Ultra low power water level transmission system using LoRaWAN technology

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***Abstract*— This work presents the development of a compact ultra low power data transmission device, using a commercial sensor with 4 to 20mA output to monitor water level of the Sapucaí river. The equipment was connected to a Chirpstack LoRaWAN network and integrated with Node-RED tools, storing the information in InfluxDB and displaying it on Grafana. The study demonstrates the feasibility of this IoT application using LoRaWAN network technology with a low consumption of energy, around 114mA during transmission and 3mA in sleep-mode, in addition having a lower cost than solutions available on the market. Furthermore, by programming the device to transmit data packets every 60 seconds and powering the equipment with two 4.2V 10000mAh batteries, the study predicts that the system will operate for approximately 4 months.**

***Keywords*— LoraWAN, Internet of Things, Ultra Low Power**

I. Introduction

The concept of Smart Cities is growing up constantly in Brazil [1]. In this context, the development of solutions that work properly, are low maintenance and affordable, is currently relevant. This study is a continuity of the work "Análise da tecnologia LoRaWAN como solução para transmissão de dados de sensor de nível e temperatura" [2], presented on SBrT 2022, and the main objective is to showcase the improvements to the proposed project, focusing on reducing the size of the solution and its energy consumption. For this, an ultra-low power IoT device was developed, consisting of a printed circuit board, capable of reading a water level sensor with an output of 4 to 20mA, and transmitting the collected data every 60 seconds using LoRaWAN communication network protocol (*Long Range Wide Area Network*). Thus, in line with the project's objective of minimizing energy consumption and ensuring equipment compactness, the need for a solar panel and a 12V 7Ah battery was eliminated. Instead, a pair of 10000mAh batteries was employed, offering a predicted system runtime of up to 4 months while powering the developed system. For tests and measurements, a prototype was installed on Sapucaí River, Dr. Antonio Braga Filho Avenue, Itajubá, MG.

II. Materials and Methods

The list of equipment used is presented below, along with their respective average prices. In addition, the schematic is presented according to the diagram in Figure 1. The prototype's average value was calculated as R$1.808,00.

- Printed Circuit Board (R$100,00);
- LoRaWAN Module 2AD66 (R$32,00);
- Transmission Antenna 2 dBi 915mhz (R$20,00);
- 2 Lithium battery 10000mAh (R$42,50 each);
- Waterproof protective case and connector (R$68,00);
- 4 to 20mA water level sensor 10 mwc (R$1503,00);

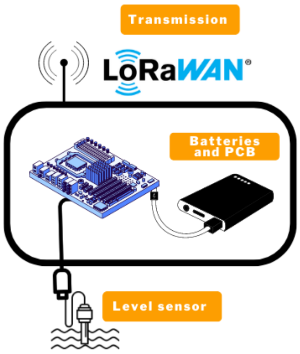

Fig. 1: Electrical schematic of the developed system

The LoRaWAN module 2AD66 was a suitable option due to its price and its efficiency. An antenna that operates in the LoRaWAN frequency band was coupled to the module to allow its connection to the gateway. That way, the LoRaWAN module was integrated with the circuit through the printed circuit board, which in turn was developed using low power consumption components to enable ultra deep sleep mode. The lithium batteries connected in parallel were chosen to power the entire system, as they are compact and can be recharged.

The water level sensor was connected to the printed circuit board's 4 to 20mA input. Unlike the sensor used in previous research [2], this sensor has a vent tube that compensates the atmospheric pressure. To ensure durability in outdoor environments, a waterproof case and connectors were used.

The microcontroller chosen for the system was the STM32F103C8T6, an ARM 32-bit Cortex™-M3 CPU [3], and the programming was developed in C++ with the LoRaWAN MAC IN C library [1]. The STM32F103xx performance line offers three low-power modes: sleep, stop, and standby mode [4]. The standby mode, which ensures the lowest power consumption, was selected while the device was not transmitting data. To enable the LoRaWAN radio, sensor and EEPROM memory after exiting standby mode, P-channel MOSFETs were used.

A. Communication and Integration

The system was connected to a LoRaWAN gateway installed at UNIFEI, located 2,08 km away from the transmissor. The frequency band used was 915MHz (AU_915_928_FSB_1) with ABP authentication. Data was sent every minute (to

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[1] https://github.com/mcci-catena/arduino-lmic

assess transmission error rates) to a ChirpStack network server and transferred via MQTT protocol to a linux server. Finally, this server used the Node-RED tool to properly format and transfer the data to the InfluxDB database. To view the results and generate graphs, the Grafana software was used.

III. Results

With the data obtained, water level curve (Fig. 2) and battery voltage curve (Fig. 3) were generated, from the period from 04/04/2023 to 17/05/2023, in addition to the curve of current consumed over a period of 125 seconds, with the device configured to transmit data each 20 seconds to project an extreme case, shown in Fig. 5, although submissions are made every minute.

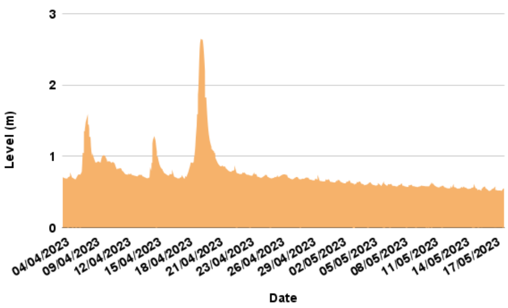

Fig. 2: Level Curve

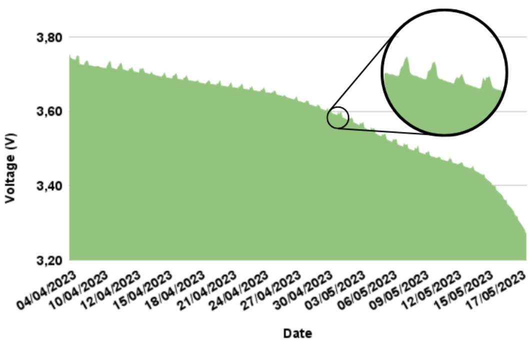

Fig. 3: Voltage Curve

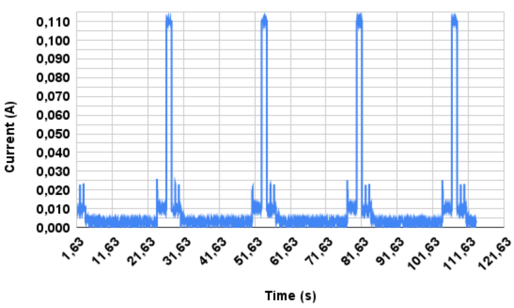

Fig. 4: Current Draw

The analysis of graphs 2 and 3 reveals accurate transmission data. However, the battery voltage and level curves exhibit deviations (small ripples), with regular variations coinciding with higher ambient temperatures, around 12 PM. The ADC's total unadjusted error (TUE) can be affected by factors like temperature changes, humidity, and pressure, leading to long-term performance drift [5].

According to Figure 4, the printed circuit board consumes 114mA during LoRaWAN transmission and operates at 3mA in standby mode. With a total battery capacity of 20Ah, the system can function autonomously for approximately 3.8 months (2752.6 hours). The following calculations show the device operation time.

- A_h = consumption in Ampere hour in transmission mode (A_{ht}) and in standby mode (A_{hs})
- I_x = current in Ampere when transmissor is on, but not transmitting (I_w), in transmission mode (I_t) and in in standby mode (I_s)
- t_x = time in seconds the transmissor is on, but not transmitting (t_w) and in transmission mode (t_t)
- bat_d = duration of the battery in hours

$$Ah_t = \frac{I_w \times t_w + I_t \times t_t}{60} \qquad Ah_s = \frac{I_s \times (60 - t_w - t_t)}{60}$$

$$bat_d = \frac{bat_{Ah}}{Ah_t + Ah_s}$$

$$Ah_t = \frac{0.0194 \times 6.017 + 0.1097 \times 1.474}{60}$$

$$Ah_s = \frac{3 \times 10^{-3} \times (60 - 6.017 - 1.474)}{60}$$

$$bat_d = \frac{20}{4.64 \times 10^{-3} + 2.625 \times 10^{-3}} = 2752.6 \ hours$$

IV. Conclusions

An efficient LoRaWAN data transmission device was developed by employing ultra low power components in the communication module hardware and utilizing the standby mode of the chosen microcontroller, achieving an autonomy of around 4 months when powered by two parallel-connected 10000mAh batteries. The key innovation of this solution, setting it apart from others in the literature, is its practical combination of structural and energy efficiency. It bridges the gap between robust yet energy-inefficient practical applications and energy-efficient but rarely applied compact projects found in the literature.

The system's compact size (12cmx5cmx2cm) ensures easy transport and installation, while maintaining a cost of approximately R$1,800 reais. Future plans involve updating research to improve chosen technologies. Additionally, plans include calibrating the ADC for better voltage reading accuracy and reducing the transmission window time to further enhance energy efficiency.

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