AQUAMON – A dependable Monitoring Platform based on Wireless Sensor Networks for Water Environments

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Abstract. Continuous monitoring of aquatic environments using water sensors is important for several applications related to aquaculture and/or water resources management, as well as for recreational activities. Since sensors are constantly being subjected to potentially strong currents and debris accumulation, and the communication between sensors may be affected by waves and electromagnetic interferences, operating sensors in the water environment presents several challenges to data quality assurance and to dependable monitoring. Thus, it is fundamental to address these challenges in order to avoid false alarms or ignoring relevant events.

In this paper we present the AQUAMON project, whose objective is to develop a dependable platform based on WSNs for monitoring in aquatic environments. The project addresses data communication and data quality problems, by performing comparative studies of available wireless technologies with respect to aspects with impact on communication quality and deployment cost and proposing new data processing approaches to detect sensor and network failures affecting data quality and to mitigate the effects of these failures.

Keywords: Dependability, Wireless Sensor Network, Aquatic Environments.

1 Introduction

Real-time water monitoring is used by water management entities and water utilities worldwide to ensure a timely response to dangerous situations [1].

Wireless Sensor Networks (WSNs) have been shown to be useful in long-duration and large-scale environmental monitoring [2] under harsh outdoor conditions, managing to monitor remote, hazardous or unwired areas. They have already been used for monitoring rivers, lakes and estuaries, and in flood warning systems [3]. The advances in wireless communication allowed for the quasi-real-time operation of water monitoring systems [4], supporting the issuing of alerts. The flexibility gained through real-time data access is also fundamental for increasing the confidence in applying numerical models for prediction purposes, dully validated with field data in real-time.

However, using sensor data for real-time environmental monitoring raises dependability questions on data timeliness and validity, which have been typically overlooked due to either the less stringent requirements of most applications, or to deployments in well controlled environments. Sensor data quality also depends on sensor faults and may benefit from data fusion approaches, which require redundant data samples and quality estimation heuristics, or by considering individual characteristics of sensors to derive validity estimates for the sensor data. AQUAMON combines different solutions for data quality in a unique framework, also including ways to bring in water dynamics processes knowledge, through behavioral and forecast models. This combination constitutes a major step ahead the state-of-the art.

Reliable data collection in AQUAMON is however dependent on the ability to communicate and transfer the information in real-time. Previously deployed sensor networks for aquatic monitoring, either stationary or mobile, employed communication subsystems using cellular phone, Wi-Fi, satellite, and 802.15.4 radio links [5]. Some of these subsystems are too expensive for applications requiring multiple sensor nodes, and others only achieve small distances between communication links which depend strongly on favorable water dynamic conditions.

AQUAMON is designed to be suitable in a large aquatic area, to collect and store information in real-time and offer mechanisms to deliver a timely notification to the managers or authorities and users of the system. An example deployment scenario, including 4 sensor nodes and a gateway node deployed across the borders of the Seixal bay, near Lisbon, is depicted in Fig. 1.

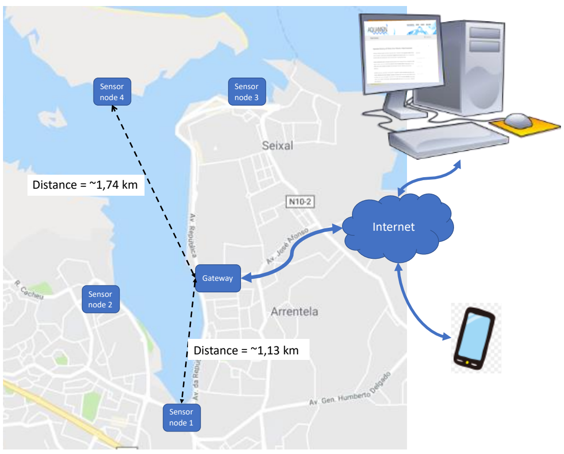

Fig. 1 *- The network architecture.*

By developing a dependable monitoring platform for application in aquatic environments, AQUAMON aims at advancing the state-of-the-art in aquatic monitoring, promoting a better and more reliable implementation of EC legislation such as the Water Framework Directive and the Maritime Directive.

2 AQUAMON Research Challenges

Achieving dependable real-time communication imposes requirements on both the link layer and the network layer. AQUAMON will conduct activities that aim to address problems in both layers, thus taking a rather holistic approach. AQUAMON will also evaluate different radio technologies, namely 802.15.4 ZigBee and ZigBee Pro, NB-IoT, LoRa and 802.11, studying the trade-offs between power consumption, communication distance and resilience to interferences caused by waves and other water disturbances on the correct reception of sensor data. Furthermore, these technologies will be tested in the field for quality and reliability evaluation, in a set of real scenarios, covering a diversity of possible operational conditions. The results will provide guidance on the best options for each considered scenario. In parallel, communication protocols will be developed with the aim to provide real-time and more predictable communication services, exploiting characteristics of the link layer such as bounded omission degree.

AQUAMON will also provide mechanisms to assess and enhance the quality of sensor data from an aquatic WSN. Different mechanisms to detect faults that affect sensor data will be developed, as well as mitigation mechanisms to correct possible data errors. In order to improve the data accuracy and awareness about the effective data quality, the combination of data processing techniques and model-based redundancy schemes will also be studied.

In terms of data transmission, the protocols and strategies already developed in the state-of-the-art will be integrated to create a dependable aquatic monitoring platform, as generic as possible for application to any water body. The platform will allow the user to flexibly define the level of desired robustness.

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