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Water detection system in a data center using IoT

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Abstract: This paper presents the development of a system whose objective was to remotely monitor the presence of water in a data center. It is based on a long-range wireless communication technology wide area network (LoRaWAN) composed of four terminal nodes and a gateway. The nodes are made up of an ESP32 module, a water sensor and a LoRa transceiver. The nodes periodically report the presence of water to a server on the Internet, which can be viewed on the user interface. When any of the nodes detects the existence of water, a WhatsApp alert message is transmitted to a mobile phone. The tests carried out showed that the range of the system is 7.450 kilometers with line of sight.

Keywords: Gateway, Internet, LoRaWAN, water sensor, WhatsApp, wireless.

I. INTRODUCTION

In data centers, or data processing centers (DPC), the heat generated indoors has as its main source the computer and telecommunications equipment housed in them. To mitigate the effects of heat and prevent equipment from stopping its operation, or even being damaged, the DPC have cooling and ventilation systems. In extreme cases, fire can be generated, and firefighting systems come into operation, which use inert gas sprinklers or water of a certain quality [1].

It is important that under normal operating conditions, there should be no water on the floor of the DPC, to avoid problems in the operation and activities of the equipment, as well as accidents in the people who work there. Water can arise from leaks, malfunctioning of cooling and fire-fighting systems, or from condensation, among other causes [2].

Currently, there are sensors in the DPC to monitor some environmental parameters such as pressure of liquids and gases, humidity, and temperature, installed in equipment rooms. The sensors are wired to a control station. In most DPC the monitoring of the presence of water is carried out visually. Maintenance and security personnel periodically visually check the floor to prevent water from causing contingencies [3].

However, with recent technological advances in digital electronics, communications, and cloud connectivity, detecting the appearance of water in a timely, efficient, and remote way can be done from the Internet. This provides the advantage of preventing health problems by reducing contact between people in times of pandemic. The proposal is to implement an Internet of Things (IoT) application for a data center [4].

The concept of IoT is being used to connect various objects, devices and things to the Internet, things like sensors, actuators and even household appliances. This allows to collect information, analyze it and make decisions to execute an action in a timely manner. The IoT streamlines productivity by saving time and resources, which has resulted in an increase in the number and diversity of IoT devices [5].

The IoT and sensor networks are transforming the operation of DPC. Data centers are extending their operation to the cloud to process, analyze and store information, as well as to remotely control tasks of their operation [6].

The IoT has been strengthened in recent years by the appearance of multiple service platforms on the Internet. The functions of these platforms include, among others: reception, storage and analysis of information, messaging, and generation of alerts. They admit a great variety of embedded modules, dedicated mainly to verify sensors, and regulate actuators, offer different options of resources, both hardware and software, to implement IoT applications [7], among which are ESP32, Arduino, Pyboard and Raspberry, to name a few.

The objective of the work presented here was to develop a remote water detection system on the floor of a data center. The system is based on a Long-Range Wide Area Network (LoRaWAN). The network is composed of four terminal nodes designed based on an embedded module and a water sensor that transmit information to an IoT server through a LoRa gateway. By means of a user interface the status of the sensors can be visualized. When any of the nodes detects the presence of water, an alert message is sent to the mobile phone of the DPC administrator. LoRa technology was used, because the terminal node furthest from the Internet access point is located at 125 meters.

LoRa is an open protocol developed by the LoRa Alliance to create Low Power Wide Area Networks (LPWAN) used in the IoT market [8]. The LoRa protocol defines the physical layer of the OSI or wireless modulation model to carry out long-distance communication. LoRa radio transceivers are low power devices that transmit small amounts of information at low speed, achieving longer battery life [9]-[10]. LPWAN that use the LoRa protocol are known as LoRaWAN and are used by wireless network operators that use unlicensed spectrum to communicate IoT devices over their network. LoRaWAN provide greater coverage than cellular wireless networks, WiFi, and ZigBee [11].

LoRaWAN work with a star topology and the nodes establish the wireless link with one or more gateways connected to the Internet. Gateways access the Internet using a standard IP connection, which makes it easy to do IoT networks. The transmission speed of a LoRaWAN varies in the range of 0.3 Kbps to 50 Kbps, the gateway manages the speed for each node of the network in order to maximize the duration of the batteries [12].

A LoRa gateway can cover entire cities or areas of several kilometers in size. LoRaWAN have a capacity of thousands of nodes and use two layers of security: one for the network and the other for the application. Network security serves to auhthenticate the node and application security ensures that the network operator does not have access to end-user information [13].

Making a review of the work carried out in research in recent years, regarding the use of IoT, LoRa technology and water sensors, it can be seen that the applications have been directed mainly along two lines [14]. The first is related to sensors used in water quality monitoring systems. This has been caused by the constant increase in the planet's population, the shortage of the vital liquid and the need to provide water for human consumption, health services and agriculture and industries [15]-[18]. In this regard, work has been carried out for remote monitoring of water in the composition of soils [19], industrial processes 4.0 [20]-[21], the environment [22], health care [23] and smart cities [24].

The second line has to do with water sensors used to measure parameters such as pressure and level [25] both in industrial and domestic applications [26] and in the preservation of the environment [27]. Among the works carried out are water level measurement systems to prevent floods and environmental disasters, whose operation is based on images [28], fiber optic sensors [29] and Bi-Wires type sensors [30]. Similarly, the systems developed have been aimed at detecting water leaks in pipes [31] and level monitoring in water dams [32].

Considering the foregoing, no work and applications have been carried out for a DPC like the one presented in this work.

II. MATERIAL AND METHODS

The methodology followed in the development of the system presented here was to design a LoRaWAN network composed of four terminal nodes, the gateway and the user interface. Each node was located under one of the air outlets of the DPC cooling and ventilation system where eventually the presence of water is more likely, as shown in the functional block diagram of Fig. 1.

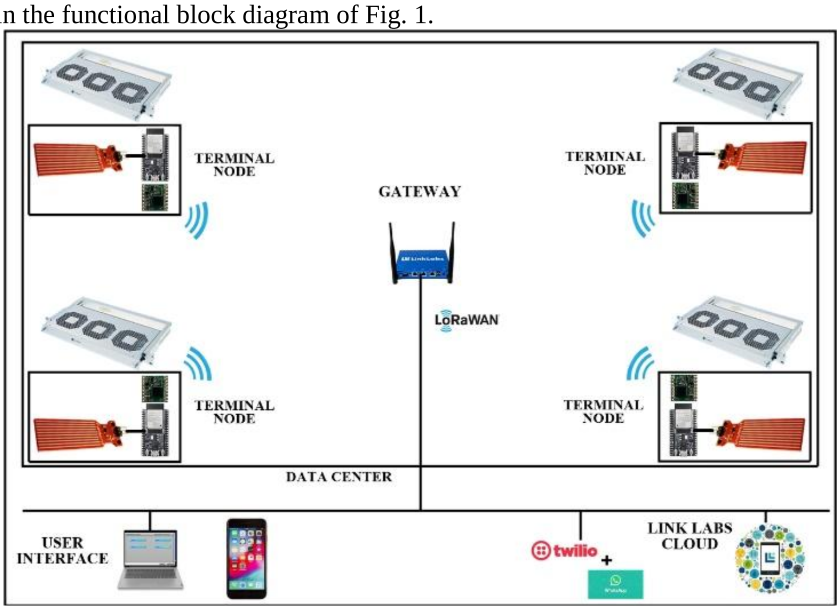

Figure 1.System functional block diagram

1.1. TERMINAL NODES

The architecture of the network end nodes is made up of four elements: the embedded module, the water sensor, the LoRa transceiver and the visual alert indicator, as indicated in Fig. 2

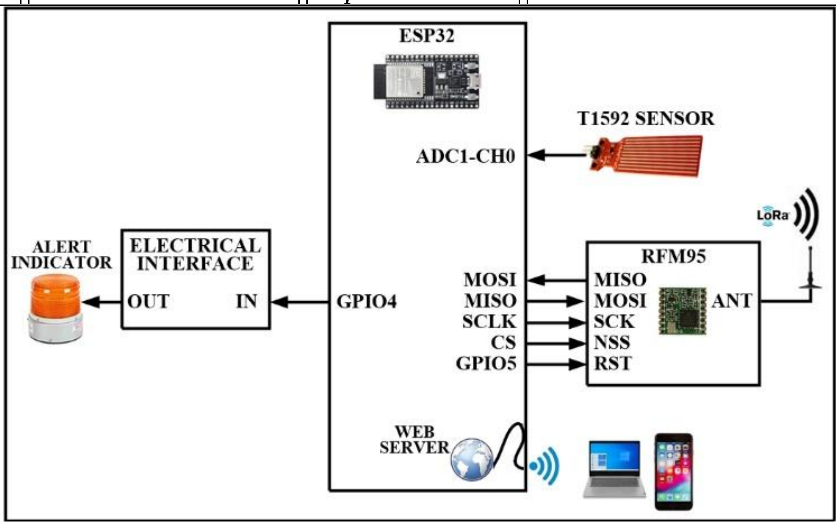

Figure2. Terminal nodes architecture.

The embedded module used was ESP32. This module has the following hardware features: 32-bit dual-core ultra-small CPU, WiFi 802.11b/g/n and BT/BLE transceivers, 520 KB SRAM, 4 MB PSRAM external memory, support for UART interfaces, SPI, I^2C, PWM, as well as two 8-channel and 10-channel 12-bit resolution ADCs, two 8-bit DACs and 25 GPIO (General Purpose Input/Output).

There are different types of water sensors available on the market. The sensor used in the LoRaWAN terminal nodes was the T1592 device. This sensor is one of the most used for detecting water due to its easy use, low current consumption, less than 20 mA, and because it is compact and inexpensive. It is built based on a set of parallel metal sheets located on its external faces that are used to determine the presence and amount of water in the environment.

The operating principle of the T1592 sensor is based on the impedance changes presented by the sheets, which varies depending on the amount of water found on them. Impedance is part of an amplifier circuit formed by an internal transistor of the sensor that delivers a voltage level proportional to the amount of water that falls on it. When there is no water, the voltage value is low, practically 0 volts. The sensor can be used as a water level meter. However, it is commonly used as a detector, working as a switch connected to the input of a digital device. This is because when the sensor is completely dry, or if it contains a drop of water, the difference in the output voltage is large and when it detects a drop, or is completely covered in water, the difference in voltage is small. The technical characteristics of the T1592 sensor are as follows: it is powered by 5 VDC, it provides an analog voltage output of 0 to 4.2 VDC, the operating temperature is 10 to 30^{o}C and the detection area is 40 mmx16 mm. It has three terminals, one for power, another for ground and the third is used to obtain the output voltage whose value is directly proportional to the amount of water. This allows the sensor to be connected directly to channel 0 of the ADC1 of the ESP32 module of the terminal nodes.

The LoRa transceiver used in the terminal nodes was the RFM95 circuit. This device communicates with the ESP32 embedded module through the SPI interface. The MISO, MOSI, SCLK terminals of the SPI bus of the ESP32 were connected to the terminals of the same name of the RFM95 and the NSS (SPI Chip Select input) and RST (Reset) terminals of the RFM95 were connected to two GPIO terminals of the ESP32 configured as output. The main characteristics of the LoRa transceiver are the following: +5 to +20 dBm output power up to 100 mW, current consumption 100 mA during transmission and ~30 mA during active listening, reach 2 kilometers with line of sight using a tuned unidirectional antenna or 20 kilometers using a directional antenna, an RF transmission speed of 0.018 to 37.5 Kbps and a maximum SPI transmission speed of 300 Kbps.

Being a master external host, the ESP32 implements the communication interface with the RFM95 transceiver through the master/slave protocol. The interface uses two types of messages: command packets and response packets. The master sends command packets, and the slave transmits reply packets. When the master sends a packet it must wait for the slave to transmit a reply packet before the next command packet; Since the RFM95 transceiver is a slave, it cannot initiate the information exchange with the master. Command packets consist of 7 fields: preamble (4 bytes), frame start (1 byte), command type (1 byte), message number (1 byte), message length (2 bytes), message (up to 256 bytes) and checksum to verify the integrity of the packet (2 bytes). The SPI port of the RFM95 transceiver on the terminal nodes was connected to the SPI port of the ESP32 module. To obtain a range greater than 2 kilometers, an outdoor antenna with a 915 MHz Omni Lora type gain was connected to the nodes' RFM95 transceiver, whose characteristics are the following: gain 8 dBi, female N type connector, impedance 50 ohms and length 1,145 mm. This was done because it is planned to expand the DPC and locate the terminal node furthest from the Internet access point, or LoRa gateway, at a distance greater than 2 kilometers.

The visual alert indicator used was an 88 flashes per minute LED strobe light, model Larson Electronics SLEDB-110V-ILS-10C Class 1, which is activated when the terminal node detects water. The lamp was connected, through the electrical interface, to the GPIO 4 terminal of the ESP32 module configured as an output. Fig. 3 shows the diagram of the electrical interface used to activate the alert lamp.

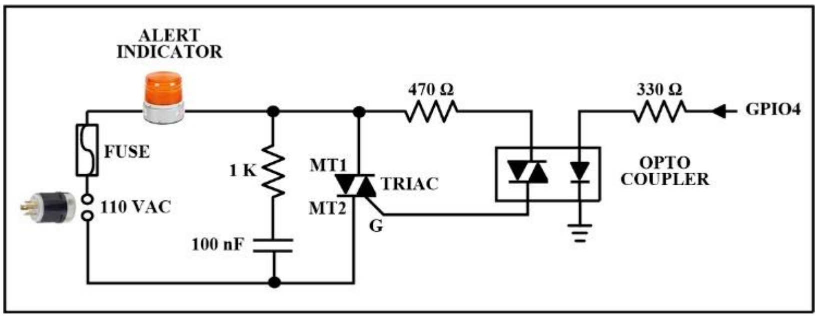

Figure3. Alert indicator electrical interface.

The terminal nodes perform the following tasks: they periodically read the output of the water sensor every 30 seconds, determine if there is the presence of water, and transmit the previous result to the gateway through the SPI interface. In case of detecting water, the terminal node activates the visual alert indicator, which turns off when no water is detected. The program to execute these activities was done using the Arduino integrated development environment (IDE), which implements the full Python 3.4 syntax. It was based on the flowchart in Fig. 4, runs in the foreground, and makes use of the open-source libraries *SPI.h* and *WiFi.h* to configure and access the SPI and WFi interfaces, respectively, as well as the *LoRa.h* library to configure and access the RFM95 transceiver.

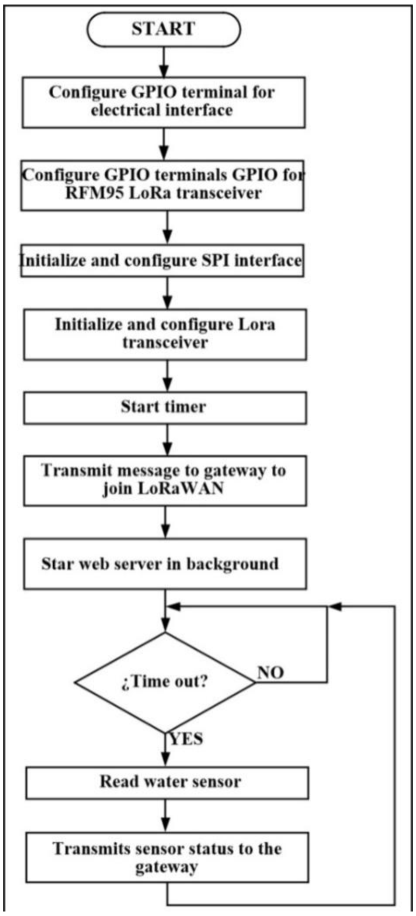

Figure4. Terminal node program flow chart

In one of the terminal nodes, the program runs a web server in the background, which is responsible for receiving requests made by clients from a browser on the Internet, through the HTTP protocol, and responding by sending the pages made in HTML of the user interface. When one of the terminal nodes detects the presence of water, the web server is responsible for sending the WhatsApp alert message, using Twilio, to the mobile phone of the DPC administrator. Fig. 5 shows one of the alert messages.

Figure5. Water presence alert message.

Twilio is one of the communications platforms and services in the cloud, known as CPaaS (Communications Platform as a Service), most used today by companies and application developers. Through the Twilio APIs you can transmit text messages, video, make calls or start a chat from applications and websites using a small number of lines of code. The Twilio user only pays for what he uses, obtaining a reliable communication mechanism with global reach. Twilio allows you to send programmed messages to WhatsApp from programs made in Java, PHP, Python, C # and Node.js.

To use Twilio's services in this work, it was necessary to create an account and obtain the Account SID and Auth Token, as well as activate the WhatsApp Sandbox in order to be able to use the Twilio messaging API. The routine that sends the alert message carries out the following actions: imports the Twilio function library for Python, starts the client from the previous library, sets the recipient's mobile phone number, sets the sender's phone number to the Sandbox of WhatsApp, and define the message to send.

1.2. THE GATEWAY

The gateway used in the star topology LoRaWAN was the LL-BST-8 appliance from Link Labs-Symphony Link. The LL-BST-8 integrates two Ethernet ports, the first allows connection to the Internet and the second is used to configure the gateway. The role of the gateway is to transmit the information received from the terminal nodes to Link Labs' Conductor cloud-based data services platform.

1.3. THE USER INTERFACE

The user interface of the system was implemented through the web server and HTML pages. It allows the user to view the status of the terminal node sensors online and has two buttons: the Historical button and the Setting button. The first is used to set the sampling period of the sensors in the terminal nodes and the number of the mobile phone where the alert message will be sent. The second is used to historically download, in a text file, the status of the water sensors. The web server was made using the *ESPAsyncWebServer.h* function library, to access the information sent by the terminal nodes to the cloud using the APIs of the Link Labs Conductor platform. Fig. 6 shows the main page of the user interface.

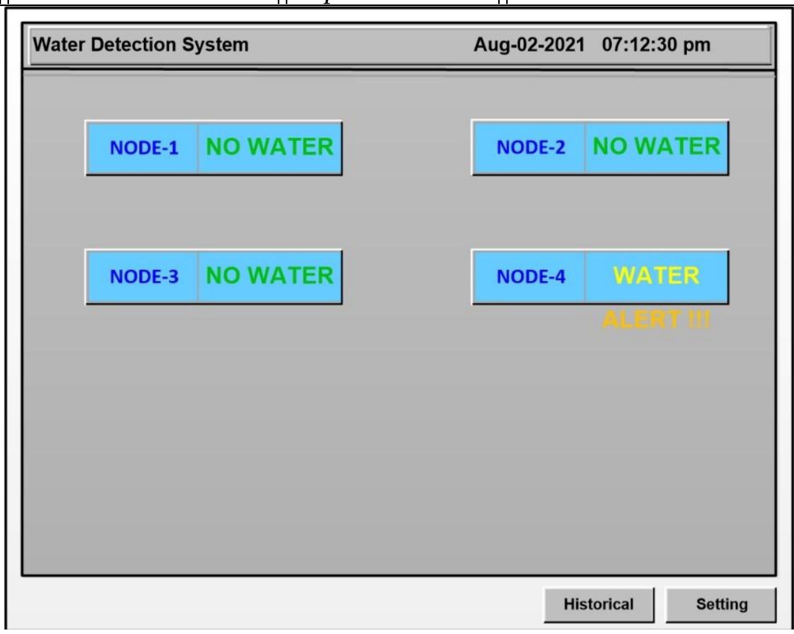

Fig.6.User interface.

III. RESULTS AND DISCUSSION

Initially, it was verified that the communication between the end nodes and the gateway will be carried out correctly. Subsequently, the detection in the four terminal nodes was verified by placing water on the sensors of the nodes to verify that the user interface showed this event. In these two scenarios, there were no problems in LoRaWAN communication.

Even though the furthest terminal node is located 125 meters from the gateway, a set of tests was carried out to determine the LoRaWAN range. The tests consisted of placing a terminal node in different positions of the DPC, with a line of sight to the gateway, and measuring the value of the received signal strength indicator (RSSI) using the Arduino IDE.

The test results showed that the LoRaWAN range is 7.45 kilometers and the RSSI value is -87 dBm. At distances greater than the previous one, communication is unstable and intermittent, the attenuation of the RSSI value decreases considerably and continues to do so constantly until communication is lost at 8.52 kilometers, as shown in the graph of Fig. 7.

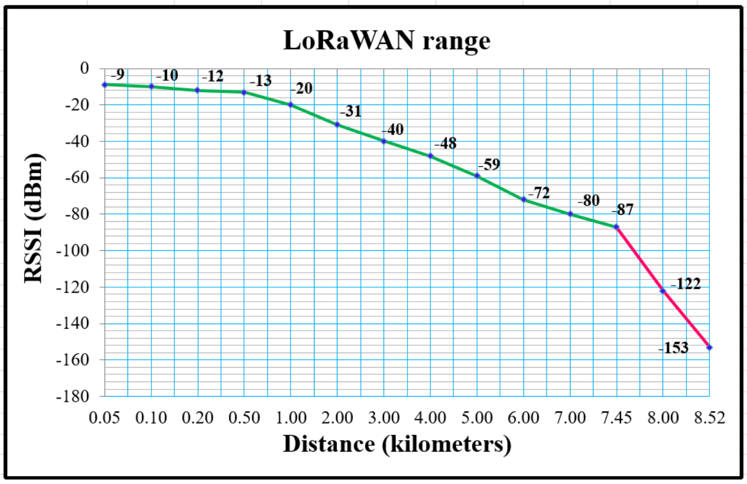

Fig.7.LoRaWAN range.

This indicates that the signal transmitted by the nodes is disturbed by interference and is diffracted or absorbed in the medium. The range of the signal depends on the power value set on the LoRa transceiver and environmental factors. The above tests were carried out under the following conditions: with line of sight between the nodes and the gateway, the RF transmit power value set on the RFM95 transceiver was 20 dBm-

100 mW, the RF frequency was 915 MHz, the BW bandwidth was 125 KHz and the DPC temperature and humidity were 18°C and 12%, respectively.

The water detection surface on the network nodes is limited to 40mm x 16mm, which is determined by the T1592 sensor used. If it is necessary to increase the covered area, more sensors can be integrated in the terminal nodes, since the ESP32 embedded module has 18 analog input channels.

IV. CONCLUSION

Considering the results obtained, a remote water detection system was obtained in a data center, developing a LoRaWAN, whose range in wireless communication allows the nodes to be located at any point in the data center, which would be difficult to achieve if other types of transceivers are used.

An important advantage of the system is that its installation does not interfere with the computing, communications, or electrical infrastructure of the DPC, since it is not intrusive, and it did not need to modify anything.

A limitation of the system is the size of the area covered by the water sensor used in the terminal nodes. To improve this limitation, an ultrasonic sensor or video camera can be used to determine if there is the presence of water. These two options increase the cost of the system and the second requires the use of another type of embedded module or an array of field programmable logic gates (FPGA) for image processing.

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