Cloud-based Tele-Monitoring System for Water and Underwater Environments

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Abstract— **Recent research in communications and computer science has been considered to advance the performances of monitoring water environments. However, constrains produced by the water environments, caused by the specific channel propagation and harsh operating conditions must be taken into account. The purpose of this paper is to define and describe a monitoring system for the water environments, based on a previous study regarding both the underwater, but also technologies that are appropriate for such surroundings. The system is based on an underwater sensors network which is connected to a cloud platform by means of a reconfigurable wireless transceiver. The sensor network integrates several low cost sensors that can measure different parameters such as water level, the water flow, temperature, pressure etc. The measured parameters will be transmitted through an operational communication node, which should be able to ensure a reliable communication with timing and variation delay constraints. Finally, the paper describes the platform interface available to end users, providing real time visualization of the water environment events.**

Keywords—wireless sensor networks; underwater sensor network; water environment monitoring; cloud computing

I. INTRODUCTION

Recently, there has been an increasing interest in monitoring water environments, the information regarding such surroundings being required by a wide audience, including research scientists, policy-makers, and also the general public. Parameters like water level, flow and sediment data are used by decision makers to resolve issues related to sustainable use, infrastructure planning and water apportionment [1]. Hydrological models use the data to improve the forecasting of floods and water supplies, and to predict the impacts of changes on flow regimes to human and aquatic health and economic activity.

There are several underwater events that can be measured, like the river level or some additional parameters like rainfall, the pressure level or temperature. The purpose of this paper is to present a solution that integrates an underwater network with low cost sensors connected to a cloud platform that can offer real time information. The sensor network integrates several sensors that can be used for different problems and can measure the water level, the water flow, temperature, pressure, but also some parameters that define the water quality. All this information is available in a cloud platform responsible for the collection of environmental data. The platform provides an interface that users can access anywhere, at any moment.

Underwater sensor networks feature a large number of nodes, consisting of static or mobile underwater sensors. These nodes may include pressure sensors used for depth approximation, temperature sensors such as thermistors, photo-diodes for measuring ambient light, fiber optic sensors, cameras and more. Sophisticated but also more expensive sensors may also be used, such as electrochemical sensors for marine environmental monitoring, or acoustic vector sensors that measure the scalar and vector components of the acoustic field in a single point, allowing for a multichannel receiver in a compact form.

A sensor network can offer coverage for a large area, compared to a single instrument platform, which can be an effective sensing tool, but it is limited to take measurements one location at a time. A sensor network can also provide differential measurement, in order to indicate different levels for a certain parameter in different points [2].

Furthermore, cloud computing provides a platform for processing big data from hundreds of different sensors, enabling the analysis of the environmental data through a large sample of datasets [3].

The paper is organized as follows: Section II describes the rationale for monitoring water environments considering the state of the art and strategic relevance, while Section III presents challenges of WSNs. Section IV presents the proposed tele-monitoring system and describes the components. Finally, Section V concludes the paper.

II. RATIONALE FOR WATER AND UNDERWATER MONITORING SYSTEMS

Despite the fact that significant progress has been made regarding sensors, communication and computing technology, the underwater sensor platforms are generally inferior to their terrestrial counterparts [4]. In opposition to terrestrial Wireless Sensor Networks (WSNs), underwater sensor nodes are more expensive and there are developed fewer sensor nodes. Data acquisition from the sensor nodes is made through autonomous underwater vehicles [5]. Also, compared to a dense deployment of sensor nodes in a terrestrial network, a sparse deployment of sensors is placed underwater [6].

The communication in the underwater environments is wireless and is established through the transmission of acoustic waves. The general problems are the limited bandwidth, long propagation delay and also the signal fading issues. Another challenge is the sensor node failure, due to the harsh environmental conditions [7]. These sensors must be able to perform self-configuration and calibration, and also they have to adapt to these environment conditions. The issue of energy conservation for underwater networks involves developing efficient underwater communication and networking techniques [8].

An Underwater Sensor Network offers a different vision, providing a real time visualization of the underwater events. The existing wireless sensor networks and tools for the development of such infrastructures are currently hot topics under research for their applicability in underwater scenarios. There are several projects and devices that offer solutions, from water level monitoring sensors used in agriculture to systems deployed on rivers banks, which aggregate multi-parameter sensors or various combinations of individual sensors.

The proposed solution consists in an underwater network with low cost sensors connected to a cloud platform that can offer real time information. The sensor network integrates several sensors that can be used for different problems and can measure the water level, the water flow, temperature, pressure, but also some parameters that define the water quality. All this information is available in a cloud platform responsible for the collection of environmental data. The platform provides an interface that users can access anywhere, at any moment, via Internet.

Existing sensors in the Black Sea's offshore area detect environmental change events and provide early warning messages—essential information for emergency organizations and residents. Furthermore, Danube's earthquake monitoring system provides data that is helping to minimize risks to residents and property. Monitoring the Danube underwater delta reveals slope stability changes that are of significance to the nearby coal port, container terminal and Zimnicea ferry terminal [9].

By using weather stations with online tele-monitoring capabilities of water parameters, new coastal monitoring services will report live weather and sea states status in the Black Sea, helping all vessels make safe decisions. Continuous observations at key sites in coastal Black Sea are helping to address global challenges, manage marine resources, monitor regional environmental and climate change, and detect hazards to coastal communities.

Underwater monitoring quantifies changes in marine environments and impacts on resources, helping shape sustainable resource management. The monitoring of major marine currents and ecosystems help decision-makers understand and predict the consequences of a spill and allow for effective critical response planning [10].

River environment monitoring helps track river productivity, including the growth and impact of phytoplankton blooms, key to productive fisheries and to mitigating the commercial and health effects of harmful red tides. Acoustic monitoring in both networks shows strong promise for further improvements in measuring fish stocks and predicting returns.

III. TECHNICAL CHALLENGES OF WSNS FOR TELE-MONITORING WATER ENVIRONMENTS

Pollution monitoring, harbour surveillance, undersea archaeology, river bottom seismic research, river life observation are among some of the fields that can benefit from the wide opportunities that Underwater Sensor Networks (UWSNs) offer. Nevertheless, before UWSNs become commercially available or widely used, there are certain issues to be addressed, as presented is this section.

A. Technological challenges

Localization is one of the major and challenging tasks in UWSNs [11]. It is important because raw sensor data without spatio- temporal tagging does not provide much information. It is challenging because GPS signal does not propagate through water and alternative cooperative positioning schemes are not applicable in practice due to acoustic channel properties. Acoustic channel have low bandwidth, high propagation delay and high bit error rate. The speed of sound is approximately 1500 m/s, yet it varies with temperature, pressure and salinity.

Another challenge is the mobility. Moreover, energy limitation is still an issue as it is in other sensor networks.

Because we intend to develop an optimal solution that integrates several fields, and to deploy this solution worldwide, we have to take in account all the requirements and limitations and adapt our solution to different environments and conditions. To solve this problematic, we need to conduct a state of art of all the equipments that are already deployed.

The main innovation represents the integration of a wireless underwater network, representing a solution that offers a low cost and low power wireless sensor network that efficiently uses available energy without compromising performances (range, data rate, latency, standard compliance). The main challenge is to use different types of low power sensors for implementing this wireless network.

B. Applicability of Standards

WSNs comprise of a large number of spatially distributed autonomous devices that may collect data using a wireless medium. They may be used to cooperatively control and monitor physical or environmental conditions, such as temperature, pH, electrical conductivity salinity, chlorophyll, sound, vibration, pressure, motion or pollutants, at different locations [12]. International standards for wireless devices and networks, such as ZigBee, WirelessHART and ISAIOO.Il a use stacks to provide a layered and abstract description of the network protocol design [13], [14]. Each layer in the stack is a collection of related functions, and each layer is responsible for providing services to the layer above it, while receiving services from the layer below it [15], [16], [17].

IV. PROPOSED TELE-MONITORING SYSTEM

This section presents the main components of the tele-monitoring system for water environments. In Fig. 1. we present the proposed network architecture for a UWSN composed by a low power sensor, a transceiver and an access point that provides the collected data to a cloud platform.

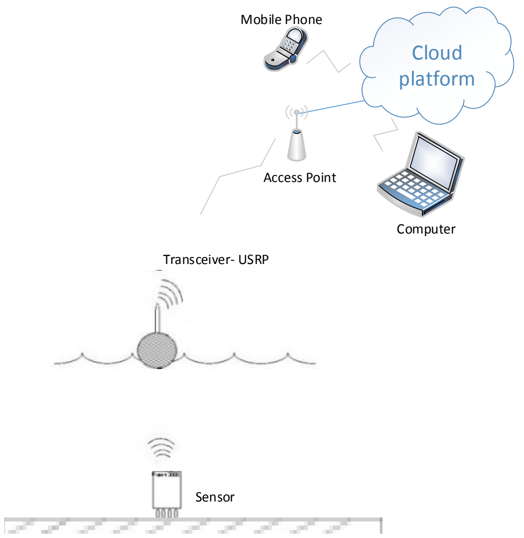

Fig. 1. Network architecture for UWSN

A. Underwater Sensors

The underwater sensor is wireless connected to the transceiver, which is powered by a local battery and solar panel, thus providing a long period of working autonomy for the system. Moreover, the transceiver stores the data and transmits at programmed intervals or when thresholds are reached in order to save battery power via GPRS or UHF unlicensed band, when the GSM signal is not available. The main environmental parameters measured by the underwater sensors are presented in Fig. 2.

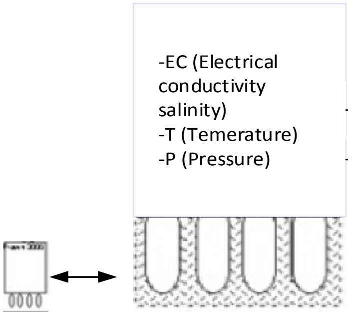

Fig. 2. Underwater Sensor

B. Transceiver and Access Point USRP

The USRP is a hardware platform that can be interfaced to a miniaturized host computer via a USB port in order to be used to create a real-time software defined radio (SDR) utilizing open-source GNU radio software [18]. It is a motherboard which contains a Field Programmable Gate Array (FPGA) for high-speed signal processing, 4 high-speed analog-to-digital converters (ADC), 4 high-speed digital-to-analog converters (DAC), and auxiliary analog and digital input/output (IO) ports.

C. Software and Cloud Platform

We used GNU Radio because it is a free software development toolkit that provides signal processing to implement SDRs using off-the-shelf RF hardware [19]. GNU Radio applications are primarily written using the Python programming language, while the performance-critical signal processing tasks are implemented in C++, as presented in Fig.3.

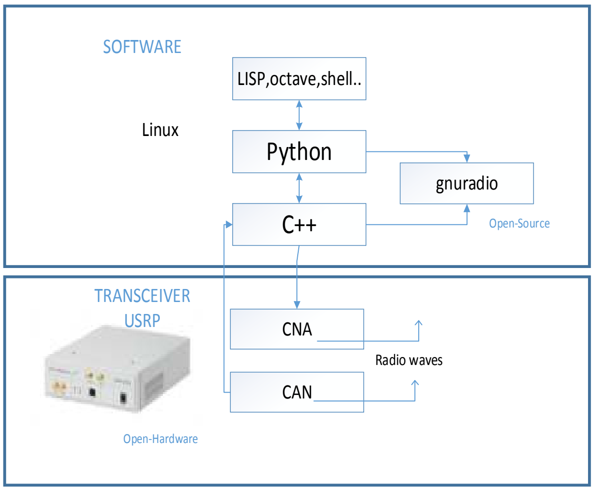

Fig. 3. Transceiver Hardware and Software integration

The platform was based on the Ubuntu Linux – Apache – MySQL software releases using our SlapOS decentralized Cloud platform hosted on several server nodes. The architecture is based on the concept of Master and Slave nodes.

Master nodes are central directory nodes cloud system, serving to allocate processes to Slave nodes and keep track of the situation of each slave node and software that are installed on each node. Slave nodes can be installed on any computer, both in data centers and in private networks and their role is to install and run software processes.

Slave nodes request to Master nodes which software they should install, which software they show run and report to Master node how much resources each running software has been using for a certain period of time. Master nodes keep track of available slave node capacity and available software. Master node also acts as a Web portal and Web service so that end users and software bots can request software instances which are instantiated and run on Slave nodes as computer partitions.

V. RESULTS AND DISCUSSIONS

The proposed system provides several parameters like water level, flow and sediment data. The measured parameters are provided in a user interface which also allows a graphical representation of the events.

To verify the measurements of the underwater sensor we compared the values captured by the underwater pressure sensor to determine the level of the water in a lake with the values of a level sensor located at the surface of the water.

First, the precipitation intensity in mm rain/sqm was measured during two months and was considered negligible, due to a drought period, as seen in Fig. 4.

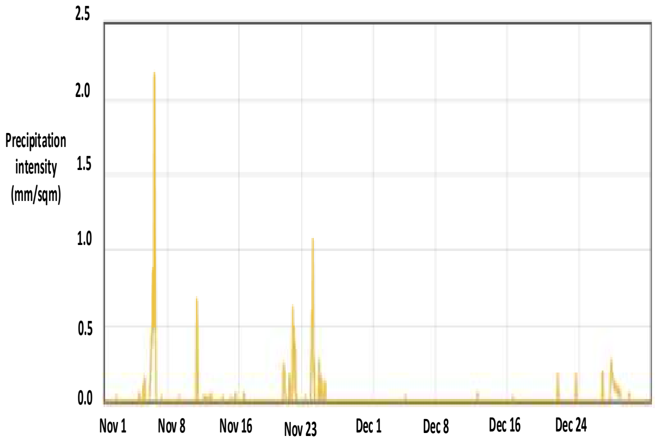

Fig. 4. Precipitation intensity graph

Next, the water intake of the river entering the lake was calculated and the lake level was measured by the underwater sensor, as seen in Fig. 5.

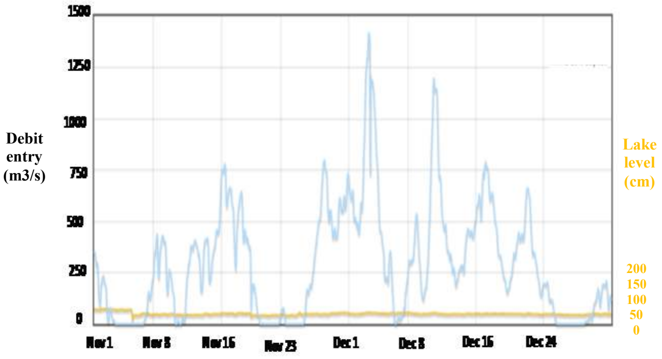

Fig. 5. Lake level in cm measured by underwater sensor (orange), surface level sensors (grey) and debit entry in m3/s (blue)intensity graph

It can be observed that the lake level is not affected by the water intake of the river, as both underwater and surface level sensor indicated.

VI. CONCLUSIONS

In this paper we presented the main challenges for a tele-monitoring UWSN system and elaborated the specific requirements for an innovative implementation and analyzed the strategic relevance of such a system. We proposed a system for monitoring the water level by using two different methods, presenting the main components and measurement results.

As future work we envision to develop a cloud platform for aggregating the data gathered from the access points, thus providing higher availability and distributed processing capacity. We could accomplish the implementation and the deployment as a Cloud Service for MAPE (Monitoring, Analyzing, Planning and Enforcing).

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