DEVELOPMENT OF AN INTEGRATED SYSTEM FOR EFFICIENT WATER RECOURSES MANAGEMENT USING ESP32, MICROPYTHON AND IOT

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Abstract This article describes the development and implementation of a water resource management system utilizing open technologies such as the ESP32 microcontroller and MicroPython. This system stands out for its low cost, high efficiency and adaptability to various environments, thanks to the integration of free or low-cost communications such as LoRaWAN and NB-IoT, as well as the use of open-source programming that offers flexibility. The article details the use of JSN-SR04T ultrasonic sensors for water level measurement and the use of 3D printing to manufacture customized components, demonstrating a scalable and replicable solution for efficient water management.

Keywords: Smart water technology, Internet of Things (IoT), ESP32 board, 3D Printing technology, Low-Power Communication, ESP32 microcontroller.

1. Introduction

The global water shortage and climate change call for urgent innovation in water resource management. This study presents a smart approach that combines the ESP32 microcontroller with MicroPython programming for the monitoring of wastewater and potable water. The design of a modular and open-source system offers an adaptable and efficient solution, ideal for implementation in various contexts, including remote areas without access to the electrical grid.

The concept of smart water-management systems has extensively described in academic articles [1]. In this review, it is concluded that the predominant applications are related to distribution processes, use of the water and water management systems, but it is detected a total absence of applications intended for wastewater and effluent reuse processes.

Now days there are powerful, low-cost platforms and low energy consumption for developing real-time telemetry devices based on IoT communication. After analyzing different options, we highlight the ESP32 card, known for its open hardware nature and programmed with MicroPython [2], which enables adaptation to diverse applications and need, leveraging its energy efficiency. This card, connected with a low-power IoT communications, such as LoraWan [3] and NBiOT [4] it is essential to highlight how these technologies contribute to a more sustainable and efficient water resource management. These low-power communication platforms are vital for the real-time data transmission from remote locations, enabling a rapid response to changing conditions and potential environmental risks. Present document outlines the design methodology and field tests that support the validity of this technology.

2. Materials, design and methods

This section describes provides an overview of the system's architecture, highlighting the integration of hardware and software components tailored for efficient data acquisition and communication.

2.1. Datalogger Design

Figure 1 shows the PCB (Printed Circuit Board) designed and installed in the system. It incorporates the components described in Table 1, and offers versatility with analog and digital inputs for a variety of sensors and devices. Field communications use the Modbus RTU protocol via RS-485 for data collection from the sensors, while data transmission to the control center uses LoRaWAN or NB-IoT depending on availability and coverage needs.

Figure 1. PCB designed.

Table 1. Principal Components and Specifications

Component	Model	Description
Microcontroller	ESP32 WROOM-32	Chosen as the system's core due to its low energy consumption, powerful processing capacity and open hardware nature. It is also compatible with MicroPython, which offers programming flexibility known for its simplicity and readability.
MAX485	MAX485	Incorporated to facilitate robust and reliable field communication through the Modbus RTU interface.
MOSFET	IRF5210 IRLZ34NPBF	Used for precise power control, allowing for the programmed activation and deactivation of sensors, which optimizes energy efficiency and extends battery life.
RTC Clock	DS3231	Essential for preserving the temporal accuracy of data
LoRaWAN and NB-IoT Chips	E220-900T22S NBiOT ESIM	Selected for their ability to provide long-range communications with minimal energy consumption, equipped with specialized antennas for optimal signal.
Rechargeable Batteries	-	Chosen to provide a longer lifespan and reduce waste generation, reflecting the project's commitment to environmentally sustainable practices.
OLED (Organic Light-Emitting Diode)	-	Added as an option for an intuitive local user interface, allowing for diagnostics and direct data display in the field.
Ultrasonic sensor	JSN-SR04T	Chosen for its accuracy, low cost, very low energy consumption, and water resistance, ensuring reliable and continuous data collection [5]

2.2. Data communication

At the heart of our communication infrastructure, we have selected LoRaWAN and NB-IoT for their remarkably low energy consumption. LoRaWAN stands out as the more efficient of the two, making it our preferred choice. This technology is characterized by not incurring periodic subscription costs, making it exceptionally suitable for applications where cost-effectiveness is crucial. On the other hand, NB-IoT, with its advantages in terms of range and signal penetration in dense urban environments, serves as an alternative in places where LoRaWAN does not offer optimal coverage.

2.3. Custom Component Design and Manufacturing

Utilizing CAD software, we designed and optimized models for supports and casings, which were then manufactured using 3D printing (Figure 2). This approach provided us the flexibility to customize the assembly of our system to the specific needs of each project, from creating a robust protective case for the datalogger to manufacturing tailor-made supports for the ultrasonic sensor. Moreover, the accessible nature of 3D printing means that any user with access to a 3D printer can independently reproduce these designs, facilitating project expansion and collaboration.

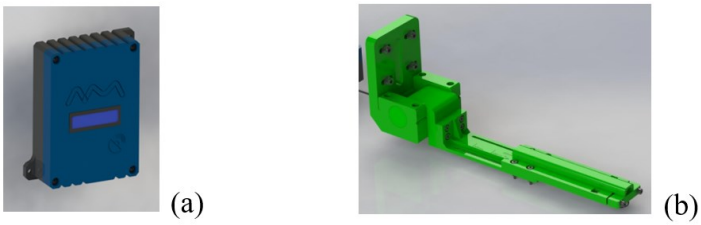

Figure 2. Customized supports: (a) Datalogger box; (b) Ultrasonic support.

3. Implementation and Testing

3.1. Ultrasonic Sensor, Materials, and Datalogger

Figure 3 shows a comparison result between the ultrasonic sensor JSN-SR04T and a commercial radar-type sensor, we found that the results were very similar. There were variations of about 1%, which can be attributed to the placement of the sensors. The ultrasonic sensor was located at a slightly different point than the radar-type sensor, in an area with a slight incline.

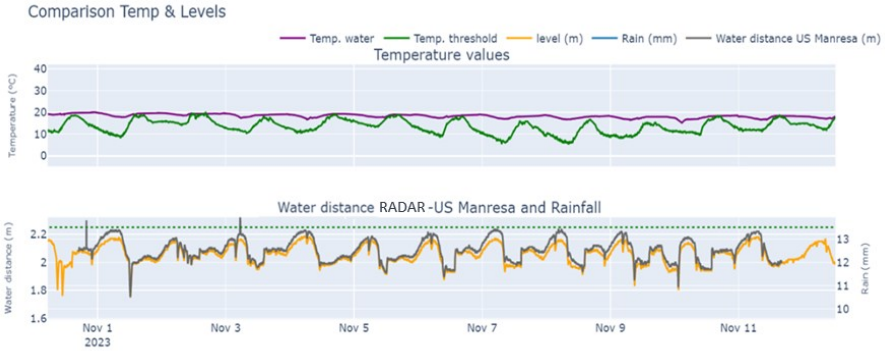

Figure 3. Comparison Temperature and Levels PCB designed.

The integration of components manufactured with 3D printing (Figure 4) proved successful, resulting in robust parts that contribute to the integrity and durability of the datalogger. The adaptability of the printed design allowed for optimization in the installation of the ultrasonic sensor, ensuring its optimal alignment and functionality.

Figure 4. (a) Datalogger; (b) Datalogger-Ultrasonic Sensor; (c) Ultrasonic Sensor.

3.2. Comunication

The deployment of three dataloggers in the “La Séquia” canal provided diversified information to assess the system's consistency across different communication scenarios. Two of these devices employed LoRaWAN technology, and the remaining one used NB-IoT, thus offering a direct comparison of the performance of these platforms in a consistent operational environment. The results showed that both technologies ensure reliable and efficient data transmission. LoRaWAN, in particular, stood out for its exceptional energy efficiency. NB-IoT, on the other hand, proved to be a robust solution in scenarios where the LoRaWAN signal was not ideal or a higher data sending frequency is required, providing an effective alternative without significant interruptions in data communication. This set of tests provides

a solid foundation for the validation of the system's architecture, confirmed by the stability and integrity of the collected information. The reliability and sustained performance of the system, even in the face of environmental and operational variables, indicate its suitability for widespread application in water resource management.

4. Conclusions

This analysis highlights the importance of adopting open and accessible technologies in water resource management. The combination of ESP32, MicroPython, and low-cost communications offers an efficient and autonomous solution for water monitoring. The successful implementation in Manresa serves as a reference for future large-scale applications, promoting more sustainable and autonomous water management.

References

1. Soares Ascenção, É.; Melo Marinangelo, F.; Meschini Almeida, C. F.; Kagan, N.; Dias, E. M. Applications of Smart Water Management Systems: A Literature Review. Water, 2023, 15(19), 3492.
2. Beaudoin, L.; Avanthey, N.; Villard, C. Porting ardupilot to esp32: towards a universal open-source architecture for agile and easily replicable multi-domains mapping robots. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2020, 43, 933-939.
3. Ragnoli, M.; Barile,G.; Leoni,A.; Ferri, G.; Stornelli, V. An Autonomous Low-Power LoRa-Based Flood-Monitoring System. Low Power, 2020, 10(15), 15.
4. Mekki, K.; Bajic, E.; Chaxel, F.; Meyer, F. A comparative study of LPWAN technologies for large-scale IoT deployment, ICT express, 2019, 5(1), 1-7.
5. Kumar, A. K.; Sarangi, A.; Singh, D. K.; Dash, S.; Mani, I. Evaluation of Ultrasonic Sensor for Flow Measurement in Open Channel. Journal of Scientific & Industrial Research (JSIR), 2023, 82(10), 1091-1099.