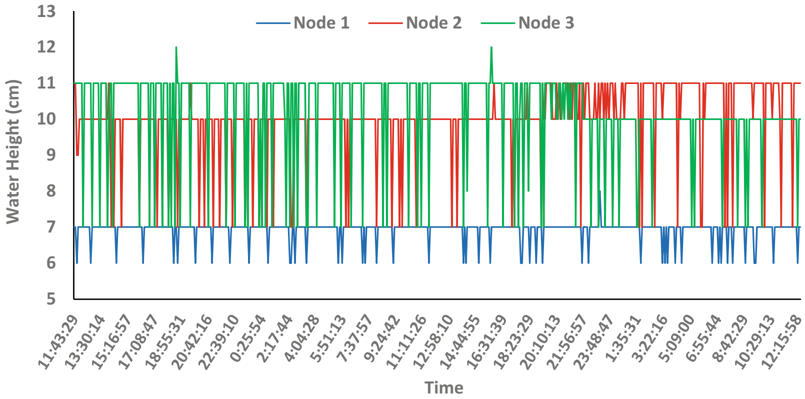

Fig. 11. Water height in cm.

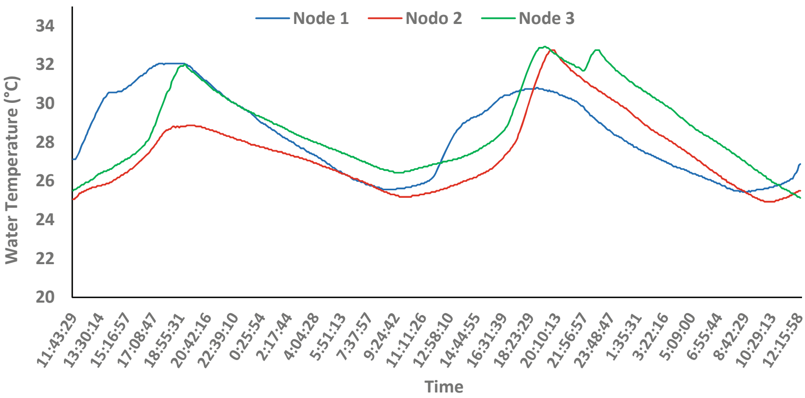

Fig. 12. Water temperature in °C.

Finally, water turbidity is displayed in Fig. 13. Gravity turbidity sensor SEN0189 allows measuring turbidity thanks to its relationship with output voltage [28]. When comparing this graph with temperature, one can easily observe that turbidity levels rise with the increase of temperature. This may be due to the increase of activity of the aforementioned invertebrates and suspended particles.

Finally, the coverage of LoRa nodes was tested. In order to carry out these measurements, TTN Mapper mobile application [31] was used. Figure 14 shows the surface covered to check the signal levels detected by our node, and the Received Signal Strength Indicator (RSSI) measured. The maximum distance at which the node managed to send data was 910 m.

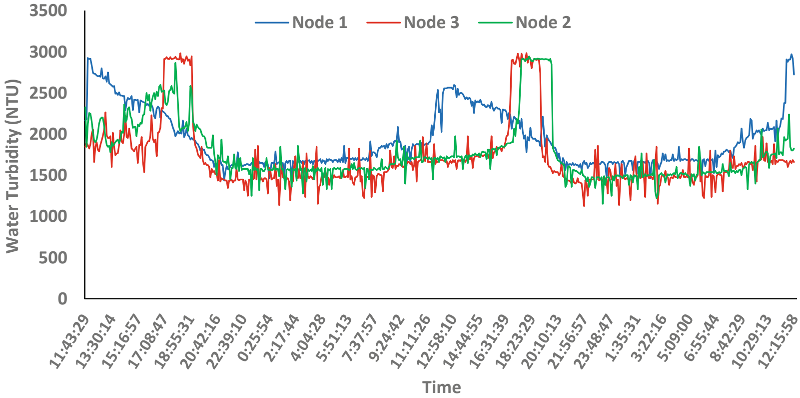

Fig. 13. Water turbidity in NTU.

Fig. 14. Values of RSSI measured during the test.

Figure 15 shows the results of RSSI obtained as a function of the distance, while Fig. 16 shows the results of SNR obtained as a function of the distance.

The distance was measured from the gateway (which is our reference point), to the node that collects the data. It should be taken into account that the selected area to perform this test has several buildings with a height lower than 10 m. In spite of this, the height of the buildings obstruct the signal propagation, significantly reducing the SNR and RSSI levels. As we can see, it was possible to collect data at 910 m from the gateway. Moreover, the average value of SNR was around 0 dB, which indicates that the signal levels are balanced with the received noise levels. Therefore, we can conclude that these devices can correctly deploy a network area of 900 m of diameter.

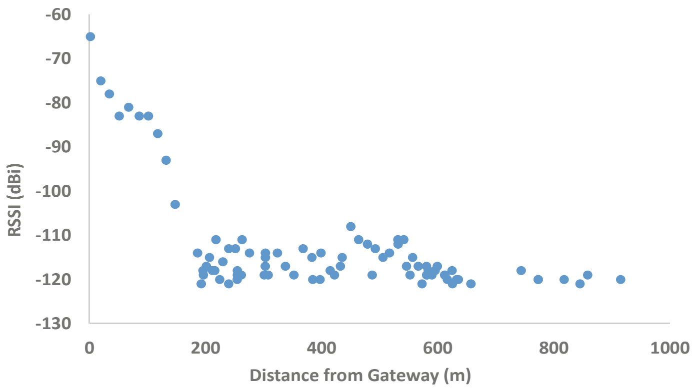

Fig. 15. Values of RSSI as a function of the distance to the gateway.

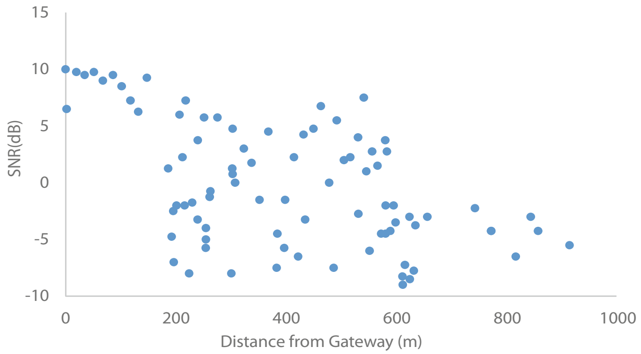

Fig. 16. Values of SNR as a function of the distance to the gateway.

5 Conclusion and Future Work

The conservation of natural resources, such as water, is currently a hot topic. However, this task must be carried out not only by researchers but also by citizens. Therefore, it is interesting to apply current technology to monitor the state of these resources and bring this type of project closer to the population. This way, we would be able to make the population aware of the importance of conserving our natural areas. To this end, this paper presented the design and development of a hardware and software platform that allows real-time monitoring of different water parameters, at different points of a river network. The system is made up of a LoRa-based network with different wireless nodes that send data to a central database that allows its visualization through a website. The entire network has been tested in a real environment with three nodes and results have shown interesting results. On the one hand, we have noticed that water turbidity is closely related to water temperature. On the other hand, LoRa coverage tests have demonstrated that it is very difficult to reach the coverage distances indicated by manufacturers. According to the device's specifications, we could reach up to 10 km (without obstacles). However, we performed the coverage tests in a semi-urban scenario and the maximum distance reached in our experiments was only 910 m, which is much lower than the expected one.

Currently, there is a growing trend in the creation of these observatories to apply Big Data techniques and artificial intelligence algorithms to improve the sustainability of an area or productive sector using real data. Therefore, an interesting future work would be improving the network performance in terms of coverage, integrating more gateways and nodes, as well as other sensors, to create a bigger network and apply Big Data techniques and artificial intelligence algorithms to make intelligent decisions, create alarms, and correct possible pollution problems.

The infrastructure proposed in this paper has many extensions and applications. A network of these characteristics allows monitoring water quality in harbours and areas with aquaculture activity. In addition, it can help promote tourist activity in an area ("blue tourism") and ensure that water activities are carried out in waters of excellent quality.

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