Lecture Notes in Networks and Systems 1040

Marcelo Zambrano Vizuete · Miguel Botto-Tobar · Sonia Casillas · Carina Gonzalez · Carlos Sánchez · Gabriel Gomes · Benjamin Durakovic *Editors*

Innovation and Research – Smart Technologies & Systems

Proceedings of the CI3 2023, Volume 1

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Preface

The 4th edition of the International Research and Innovation Congress – Smart Technologies and Systems, CI3 2023, took place from August 30 to September 1, 2023, at the facilities of the Instituto Tecnológico Universitario Rumiñahui, located in the city of SangolquÍ, Pichincha, Ecuador.

The conference was organized by the Red de Investigación, Innovación y Transferencia de Tecnología RIT2, made up of the most relevant university institutes in Ecuador, among which are ITCA, BOLIVARIANO, ARGOS, VIDA NUEVA, ESPÍRITU SANTO, SUDAMERICANO, ISMAC, SAN ISIDRO, ARTES GRÁFICAS, ORIENTE, HUMANE, SUCRE, CENTRAL TÉCNICO, POLICÍA NACIONAL and RUMIÑAHUI.

Additionally, the event is sponsored by the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación SENESCYT, Labortorio de Comunicación Visual de la Universidad Estatal de Campinas—Brazil, Universidad Ana G. Méndez—Puerto Rico, Centro de Investigaciones Psicopedagógicas y Sociológicas—Cuba, Instituto Superior de Diseño de la Universidad de La Habana—Cuba, GDEON and the Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia—CEDIA.

The main objective of CI3 2023 is to generate a space for dissemination and collaboration, where academia, industry and government can share their ideas, experiences and results of their projects and research.

"Research as a pillar of higher education and business improvement" is the motto of the Conference and suggests how research, innovation and academia must coincide with the productive sector to leverage social and economic development.

CI3 2023 had 145 papers submitted, of which 52 were accepted for publication and presentation. To guarantee the quality of the publications, the event has a staff of more than 70 experts, from different countries such as Spain, Argentina, Chile, Mexico, Peru, Brazil, Ecuador, among others, who carry out an exhaustive review of each proposal sent.

Likewise, during the event a series of keynote conferences were held, given by both national and international experts, allowing attendees to get in touch with the latest trends and technological advances around the world. Keynote speakers included: Ph.D. Carina González, University of La Laguna, Spain; Ph.D. Gabriel Gómez, State University of Campinas, Brazil; Ph.D. Carlos Sanchez, University of Zaragoza, Spain; Ph.D. Juan Minango, Instituto Tecnológico Superior Rumiñahui; Dr. Iván Cherrez, Universidad Espíritu Santo, Ecuador; and Ph.D. Nela Paustizaca, Escuela Politécnica del Litoral, Ecuador.

The content of this proceeding is related to the following topics:

- Smart Cities
- Innovation and Development
- Applied Technologies
- Economics and Management
- ICT for Educations.

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Contents

Designing a Water Level Measurement System to Monitor the Flow of Water from the Primary Catchment Source of Tulcán City Using LoRa Communication Technology

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Abstract. This study focuses on utilizing LoRa wireless communication technology to create a sensor network that measures the water level of a river. The collected data can help assess the current state of the river and detect any changes in its level. Alerts can be sent via email if any changes are detected. The system consists of various components. Firstly, sensor nodes are utilized that employ HC-SR04 sensors for level calculation. Secondly, the ESP32 microcontroller is connected to the LoRa RFM95 module for wireless transmission using LoRa. Finally, the microcontroller handles the processing tasks. The central node acts as a receiver for the data gathered by the sensor nodes. It consists of an Arduino Uno compatible with the LoRa RFM95 module. The central node is connected to a Raspberry PI 4 for processing and then sending the data using the MQTT protocol to the server. The information can then be viewed on the ThingSpeak platform. Tests have been conducted to verify the established communication between the nodes and the Gateway. The results have shown that the LoRa communication parameters are accurately established in the RFM95 modules. Additionally, the data sent from the nodes to the Gateway is visualized on ThingSpeak.

Keywords: LoRa · LoRa Gateway · ThingSpeak · catchment source

1 Introduction

Low-power communications and data transmission are the main objectives of the LoRa Alliance association, which developed and promoted the LoRa technology.

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In addition, the use of physical layer techniques allows for coverage of wide areas in terms of kilometers, as reported by [1].

LoRa has been chosen as the technology for designing the wireless sensor network because it provides advantages over its primary rival, SigFox. In contrast to SigFox, LoRa's standard modules serve as both transmitters and receivers without any limitation on data transmission. The acronym LoRa represents 'long-range', indicating one of its primary features. This is achieved through the utilization of a spread spectrum modulation technique known as spread spectrum chirp technology or CSS. LoRa technology is ideal for usage in wireless sensor networks and the Internet of Things due to its ability to implement a wide area network with low power consumption. This enables the maintenance of hundreds of devices connected through a wireless link to a hub or Gateway, which communicates with all network nodes, manages traffic, and shares information to the required destination [2].

A system for measuring the water level of Tulcan City's main water supply source will be developed using wireless communication technology. The system will use a network of wireless sensors connected through LoRa communication technology to identify high and low water levels witnessed in the source's channel.

Awareness of the water level in a water source is vital due to climate change leading to fluctuations in ambient temperature, rainfall frequency, and volume. Knowledge of this physical variable can indicate the potential for floods or droughts and can enable measures to decrease or increase water levels. The water resource level will be measured using an ultrasonic sensor that operates non-invasively without direct water contact. The microcontroller board equipped with a LoRa module processes the sensor signal to facilitate long-range communication with the concentrator node or the dedicated LoRa Gateway board. Processed data will be sent to the cloud and can be accessed via the Internet. The system monitors the water resource level daily, enabling frequent checks to identify changes in water levels and detect increasing or decreasing trends within the flow.

2 Related Work

The paper [3] addresses the problem of efficiently monitoring water levels in natural environments as a disaster prevention measure. Developed by Shinshu University in Japan, the system's objective is to effectively transmit water level, temperature, and humidity data. To achieve this, it employs LoRa technology in the 429 MHz band and a technique called Packet Level Index Modulation (PLIM). The system was implemented in Nagano City, Japan, for real-world testing. The study's conclusions indicate that the system demonstrated stable information aggregation and the ability to avoid packet collisions.

The study [4] tackles the challenge of real-time monitoring and predicting flash floods in Uttarakhand, India, using the Internet of Things (IoT). The aim is to create a low-cost, energy-efficient system that employs a variety of sensors and an Arduino UNO microcontroller. This data is then analyzed using a Long

Short-Term Memory (LSTM) model to issue real-time flood alerts. The system has shown high accuracy, with F1 scores of 97–98% for different alert levels, making it a valuable tool for disaster management.

In [5], the study focuses on addressing the issue of unanticipated flooding by developing an IoT-based monitoring system. Using an ultrasonic sensor and a NodeMCU microcontroller, the system sends data to the ThingSpeak platform for real-time monitoring and alert generation. Although tested in an academic setting, the system has the potential for application in flood-prone areas. The findings indicate that the system is effective in detecting changes in water levels and issuing alerts, which could be crucial for flood preparedness and response.

The authors of the paper [6], addresses the issue of inefficient water level management in dams, which can lead to either man-made or natural disasters. The aim is to develop an IoT-based monitoring system that can automatically route water from dams into canals. This system was tested using a model that includes an Arduino Uno microcontroller and an ultrasonic sensor to measure water levels in real-time. The data is sent to a base station and then stored in the cloud, where a command center makes decisions about opening or closing the dam gates. The findings suggest that the system could be effective in managing water resources and preventing calamities.

The paper [7] addresses the issue of real-time monitoring of water levels in the Al-Gharraf river in Wasit city, Iraq. The aim is to design a low-cost system that uses a microprocessor and an ultrasonic sensor to track water levels and relay the data via GPRS technology. The system was implemented at regulator No.1 in Al-Hay city and utilizes an Arduino Uno board and a JSN-SR04T ultrasonic distance sensor. The data is visualized on a ThingSpeak platform and updates every three minutes. The system achieved an accuracy rate of 96.84% and suggests that it could be improved with an additional network of sensors.

The study [8] tackles the issue of water pollution in the river in Riau Province, Indonesia. It aims to develop a smart sensor node to monitor multiple water parameters such as temperature, pH, dissolved oxygen, and electrical conductivity using Wireless Sensor Networks (WSN). The system was implemented in a laboratory setting and plans to be tested on the actual site. It utilizes a microcontroller and a variety of sensors, and the data is sent to a back-end system for analysis. Initial results show good agreement between theoretical and measured data, suggesting that the system is ready for real-environment testing.

The paper [9] focuses on the issue of water pollution in the Citarum River in Indonesia. The aim is to develop a fuzzy logic-controlled floating robot to monitor water quality in real-time. The system was tested in a controlled environment and uses an Arduino Uno microcontroller and sensors like the MPU6050 for stabilization. The robot can be manually or automatically controlled and sends data via an HC05 Bluetooth module. Although the robot is still not perfect in maintaining its position and has a tendency to sink due to the PLA material used, the results show that the system has a 92.67% accuracy in distance calculation using the Haversine Formula.

3 Development of the Water Level Monitoring System

The project is being developed in the parish of Rio Chico, Tufiño, which corresponds to the city of Tulcán in the province of Carchi. Rio Chico is a tributary of the river of the same name, which is recognised as a source for purifying water due to its special characteristics.

3.1 System Design

The system has been designed with three stages in mind: the sensing stage, the control stage, and the visualization stage. The system comprises three stages. The first stage collects data, specifically the water level variable. The control stage utilizes a control board for data processing while the visualization stage presents detailed information of the measured physical variable.

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The control stage utilizes a printed circuit controller board and a LoRa module, which establish communication with the sensors. The data collected is subsequently processed by this element and sent to the next respective stage.

The visualization stage involves observing different level measurements obtained from ultrasonic sensors on a web page accessible on the internet. This enables the variation of the water flow level to be viewed, along with other relevant information.

3.2 System Block Diagram

In Fig. 1 describe the system block diagram consists of the layers of the IoT architecture. It describes the essential elements and requirements to be employed in each layer for designing the proposed system in a general manner.

The device layer comprises ultrasonic sensors that acquire data for measurement. These sensors are connected to a micro-controller board, which executes the respective programming. Furthermore, a LoRa module facilitates wireless communication to the LoRa Gateway via this technology. In the Gateway layer, the printed circuit board or controller board with high processing capabilities is present. It is connected to a LoRa module to enable communication with the sensor nodes, forming the central node, or LoRa Gateway. This is the element of the network that receives all data collected from the sensors. The network layer establishes an internet connection, which can be achieved through wired or wireless media. In this case, the data from the LoRa Gateway is transmitted wirelessly to the servers using the MQTT connection protocol. At the Cloud layer or data center, received data is stored before being transmitted to the final layer, i.e., the application layer. Here, the data is displayed using graphical tools, such as a dashboard.

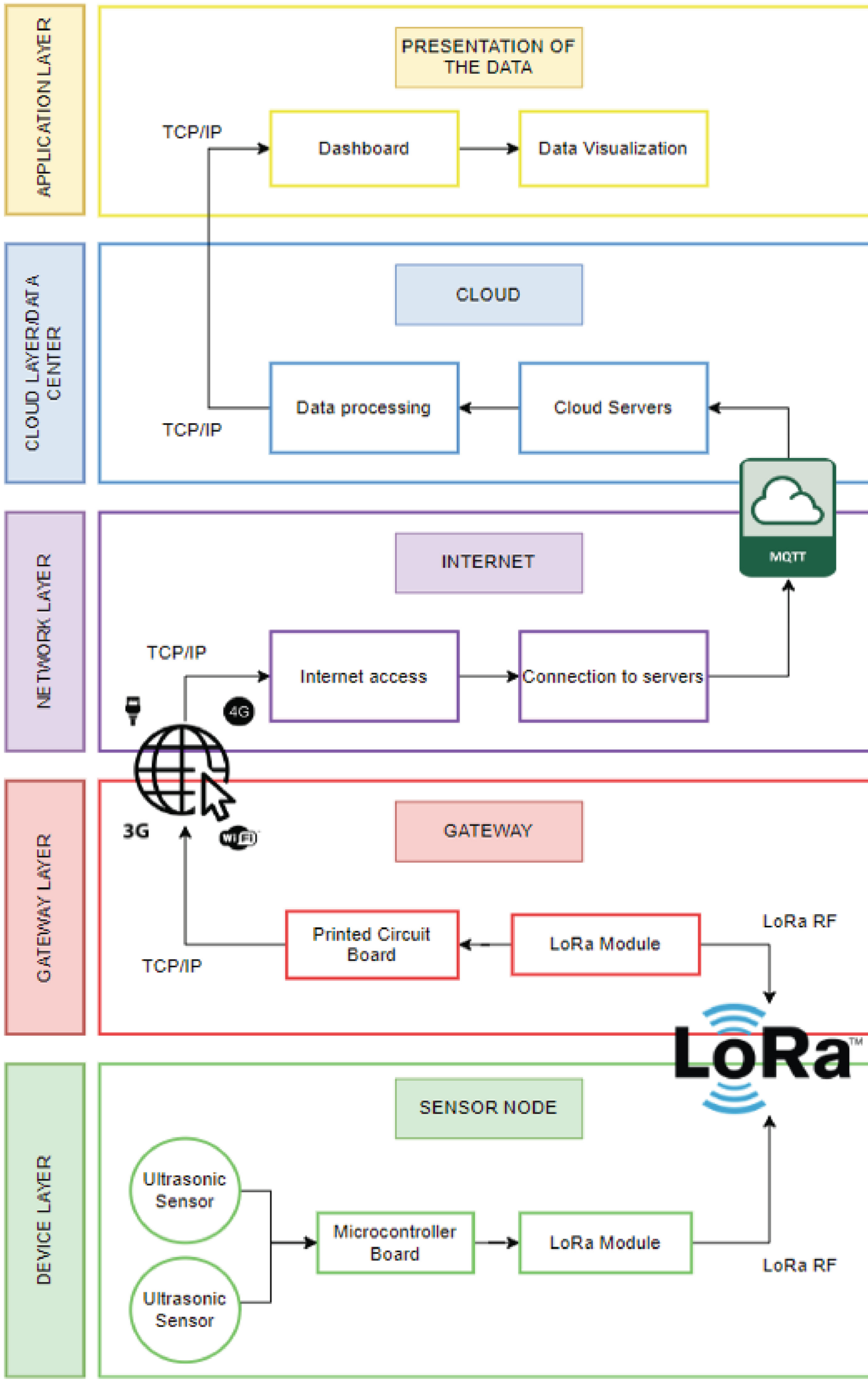

Fig. 1. The block diagram of the system with each layer of the IoT architecture.

3.3 System Architecture of the Water Level Monitoring System

The system architecture, shown in the figure below Fig. 2, represents a star network consisting of the first element, namely the collector nodes, which utilize ultrasonic sensors for measuring water levels. The ESP32 board, acting as a microcontroller, is responsible for the functioning of the sensors and the programming code. For communication between the sensors and the LoRa Gateway, LoRa RF95 modules are employed. The Gateway itself involves communication between an Arduino UNO and a Raspberry Pi 4, linked through a serial port. The final stage consists of processing data in the cloud, after which it is visualized through the use of the IoT platform ThingSpeak and made available for subsequent access by end devices.

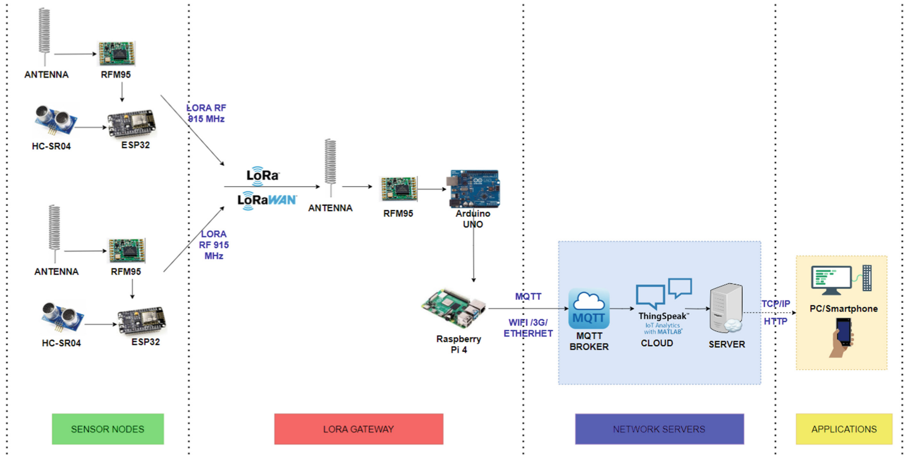

Fig. 2. System Architecture of the Water level monitoring system.

3.4 Interconnection Diagrams

After analyzing the hardware requirements and selecting the components for the sensor network development, connection diagrams for each element are presented to ensure their proper operation, including the sensor node and the LoRa Gateway node.

Sensor Node. The sensor node is composed of an ESP32 microcontroller and an ultrasonic sensor to measure water levels in a flow. The accompanying diagram outlines the connections between the two elements for their respective operation. In Fig. 3, below are the details of how each element is connected to the corresponding pins:

– The Vcc power supply pin of the HC-SR04 sensor is connected to the 5V power supply pin of the ESP32.
– The Trigger pin of the HC-SR04 sensor is connected to pin 16 of the ESP32.
– The Pin Echo of the HC-SR-04 sensor is connected to pin 17 of the ESP32.
– The GND pin, corresponding to the ground of the HC-SR04 sensor, is connected to the GND pin of the ESP32.

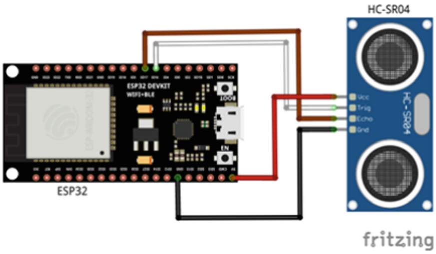

Fig. 3. C-SR04 and ESP32 sensor connection diagram.

LoRa Gateway. The central node is the network component to which all sensor nodes are connected. Its main function is to receive data from the sensors and transmit it to the internet. In this setup, a LoRa Gateway is built using a Raspberry Pi and an Arduino UNO. About other development boards, the Raspberry Pi has superior processing capabilities. This element functions as the gateway within the network that facilitates communication with the sensor nodes that require LoRa communication technology. For this purpose, the RFM95 [13] module is connected to the Arduino UNO as illustrated in the diagram in Fig. 4. The Arduino UNO, in turn, is connected to the Raspberry Pi through a serial connection. The connections made are further detailed below:

– The 3.3 V power pin of the RFM95 module should be connected to the 3.3V pin on the Arduino UNO.
– The ground pin of the RFM95 module must be connected to the ground pin of the Arduino UNO.
– Pin 2 on the Arduino UNO should be connected to the DIO0 pin on the RFM95 module.
– The RST pin of the RFM95 module must be connected to pin 9 on the Arduino UNO.
– Pin 10 on the Arduino UNO should be connected to the NSS pin on the RFM95 module.
– Pin 11 of the Arduino UNO is connected to the MOSI pin of the RFM95 module.
– Pin 12 of the Arduino UNO is connected to the MISO pin of the RFM95 module.

– Pin 13 of the Arduino UNO is connected to the SCK pin, which corresponds to the clock signal of the RFM95 module.
– The antenna is connected to the ANT pin and operates at the required frequency based on its size.
– To read the data via serial communication, the Arduino UNO is connected to the Raspberry PI through a USB cable.

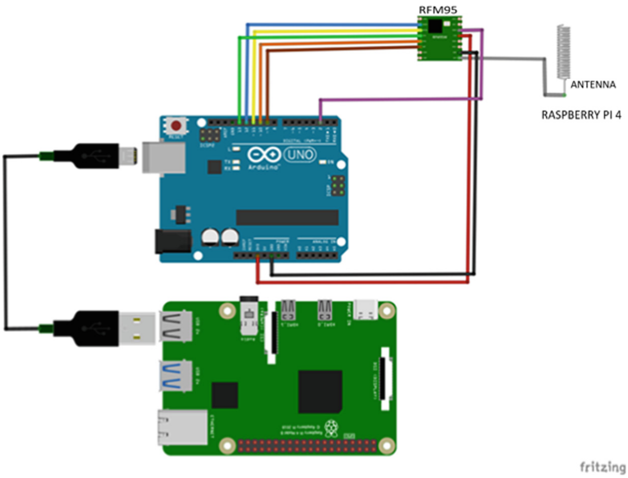

Fig. 4. Connection diagram of LoRa Gateway.

System Flow Diagram. The system flow diagram shows the processes involved and the different functions described in Fig. 5. The process begins with connecting the LoRa RFM95 modules to the ESP32 microcontroller using digital pins to establish wireless communication via LoRa technology. The modules are then verified for proper initialization, which is necessary for establishing a connection to the LoRa Gateway. To measure river flow level, the ultrasonic sensors are connected to the ESP32 microcontroller using its pins. Verification is done to ensure that the sensors are operating correctly, and the data obtained from them is then sent to the LoRa Gateway. Specifically, the LoRa Gateway consists of an Arduino UNO board connected to the Raspberry Pi 4 via serial port. Afterwards, the system confirms that the data is received at this network element and then measures whether the flow level increased or decreased compared to the average value. This information is then used to send out an email alert. Following this, the data is sent to the ThingSpeak platform for cloud storage, which can later be accessed online.

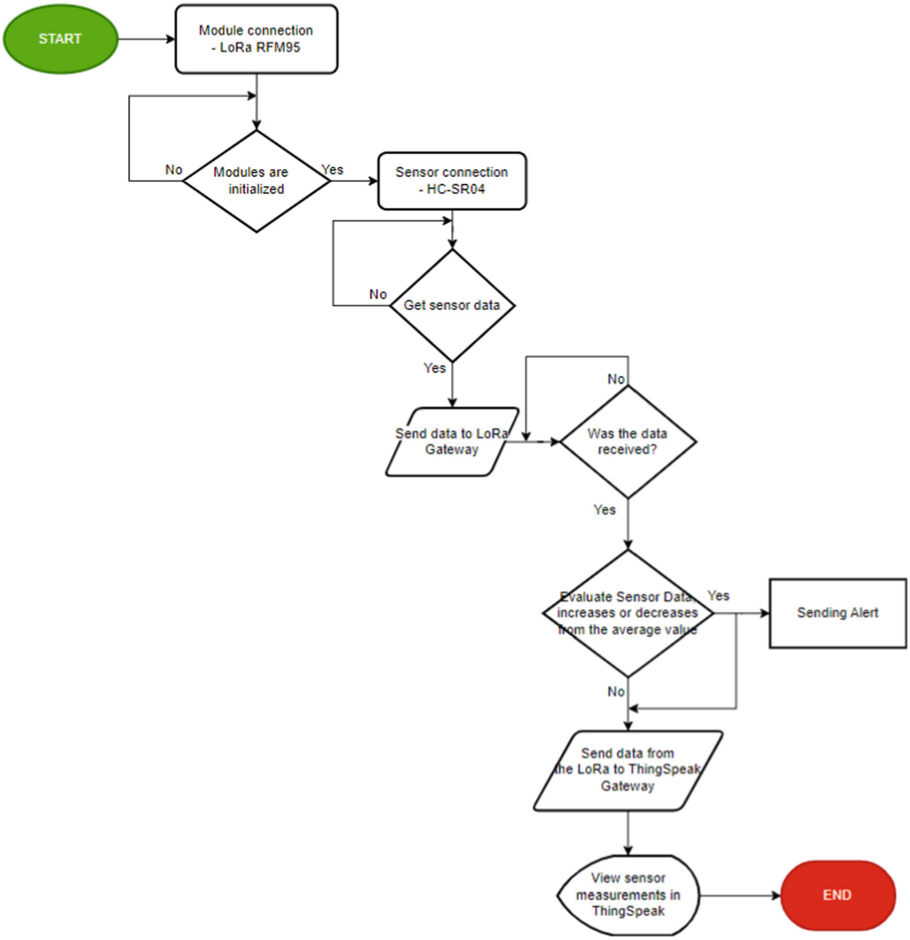

Fig. 5. System flow diagram.

4 Results

4.1 Component Integration

After selecting the appropriate hardware for each network element, the equipment is physically connected according to the established configurations in the previous step.

Peripheral devices are connected to the ESP32 board for the sensor node. Figure 1 illustrates the implementation of the sensor node. It comprises of an HC-SR04 ultrasonic sensor connected to the ESP32 board and a LoRa RFM95 module also connected to the ESP32 board. These are powered by a lithium battery with 5 V input for autonomous operation. The assembled sensor node inside its case looks as Fig. 6:

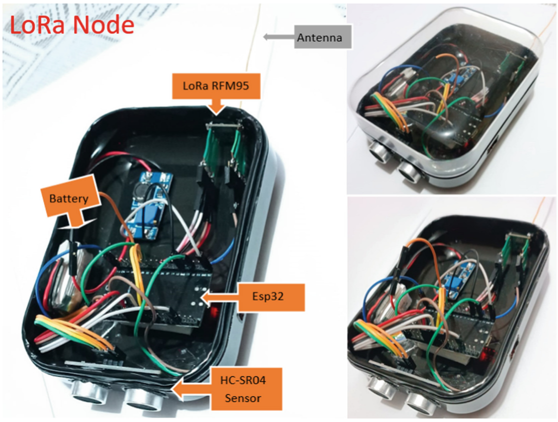

Fig. 6. LoRa sensor node.

The LoRa Gateway obtained the data collected through the RFM95 module using serial communication between the Arduino UNO and the Raspberry PI. The Raspberry PI 4 processed the data, and it was sent to the ThingSpeak platform. The assembled LoRa Gateway, or central node, can be viewed in its casing. Refer to Fig. 7 for details.

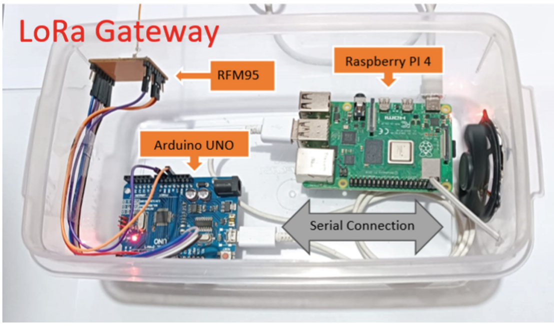

Fig. 7. Gateway LoRa.

4.2 Performance Tests

During the system operation tests, data is obtained from each sensor node, confirming the correct initialization of the LoRa RFM95 module and accuracy of the level value (in centimeters) retrieved from the sensors. Moreover, the LoRa Gateway's capability to receive the data correctly is verified. This ensures the data can be further processed and sent to the ThingSpeak platform without loss.

System Implementation. As previously analyzed in the requirements and system design phase, the project will be implemented in Rio Chico. Two sensor nodes will be placed to measure the level of the river water at two different geographic locations. The placement of sensor nodes takes into account that the water level can be calculated by measuring the cross-section of the river, which includes the distance from the bottom to the surface. In addition, to obtain the river level in centimeters, it is essential to know the total distance between the bottom of the river and the node. This can be calculated by subtracting the two measurements. Figure 8 displays a visual representation of this process.

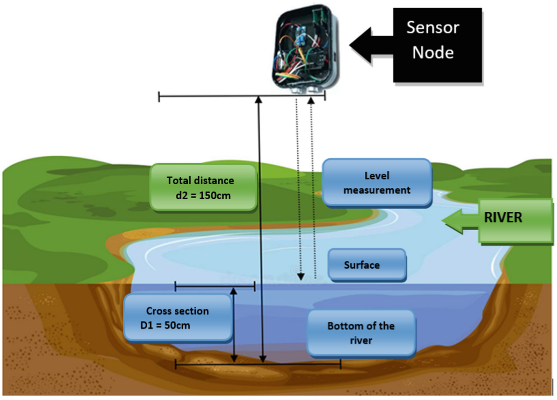

Fig. 8. Sensor node location and measurements.

We will now proceed to physically position the sensor in the chosen location, considering the measures presented in Fig. 8 for proper sensor functionality. Figure 9 displays the sensor node positioned on the river and supported by a PVC pipe structure. This allows for obtaining the required level measurement.

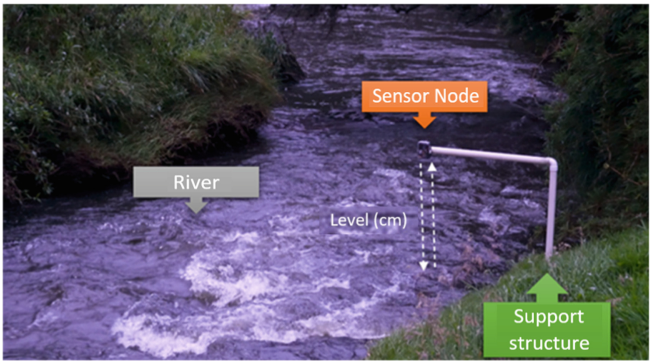

Fig. 9. Location of the sensor node on the river.

Communication Between the Sensor Node and the LoRa Gateway. In this test in Fig. 1, the sensor node is powered by a lithium battery, which allows it to operate autonomously without the need for a USB cable. This feature provides mobility to the node, which can collect and transmit data from its current location (Fig. 10).

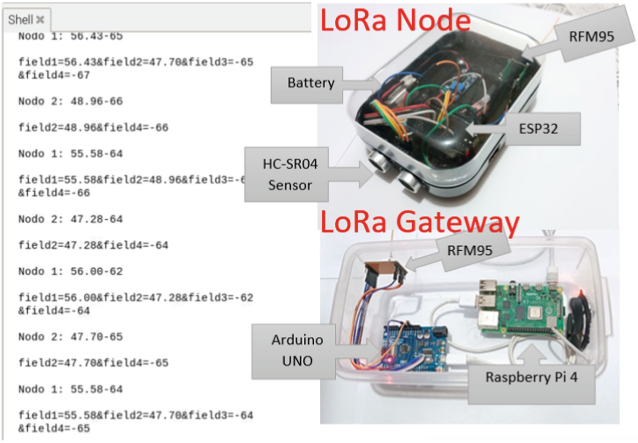

Fig. 10. Receiving data from the sensor node at the Gateway.

Receiving and Displaying Data in the ThingSpeak Platform. Data is sent to the ThingSpeak platform using the MQTT protocol as observed Fig. 11. One can observe the measurements for both Node 1 and Node 2 levels on the platform. Additionally, the RSSI of the signal, expressed in dBm, can be seen to check the signal quality for both nodes.

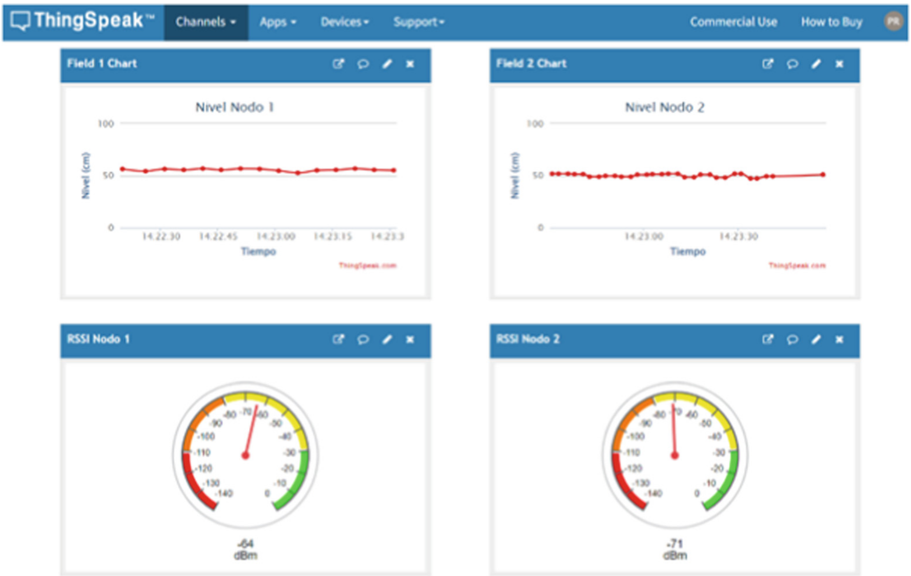

Fig. 11. Visualization platform ThingSpeak.

The data is transmitted to the ThingSpeak server through the MQTT protocol as observed Fig. 11. To verify this, we used the Wireshark sniffer to capture the packets sent, which revealed the used protocol, the payload corresponding to the fields intended for publication in the broker, the TCP port used, the address of the server, and the packet size (Fig. 12).

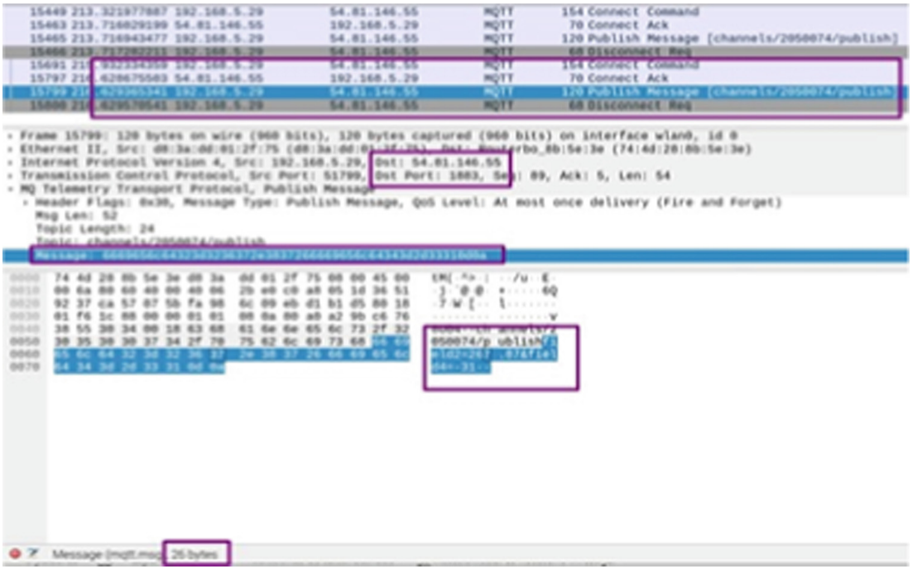

Fig. 12. Visualization platform ThingSpeak.

4.3 Testing of LoRa Wireless Communication

Communication tests were conducted at varying distances to verify communication between network nodes with the LoRa Gateway. The tests obtained data sent by the sensor as well as the RSSI of the signal. Table 1 illustrates a comparison of received signal intensities for varying distances using the following configuration: Spreading Factor (SF) of 7, Bandwidth (BW) of 125 kHz, and Code Rate (CR) of 4/5.

As can be seen in Table 1, the signal strength becomes weaker as the distance from the nodes to the Gateway increases, for longer distances the signal will be weaker and the connection between the nodes and the central node may even be lost.

Table 1. Distance and RSSI Measurements

Distance (m)	RSSI Node 1 (dBm)	RSSI Node 2 (dBm)
5	−59	−61
10	−64	−72
20	−76	−83
30	−84	−86
40	−89	−88
50	−90	−94
70	−110	−117

5 Conclusions

The developed system meets the project's needs by enabling the sensors to read data for water level measurements. Furthermore, LoRa wireless communication technology is used to transmit this data. By analyzing the collected data, it's possible to determine the variation in the water level and relate it to the climatic conditions of the area.

Sensor nodes continually transmit the river level's value to display on the platform. Collecting this data makes it possible to determine if the level is consistent, increasing, or decreasing. From this data, we can analyze whether there is rainfall or drought in the area.

Tests establish correct module configurations according to LoRa requirements since the data collected from sensor nodes can transmit to the Gateway for processing and visualization.

LoRa communication technology widely employed in wireless sensor networks interconnects devices separated over long distances. This feature sets it apart from other wireless communication technologies.

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