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Platform for the management of hydraulic chambers based on mobile devices and Bluetooth Low-Energy motes

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ABSTRACT

Agencies and institutions that are in charge of water distribution and treatment facilities devote significant resources to inspection and control of such facilities. In this paper, the procedures involved in these activities are discussed and optimized for automated treatment with mobile devices. To this purpose, a novel remote control application for the management and detection of faults and breakdowns of collective water distribution networks in irrigation systems has been developed. The developed platform makes use of BLE (Bluetooth Low-Energy) technology to provide contactless, context-and-positioning sensitive information to the user, simplifying periodic inspections and repairing tasks of the network infrastructure. Devices would be equipped with BLE-enabled motes capable of transmitting a beacon signal for equipment discovering. Operators in turn, would carry tablets or smartphones configured to detect the motes and stablish a link in case additional data must be exchanged. The tablet also allows the operator to revise and fill in a device's form customized with context sensitive information gathered from both the mote and the enterprise cloud services and finally, to update the information in the online databases.

1. Introduction

In geographical zones with limited water availability, one of the main objectives for the infrastructures that are managing water in agriculture is the improvement in the optimization of water and energy. An example of this infrastructure is the collective pipe networks for irrigation in water users associations (WUAs). Controlling the excessive water and energy consumption and achieving cost savings, it is possible to pursuit an efficient water management (Fernández-Pacheco et al., 2015; Bagirov et al., 2013; Rodríguez Díaz et al., 2011). The achievement of this objective can be obtained by means of several technologies and devices: decision support systems tools (Khan et al., 2010), software for management of pump stations (Lamaddalena and Khila, 2013), devices for energy management (Reca et al., 2014), employment of performance indicators (Córcoles et al., 2012), etc. Among the existing technologies for the adequate management of water and energy resources, irrigation systems management based upon automation and remote control tools is one of the simplest and robust methods for saving water and energy. Using a periodical control of several parameters (performance indicators of water and energy consumption, detection of faults and breakdowns, among others) at several levels (collective pipe network of a WUA, irrigation pipe network of a farmer, irrigation zone, among others) it is possible to detect, measure and manage the quantity and quality of water and the energy that is flowing in several places of the pipe network in a determined time. Based on the information provided by these devices, it is possible to suggest different scenarios of water and energy consumption. According to these scenarios, intelligent systems for opening and closing valves (Sweigard, 2003) and remote control systems for the maintenance of irrigation pipe network (Abderrahman et al., 2001) can be activated.

Moreover, water distribution and treatment facilities demand significant resources for inspection and control procedures. Therefore, efforts towards standardization, systematization and automation of these processes are currently strategic lines for many of the institutions in charge of these facilities, as they allow reducing errors, response times, rework, and ultimately, the costs associated with the facilities management (Bueno et al., 2015; Jiménez-Buendía et al., 2015).

Within this context, this paper presents a proposal for a distributed telemetry and control system, which is specifically tailored to the monitoring of distribution water infrastructures (canals, chambers, tanks, etc.) for collective pipe networks in WUA. The

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proposed platform brings as main innovations the use of mobile devices for operators and BLE (Bluetooth Low Energy) enabled sensors, or *motes*, for data acquisition.

Over the las decade, RFID (Radio Frequency IDentification) technology has been used in some cases for this kind of applications. However, RFID is limited to transmitting very little data within a short distance (centimeters). Moreover, this technology requires specialized scanners and greater effort to perform the data transmission. Both restrictions have kept its use limited to a few applications (Ruiz-Garcia and Lunadei, 2011).

Other technologies for low power wireless sensor communication, like Zigbee and ANT, lack common hardware support in consumer devices. In (Balmos Andrew et al., 2013) the authors suggest that using a more ubiquitous technology, such as BLE, that is already owned by most farmers or operators could significantly reduce cost and complexity. Their estimations for the battery life of a typical device under different duty cycles, demonstrate lifetimes of more than 2 years, which is also desirable. Other authors have studied commercial sensor nodes for wireless systems on battery supply and provided energy management approaches (Junaid Ahmed et al., 2014; Stefanos et al., 2015; Anisi et al., 2014).

In addition, the use of BLE beacons provides the advantage of facilitating the inspection and control, allowing the operator to receive automatically on his/her mobile device the relevant information for each indicator when approaching it, without having to take any kind of action. This eliminates the need for manually inspecting and recording data from information panels, or having to connect physically to the instruments, minimizing errors and accelerating the data intake.

This transparent flow of context-sensitive data is particularly useful indoors, where GPS-based systems are useless; but it is also advantageous in outdoor applications that require small sensors or a large number of devices, what would prevent the use of GPS in practice, due to the higher size-weight, power consumption and cost of this equipment (Ojha et al., 2015).

An extensive review of wireless sensor networks (WSN) with application in agriculture can be found in (Aqeel-Ur-Rehman et al., 2014), where the authors compare sensors used in agriculture domain from different points of view, including measuring principle, application purpose, communication technology and energy consumption. Bluetooth is exposed as a technology with the adequate tradeoff between cost, security, data rate, distance range and availability.

The rest of the paper is organized as follows. Section 2 describes the underlying platform developed for the inspection of water distribution and similar facilities. Then, Section 3 presents a methodology for the inspection procedures and results of the proposed method, along with a sample usage of the software. Finally, the most relevant conclusions and future research lines are drawn in Section 4.

2. Materials and methods

The advantages of WSNs in precision agriculture have been widely documented. Applications for intelligent irrigation systems (Yu et al., 2013; Navarro-Hellín et al., 2015; Coates et al., 2013) or general environmental monitoring systems (Mesas-Carrascosa et al., 2015; Shining et al., 2011; Srbinovska et al., 2015) are some of the most recent references. However, most of these applications require the interconnection of the sensors in a wide-area mesh, the use of GPRS modems or WiMAX technologies to connect to central nodes, or both. Our case study, however, differs from the architectures found in the bibliography in that there is no need of a direct link between the sensors nodes and the central host, as this link is provided by the operator‘s mobile device at the time of the regular inspection. Thus, in our case, only local (wired) connections are needed from the BLE Nano mote to its surrounding sensors. This fact simplifies and cheapens the system architecture, and does not prevent from including some special nodes with direct online connection if required for a particular setup. With these premises, the architecture of the developed platform has three principal components, as it is shown in Fig. 1. Their behavior is depicted in the following paragraphs.

2.1. Data acquisition and BLE beaconing subsystem

The mote selected for the sensor platform was the BLE Nano Kit from Red Bear Company Limited (RedBear, 2016). The Nano is one of the smallest BLE-enabled boards, only 18.5 × 21.0 mm, and one of the cheapest, to our best knowledge. It is based on the Nordic nRF51822 chip, which includes an ARM cortex-M0 SoC plus the BLE radio running at 16 MHz with ultra-low power consumption, less than 3 μA when it is powered from 1.8 V to 3.6 V in idle mode.

Fig. 2a shows a block diagram of the data acquisition and beaconing subsystem. It includes the Nano board and a number of dedicated signal conditioning stages or boards as needed. The PC boards are assembled and connected to the shockproof terminal blocks inside a fully insulated enclosure for standard DIN rails, as shown in Fig. 2b.

Software applications (apps) can be developed for the Nano using three different environments. For small prototypes, Arduino sketches, by means of the Arduino Library for nRF51822 developed by RedBear is the simplest option. For professional rapid development of products based on ARM microcontrollers, a better option is using the mbed Platform developed by ARM. Finally, for the most demanding applications, the nRF51822 SDK provided by Nordic gives full access to fine-tuning every chip's feature. In this case, the ARM mbed framework was selected, as it already includes standard access to advanced communication libraries for BLE, which accelerated our software development cycle. The active online community provides also a large set of modules as C++ APIs that are free and ready to use.

The app in the BLE Nano consists of two stages. The acquisition stage is able to capture data from a flow meter, valve or pressure sensor using 4–20 mA analogue inputs, digital inputs or typical industrial protocols such as Modbus, in our case. Other interfaces (I2C, SPI, RS232, etc.) have been tested on board and could be implemented if needed.

The second stage is devoted to BLE communication. Compared to Bluetooth Classic, BLE consumes less power and requires less time and effort to pair devices, but provides lower connection speeds. This stage implements the GAP and GATT profiles to a private high-level interface that is shared with the mobile device. The Generic Access Profile (GAP) stablishes the peripheral role for the Nano and sets up the advertising mode, what keeps it sending a beacon signal regularly so that it can be detected. This includes configuring the advertisement interval, which can be set from 20 ms to 10.24 s. In our case, a 2 s gap was selected, as an adequate tradeoff between speed and power consumption. It is worth noting that while in broadcasting (advertising) mode no connection is stablished, which allows considerable energy savings, which is mostly spent during the connection phase.

The GAP Beacon payload, encapsulated within the advertising data structure, has three fields: a 16 bytes identification code (UUID), a 2 bytes Mayor/Minor field, and one additional byte for the Tx Power. These fields could be used for small data broadcasting from sensors, providing enough space for most IoT applications, as in our case. However, in anticipation of future enhancements that could require larger data exchanges, we decided to include a separate GATT service for data exchange.