Smart System for Monitoring and Control of Swimming Pools

Gonçalo Simões[1,2], Carolina Dionísio[1,2], André Glória[1,2], Pedro Sebastião[1,2], Nuno Souto[1,2]
[1] ISCTE – IUL, Av. Forças
[2] Instituto de Telecomunicações, Av. Rovisco Pais, 1, Lisbon, Portugal
garss@iscte-iul.pt, cadoo@iscte-iul.pt, afxga@iscte-iul.pt, pedro.sebastiao@iscte-iul.pt, nuno.souto@iscte-iul.pt

***Abstract*— This paper proposes a new scheme for monitoring and controlling the swimming pool's quality through a low-cost system based on wireless sensor networks, which can reduce the requirements for human intervention in the swimming pool maintenance. The main purpose of this system is to provide resources savings for the final user in financial and natural resources, contributing to a sustainable environment. This article also presents a mobile application for interacting with the proposed system which enables users with administrator permissions to control some actions in the swimming pool, in order to stabilize some required parameters for its good quality.**

Keywords—Internet of Things, Wireless Sensor Network, Swimming Pool, ESP32, LoRa, Sustainability

I. INTRODUCTION

Information and communications technology, over the years, has been progressively present in human life, being a branch that is in constant evolution and an essential part in our everyday life. With this evolution there is a growing number of physical objects and devices connected to the Internet, giving rise to the concept of the Internet of Things (IoT) [1]. IoT consists of a network of physical objects that are able of being connected to the Internet, identifying themselves, and communicating with each other to achieve a common goal. The main purpose of this technology is to exchange and update data between physical objects and hence to achieve an optimum performance [2].

When talking about IoT it is also useful to approach another concept called Wireless Sensor Networks (WSN), a technology that is inherent in the development of smart systems. Recently, IoT and WSN have been great bets in the development of monitoring and control systems by researchers [3]. This capability of monitoring and control covers a growing range of applications, among which some related to monitoring of swimming pools.

Swimming pool conditions directly depend on how well their chemical properties are monitored [4]. Its maintenance requires the performance of some tests that may be more complex when performed by a human. Therefore, it is important to implement a sensor network that is able to perform those tests correctly and more precisely. To optimize its daily maintenance, instead of manually evaluate the water properties (pH, chlorine, water level, temperature), machine room condition and surrounding space quality, comes up the proposed system, which main purpose is to control and monitoring swimming pools automatically.

Sustainability assumes an important role in preserving the planet Earth sources. Thus, it is increasingly important for the society to have sustainable attitudes in simple daily activities and particularly in the development of new technologies. In the specific case of swimming pools, it becomes relevant to monitor the water and energy consumption levels through a sensor network and, consequently, to adjust their consumption, so that there is no waste of those resources for purposes deemed not essential for the correct operation and maintenance of swimming pools.

Taking into consideration that the incorrect use of fresh water in recreational activities is nowadays a big concern as well as the need to keep track of water quality in order to inform the user about potential risk situations, swimming pool monitoring systems is something we can see in numerous automation projects already developed.

In [3], the authors developed an information and management system for swimming pools. This system consists of a sensor node interfacing with sensors (to measure pH, chlorine level, temperature, cleaner mobility and water level) and actuators, and a web-based user interface that can be accessed remotely for controlling the system. The project has really accurate sensors, providing an optimum maintenance of the swimming pools. However, the implemented sensors are extremely expensive, which creates a system that is not easily accessible to all users.

The authors in [4] developed a low-cost swimming pool automation system that, to keep the swimming pool in good conditions, performs tests on chlorine level and pH and automatically makes the necessary adjustments. The main goal of this project was to lower the energy consumption of the system by reducing automatically the functioning time of the water pump.

Some solutions already exist for the intended application but none was based on the deployment of a WSN with multiples nodes spread across the pool to compare values in multiple locations. Our proposal differs as it adopts a full WSN approach, in a modular architecture where new sensors can be added without compromising the network performance. The system is based on the use of low power consumption nodes and a communication protocol capable of connecting nodes spread along large areas with high reliability and low power.

Saying that, in this paper the authors propose a new system that can monitor and control the water properties (pH, chlorine, water level, temperature, water pressure), machine room and surrounding space quality bearing in mind the reduction of the consumption of natural and material resources, and the monetary saving by the final user.

II. PROPOSED SYSTEM ARCHITECTURE

The purpose of this paper is to develop a control and monitoring system applied to swimming pools (public and private domain). This system is responsible for collecting some significant data from the point of view of maintenance,

978-1-5386-4980-0/19/$31.00 ©2019 IEEE

through a low-cost WSN, in order to evaluate if the swimming pool quality is within the desired parameters, whether at water level, piping leakage, environment quality or engine room efficiency.

The data obtained from the sensors will be stored and treated in such a way as to keep the user informed about the parameters considered relevant to the swimming pool quality. These will be presented to all the pool users and can only be controlled by a user with administrator permissions through an app (in case of private pools, by their owner and in case of public pools by their maintainer). When an anomaly is detected, the user will be notified and able to remotely control some actions on the swimming pool in order to stabilize the anomalous values that triggered the alert.

The proposed architecture follows the same structure of a common WSN. This type of networks can be composed by a microcontroller, a communication system for inter and intra communication between the nodes and a set of sensors [5]. A high-level view of the adopted system architecture can be seen in the Figure 1.

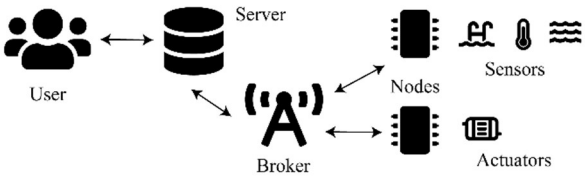

Fig. 1. Proposed system architecture

A. Communication

The system architecture is composed of a single gateway (broker), a set of sensor nodes (each node can support a maximum of eight sensors) and actuator nodes. The gateway is in constant communication with an online server through the Message Queuing Telemetry Transport (MQTT) protocol via WiFi connection. The MQTT protocol is a protocol well-suited for IoT communications, as it is able to provide routing for small, low power, low cost and low memory devices in low bandwidth networks [1].

Although a swimming pool is normally a confined environment, some nodes can be hundreds of meters apart (distance between an outdoor pool and its compensation tank). This combined with the need to have power efficient nodes implies that is useful to select a communication protocol able to meet these requirements. As can be seen in [6], one of the wireless communication protocols that best suits the mentioned characteristics is LoRa, since it is a bidirectional communication protocol that can provide a low power and long range communications, meeting all the requirements for the proposed system and presenting better characteristics when facing, for example, WiFi, Bluetooth, ZigBee or LTE. Therefore, the sensor/actuator nodes will communicate with the broker through a peer-to-peer LoRa connection.

B. Hardware

The proposed sensor network has three types of nodes in its constitution: sensor nodes, actuator nodes and a gateway.

The first has the capability to sense, process and communicate data by themselves [7]. These are mainly composed of a set of sensors that will be periodically sensing a specific type of data. These nodes will only be awake for short periods of time, as they will be powered by batteries, as shown in Figure 2.

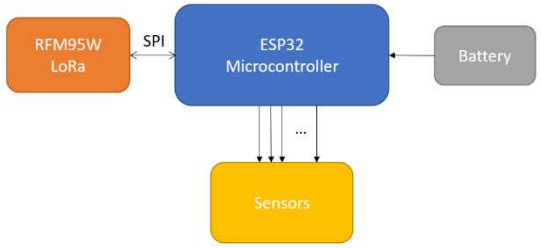

Fig. 2. Sensor node block diagram

Actuator nodes architecture is represented in Figure 3. They are responsible for the system control, having the capability to control and manipulate the system conditions. Particularly, in the presented system, these nodes will provide the user the ability to control the water pumps and pool's chemical conditions.

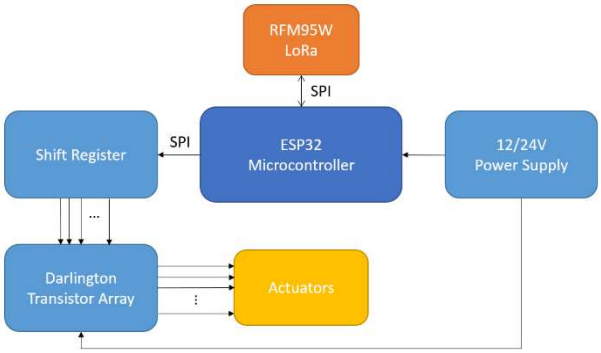

Fig. 3. Actuator node block diagram

The gateway is composed of a microcontroller and a communication module, as shown in Figure 4. This node does not read the sensors data and have the responsibility of collecting data from all the sensor nodes and sending them to the server.

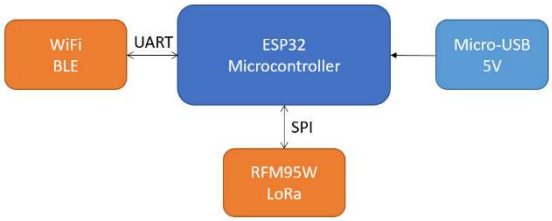

Fig. 4. Gateway block diagram

Each one of the described nodes, despite its different functionalities, will be using the same hardware, which is composed of:

- ESP32 - a microcontroller compatible with IoT applications due to its low cost, low power system with integrated WiFi and dual-mode Bluetooth capabilities [8]. Besides that, it has power saving features, among which there is one named Deep Sleep. This feature will be applied to the sensor nodes so that they only "wake up" when they need to send data to the broker.

- RFM95W - LoRa transceiver that provides ultra-long-range communication and high interference immunity whilst minimising current consumption with a sleep function which contributes for a lower power consumption [9].

The selected hardware was chosen due to its high performance and characteristics. Regarding the microcontroller, the dual-core, low consumption in Deep Sleep Mode, and multiple communication protocols available were decisive when facing other common microcontrollers for IoT projects, such as the ESP8266, Arduino Uno or Raspberry Pi. In terms of communication modules, the RFM95W is the most common LoRa transceiver, allowing not only a local network but also LoRaWAN connectivity, something that the RFM69, RFM98 or RN2483 are not capable.

To accomplish the power saving criteria, the minimum time interval for sensor data collection will be analysed so that the sensors do not have to send constant data in real time, and thus can have lower energy requirements.

C. *Software*

The collected data will be treated and stored in an online server that sends these values to an Android application (Figure 5). This app will present all the stored data to the swimming pool users. Besides the data representation, the app will enable users with administrator permissions to remotely control the actuators so as to stabilize the anomalous values detected.

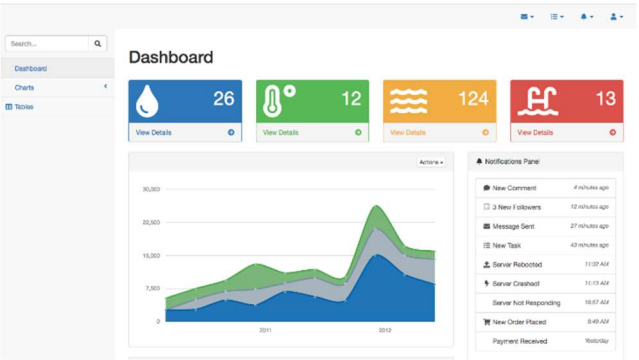

Fig. 5. Android application

The whole process, starting from the data collection to its presentation in the android application is represented in Figure 6.

The system nodes communicate with each other through a peer-to-peer LoRa connection, using the RFM95W modules. This system will use the Arduino library RadioHead [10], that enables the nodes addressing.

The nodes can communicate in two different ways, both encrypted by the API:

- Send directly a message to a specific node, using the destination address;
- Sending a broadcast message with the destination node ID to every node in the network;

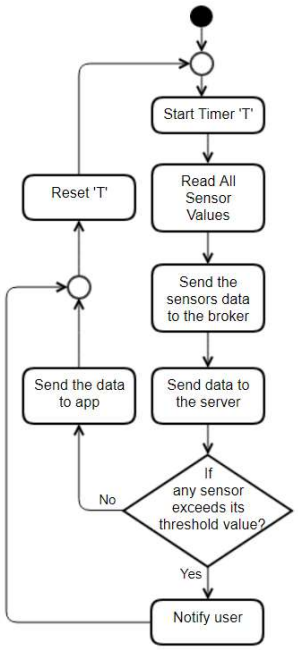

Fig. 6. Flowchart of software implementation

In the first scenario, the RadioHead library assures the network fidelity by sending an automatic ACK response to the origin node that sent the message, using its ID. However, when broadcast message is sent, the library cannot guarantee the reliability of the network. To cope with this limitation, each destination node will read the ID on the message, and if this parameter corresponds to its ID, the node will accept the message, confirming that it was received by sending an ACK response to the origin node. Our proposed system uses both communication methods, the first when sensor nodes send information to the gateway and the second when the gateway sends information to the sensor node.

The use of an ACK response will improve some key features in IoT systems, such as network efficiency and reliability.

III. Proposed System Implementation

Designed and presented the system architecture capable of control and monitoring swimming pools, will be realized the following implementation to evaluate the system architecture.

The proposed system implementation consists of three sensor nodes to be applied as follows:

1. In the compensation tank, an integrated component in common swimming pool systems, located away from the pool users, and whose purpose is just to control the pool quality. The node will be incorporate chlorine level, pH, temperature and water pressure sensors;
2. In the swimming pool itself. The node will be composed of two water level sensors placed in the swimming pool borders;
3. In the swimming pool surroundings, indoor or outdoor. The node will include a humidity and temperature sensor to evaluate the environment humidity and temperature in the pool location.

To measure the mentioned parameters, the following sensors will be used:

- DS18B20, a digital thermometer that allows temperature readings from -55ºC to +125ºC [11] and will be used to measure the water temperature;
- DHT22, a temperature and humidity sensor that allow temperature readings between -40ºC and +80ºC and humidity readings between 0% to 100% [12] (environment temperature and humidity);
- POW110D3B, a water flow sensor composed of a valve body, a water rotor and a hall-effect sensor that outputs the corresponding pulse signal [13];
- SEN01161, an analog pH meter kit, that allows pH readings from 0 to 14 [14];
- SEN0165, an analog ORP meter, that takes into account the concentration and the activity of the chlorine in the water and provides a measurement of the effectiveness of the chlorine [15];
- SEN0205, a liquid level sensor that operates using optical principles, has good sensitivity and no need for mechanical parts [16];
- SEN0189, a turbidity sensor, that detects water quality by measuring the levels of turbidity. It uses light to detect suspended particles in water by measuring the light transmittance and scattering rate [17].

When the collected data from the sensors exceeds the threshold values, the system will notify the user through his smartphone, so that the he can take control of the swimming pool to stabilise the values that triggered the alert. For that, an actuator node will be implemented alongside the pumps and chemicals controllers.

The proposed system is flexible in the sense that new nodes can be added to create more rigorous analyzes, without compromising the network capabilities.

IV. Conclusions and Future Work

This paper presents a proposal for a system that provides users the capability to effectively control and monitor their swimming pools. The proposed solution has the main goal of promoting a sustainable environment, reducing the consumption of natural and financial resources for the final user and thus achieve a high-efficiency level. The proposed architecture is based on WSNs, combining low-cost and low power hardware with long range communication modules, that allows the system to be more efficient and run on batteries for extensive time periods.

For future work, the system needs to be implemented and tested in real case environments in order to analyse its performance and thus conclude if it is possible to reach the desired efficiency level.

Although this system was designed for swimming pools, other water features, such as artificial fountains or lakes, can be used as additional implementation scenarios.

Acknowledgements

This work was supported in part by ISCTE – Instituto Universitário de Lisboa from Portugal under the project ISCTE-IUL-ISTA-BM-2018 and by the FCT – Fundação para a Ciência e Tecnologia and Instituto de Telecomunicações under project UID/EEA/50008/2013

References

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015.

[2] H. N. Saha, A. Mandal, and A. Sinha, "Recent trends in the Internet of Things," *2017 IEEE 7th Annu. Comput. Commun. Work. Conf. CCWC 2017*, pp. 15–18, 2017.

[3] J. M. Marais, D. V. Bhatt, G. P. Hancke, and T. D. Ramotsoela, "A web-based swimming pool information and management system," *IEEE Int. Conf. Ind. Informatics*, pp. 980–985, 2017.

[4] R. Gouws and A. Nieuwoudt, "Design and cost analysis of an automation system for swimming pools in South Africa," *(DUE), 2012 Proc. 20th*, no. 2, pp. 9–15, 2012.

[5] G. S. Menon, M. V. Ramesh, and P. Divya, "A low cost wireless sensor network for water quality monitoring in natural water bodies," *GHTC 2017 - IEEE Glob. Humanit. Technol. Conf. Proc.*, vol. 2017–Janua, pp. 1–8, 2017.

[6] A. Gloria, F. Cercas, and N. Souto, "Comparison of communication protocols for low cost Internet of Things devices," *South-East Eur. Des. Autom. Comput. Eng. Comput. Networks Soc. Media Conf. SEEDA-CECNSM 2017*, 2017.

[7] K. R. R. Babu, S. J. George, and P. Samuel, "Optimal sensor selection from sensor pool in IoT environment," *Proc. 2016 2nd Int. Conf. Appl. Theor. Comput. Commun. Technol. iCATccT 2016*, pp. 697–702, 2017.

[8] S. B. Biswas, "Solar Water Pumping System Control Using a Low Cost ESP32 Microcontroller," *2018 IEEE Can. Conf. Electr. Comput. Eng.*, pp. 1–5, 2018.

[9] Adafruit, "RFM95_96_97_98W." [Online]. Available: https://cdn-learn.adafruit.com/assets/assets/000/031/659/original/RFM95_96_97_98W.pdf?1460518717. [Accessed: 04-Dec-2018].

[10] Adafruit, "RadioHead." [Online]. Available: https://github.com/adafruit/RadioHead. [Accessed: 05-Dec-2018].

[11] M. Integrated, "DS18B20 Datasheet." [Online]. Available: https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf. [Accessed: 07-Dec-2018].

[12] SparkFun, "Humidity and Temperature Sensor - DHT22." [Online]. Available: https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf. [Accessed: 07-Dec-2018].

[13] Chipdip, "G 1/2 Water Flow sensor." [Online]. Available: https://lib.chipdip.ru/583/DOC000583441.pdf. [Accessed: 10-Dec-2018].

[14] DFRobot, "PH meter(SKU: SEN0161)." [Online]. Available: https://www.dfrobot.com/wiki/index.php/PH_meter(SKU:_SEN0161). [Accessed: 10-Dec-2018].

[15] DFRobot, "Analog ORP Meter(SKU:SEN0165)." [Online]. Available: https://www.dfrobot.com/wiki/index.php/Analog_ORP_Meter(SKU:SEN0165). [Accessed: 10-Dec-2018].

[16] DFRobot, "Liquid Level Sensor-FS-IR02 SKU: SEN0205." [Online]. Available: https://www.dfrobot.com/wiki/index.php/Liquid_Level_Sensor-FS-IR02_SKU:_SEN0205. [Accessed: 10-Dec-2018].

[17] DFRobot, "Turbidity sensor SKU: SEN0189." [Online]. Available: https://www.dfrobot.com/wiki/index.php/Turbidity_sensor_SKU:_SEN0189. [Accessed: 10-Dec-2018].