LoRa-based Measurement Station for Water Quality Monitoring: Case of Botanical Garden Pool

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***Abstract*—The advent of Internet of Things (IoT) has made easier to build number of applications. In fact, the remote monitoring or sensing has been facilitated by the IoT. A number of sensor nodes with a networking capability can be deployed in order to have an ad hoc or continuous monitoring system. However, physicists at UCAD's Faculty of Science still use traditional means to collect their water quality data from a pool in the faculty's Botanical Garden with on-site measurements. This pool is used for aquaculture and to study some aquatic species. In this paper, we present a water quality monitoring system through LoRa transmission. It's a low cost infrastructure composed of a remote station for real-time data collection and a web platform for visualization and exploitation. To evaluate the reliability and efficiency of the system, we perform some performance tests and the results are also presented.**

***Keywords* —Water Quality Monitoring, Wireless Sensors Network, LoRa, Data Visualization**

I. INTRODUCTION

Department of Plant Biology is located within Faculty of Science and Technology (FST). This is why a green space is set up next door for the students' educational activities and the protection and preservation of the environment. This place is called Botanical Garden and extends over three hectares. The main role of the botanical garden is the conservation of the bio-diversity of Senegalese flora, ie saving endangered species and ensuring the protection of plants. At the entrance to the botanical garden is a large pool where swim aquatic species. This pool is used for aquaculture and to study certain aquatic species. It therefore seems important to take into account water quality data.

Water quality can be described as a function of the concentration and state of organic and inorganic material in the water, as well as some physical characteristics of the water [1]. The main elements of water quality monitoring are therefore measurements, collection and analysis of water samples, study and evaluation of analytic results and reporting of results [2]. For many years, the procedure for testing the quality of water followed a simple work flow that involved manually collecting samples of the water and then transporting these samples to a laboratory for analysis to detect chemicals and microbial contaminants [2]–[4]. This process has several limitations:

- Water samples may be lost and this approach is time consuming due to the dependence on human interactions and the need to transport samples from the water source to the laboratory for analysis.
- There is an inability to conduct trend analysis based on historic data, as data may not be sampled frequently enough for some analyses, and additionally data can be lost at any given time due to the manual processes involved in data collection and recording.
- It is very difficult to determine changes in the water conditions over time, as the samples cannot be collected and tested within short intervals.
- The results of the analyzes carried out on a single water sample are only valid for the place and time the sample was taken. In view of all these limitations, it is necessary to have another more reliable approach to collecting water parameters to measure the quality of the water [5].

With advanced wireless sensor network technologies, several authors have focused on improving sensors for water quality measurements and give an answer to this kind of problem. Among the major applications foreseen, a novel system of remote water quality measuring and monitoring based on wireless sensor network (WSN) and Code Division Multiple Access ($CDMA$) technology is proposed by Ji Wang et al. [6]. In their paper, they build a detection system with three sensors, Carbon Dioxide, pH, Conductivity. In [7], Kageyama et al. propose water quality monitoring and field-tested it with several sensors in the lake. Their data is transmitted every 10 minutes to the server through the Internet connection via the 3G mobile network and their logged data are displayed on the Google spreadsheet. In their paper, they did not develop a platform for real-time visualization. Zulhani Rasin et al. used a $Zigbee$ based technology together with the $IEEE$ 802.15.4 compatible transceiver to setup an ad-hoc and low cost System [8]. Furthermore, sensors have been also deployed to build a system aimed to provide a platform capable of ensuring the monitoring requirements of the Water Framework Directive [9].

In this paper, we build a remote measuring station for real-time water quality monitoring through LoRa wireless data transmission. We develop a web-platform for data visualization and we present the communication architecture with a bi-directional link which allows a command system from the server to the node.

The remainder of the paper is organized as follow. Section II describes how the measurement station is designed. Section III presents and discusses about the results. Finally, in Section IV, we conclude our work.

II. DESIGN AND IMPLEMENTATION OF MEASUREMENT STATION

The measurement station consists of a acquisition node and a gateway show in Fig. 1.

A. *Acquisition node*

We designed and deployed an acquisition node system in the Botanical Garden pool. The acquisition system consists of a micro controller which all the sensors of the system are connected. It is powered by a solar power source (solar panel + battery) and is equipped with a $LoRa$ module for transmitting data to the gateway.

1) Sensors: In this system, four sensors are used for the measurement of water quality parameters (pH, Electrical Conductivity (EC), oxidation/reduction potential(ORP) and water temperature). However, the acquisition node is scalable to allow the addition of several sensors as needed. Table I lists all the sensors used by acquisition node. The micro controller used to collect and process the parameters of the pool is an arduino Mega 2560 card. The particularity of $Arduino$ cards is that they are composed of a flexible hardware and software part and easy to use [10].

TABLE I: Sensors

Parameters	Sensors	Measurement range	Accuracy
temperature	DS18B20	$-10°C$ to $+85°C$	$\pm 0.5°C$
z pH	SEN0169	0 - 14	$\pm 0.1pH(25°C)$
ORP	SEN0165	$-2000mV$ to $2000mV$	$\pm 10mV(25°C)$
EC	DFR0300	$1ms/cm$-$20ms/cm$	$\prec \pm 1ms/mm$

2) Transmission Module: The pool is located about 500 meters from the building of the Department of Plant Biology where the Gateway is deployed. To ensure good communication, we used $LoRa$ transmission. Since $LoRa$ modulated signals are transmitted in ISM bands, we do not have to pay any fee to the local Telecommunication operator. Before deploying our system, as we did in [12], we made coverage tests to choose an optimal position of the acquisition node to minimize the packet loss ratio. We sent 624 packets and we received 599. It gives us a packet error rate of 4% and the $RSSI$ gateway is below -75 dBm. For the measurement station, the transmission between the sensor node and the gateway is done using structured frames showed in Fig.2. The proposed frame structure is as follows:

Fig. 1: Measurement station architecture

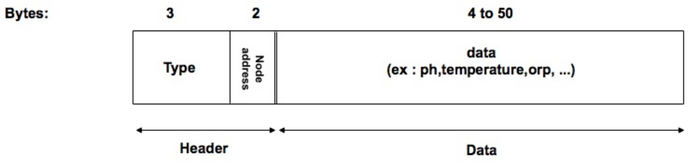

Fig. 2: Frame

- **Type** is used to define frame type. There are two types of frame *INF* and *CMD*. *INF* frames are up link, data from sensors are encapsulated in these frame. *CMD* frames are down link,in which commands are stored from platform to the acquisition node.
- **Node Address**: this field is for destination node address.
- **Data**: The payload is stored in it.

The type of the frame defines the size of the latter. For up link frames (INF data frame) the size can reach up to 60 bytes and 15 bytes for down link frames (CMD type).

3) Flowchart of the Acquisition node: The acquisition node program is represented as a flowchart in Fig. 3. We start the program with **start** function, the **initialization** function start. The $LoRa$ Module is initialized with the basic configuration(spreading factor, coding rate, frequency), the basic parameters of the sensors are also initialized. Then in the loop we define a default waiting period of 10 minutes **TIMEOUT** . After that delay, the data are collected from the sensors and encapsulated in a *INF* frame which is sent to the gateway through $LoRa$ network. During the waiting delay, the node listen to the messages that would come from the server because it can receive a *CMD* frame at any moment. In a *CMD* frame, the server can whether ask for immediate data or can ask to the node to change the delay time. In those cases, the node collects the data from sensors and send it to the server and update the waiting **TIMEOUT**.

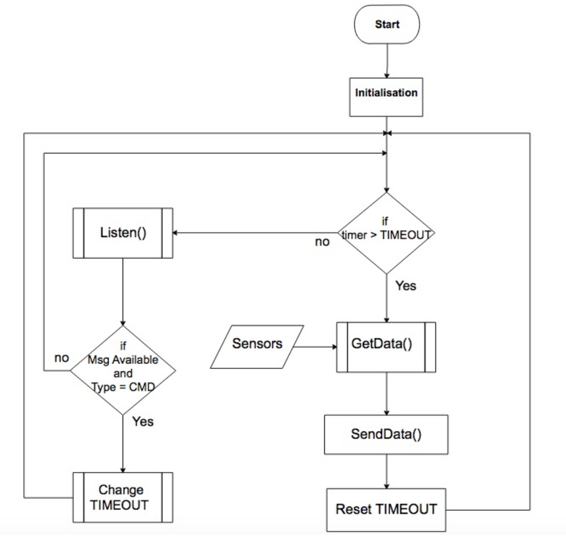

Fig. 3: Acquisition node flowchart

4) Sizing of the Power supply : All the used device in the measurement station are low power consumption. As explained before, the central node of the station is an $ArduinoMega2560$ card. All used sensors are powered by an output voltage of $5V$. The sum of the set of active currents is estimated at almost $1A$. Hence, the instantaneous power consumption of the station is around $5W$.

Senegal is an area where solar irradiation is very important. Sunshine duration ranges from 7 to 12 hours by day overall the year. However, to guarantee the operation of the station in all seasons, we chose in the sizing of the battery, an autonomy of 3 days. Therefore, by using a battery of $12V$ output voltage, the required capacity is $30Ah$ as proven by the following equality: $360Wh = 12V \times 30Ah$.

To charge this battery, we chose a $50W = 12V \times 4.17A$ solar panel with a voltage of $12V$. In the ideal conditions of sunshine, the charging of the battery will take approximately $7h = 30Ah/4.17A$.

B. Gateway node

The gateway makes it possible to relay the frames between the acquisition node and the platform. It consists of a $Dragino\ LG01 - P$ box which has four interfaces: $LoRa$, $WiFi$, $Ethernet$, $3G/4G$. Upon receipt of a frame from the $LoRa$ network, the frame is sent to a local server via the Ethernet interface and stored in a database. After that, the data is then replicated to a cloud database if the internet connection is active. This replication enables to have a backup system and the possibility to access to collected data directly via Internet.

The deployed measurement station is shown in Fig. 4

III. VISUALIZATION

We developed a web-platform in order to see data in real time with dynamic charts and also download them. The platform has two interfaces:

- **Users Interface**: This interface is made for researchers, they are able to see data in charts. Data is updated every 5 seconds and can be downloaded in $Excel$ and CSV format.
- **Admin Interface**: The administration interface allows the management of user sand a configuration of the sensor network. Bidirectional commands are also executed from this interface.

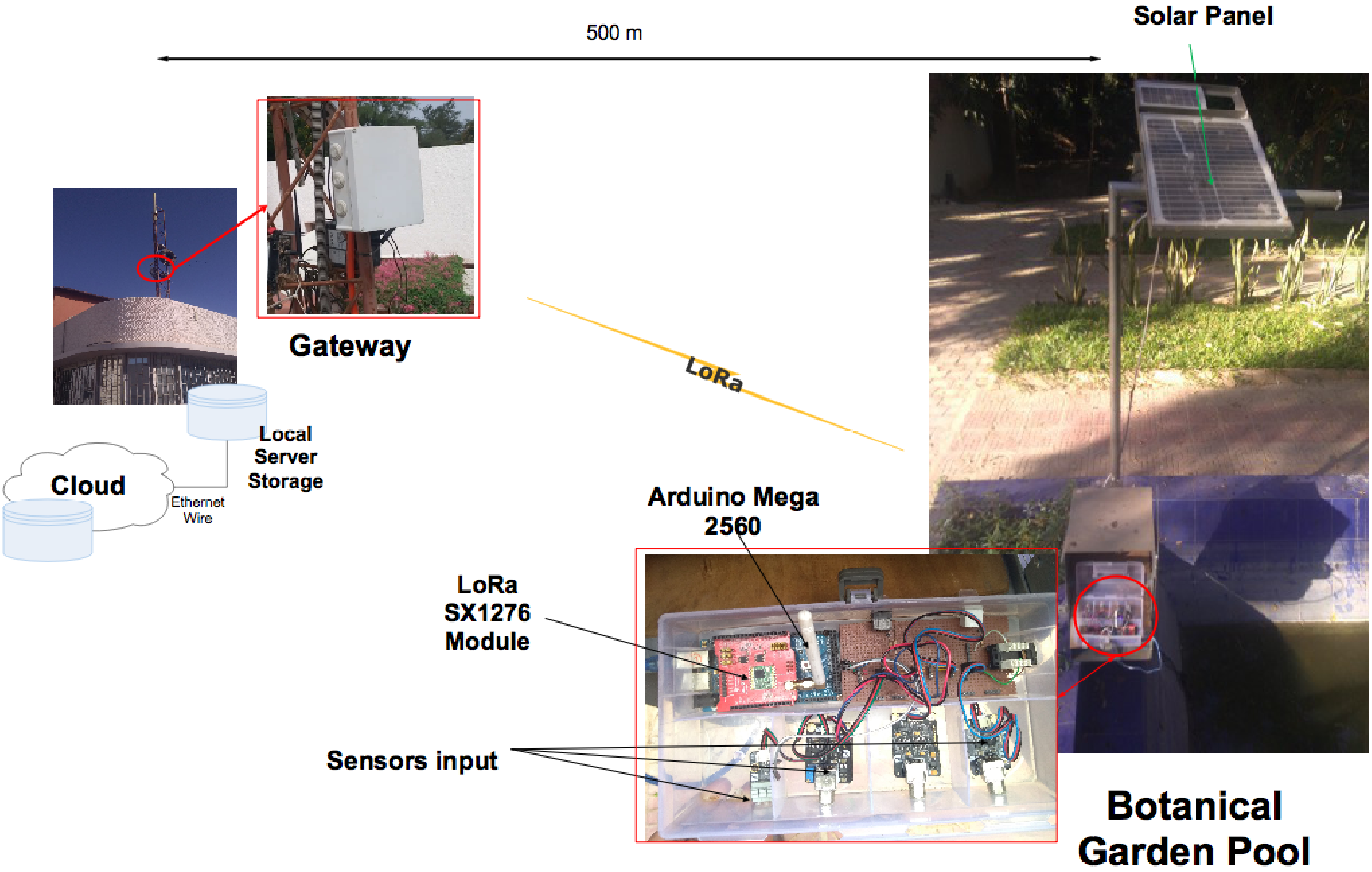

Fig. 4: Monitoring System.

Fig. 5 represents the user interface with a data capture of a measurement day in real time. We note that the parameters of the water vary little. The water temperature increases between 10 am to 4 pm which influences pH variation within this interval. In the interface, we have a tab *Global visualization* where the data of several years can be displayed. The *Threshold Visualization* tab allows to view charts with user-defined thresholds, or to combine several parameters in a graph in the *Combination* tab. The user can download the data in different formats by clicking the *import/export* button.

IV. CONCLUSION

In this paper, we designed and implemented a water quality measurement station coupled with a real-time data visualization platform. The system is deployed at the Botanical Garden Basin. We showed all the components and also presented the data collected and visualized.

As future work, we plan to improve this system by taking into account a large set of physico-chemical and bacteriological parameters of water. We plan also to develop a risk assessment algorithm for combining the different sensors to assess the water contamination risk. Then it will allow us to set up a epidemiological surveillance for aquatic diseases.

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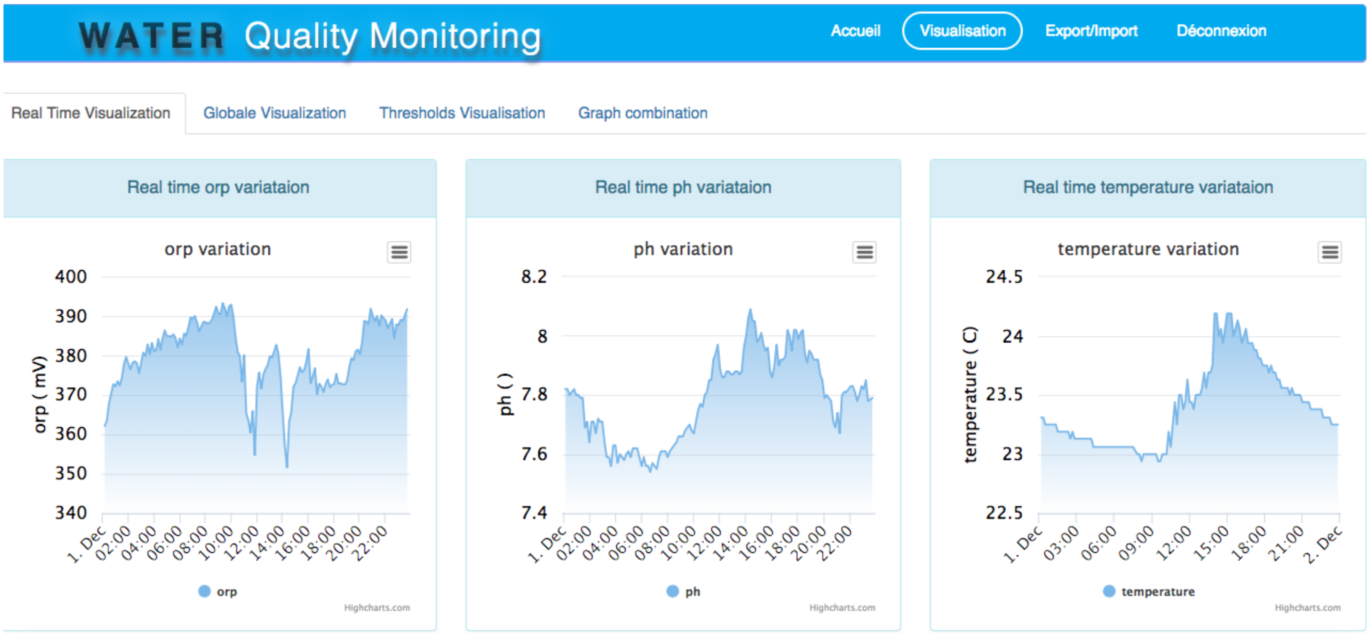

Fig. 5: Real-time data visualization