Low-cost alarm design using the LoRa physical layer protocol

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***Abstract*—This paper presents the design, implementation, and empirical field evaluation of a low-cost security alarm system based on peer-to-peer (P2P) communication over the LoRa physical layer (Raw LoRa). Developed on the ESP32 microcontroller platform, the system integrates hardware debouncing for magnetic reed sensors and incorporates an automated repetition request (ARQ) retransmission mechanism designed to guarantee frame delivery under adverse conditions. Field testing was conducted in a dense, highly built-up urban environment across multiple operational distances to evaluate the practical limitations of the link. The performance of the system was rigorously analyzed based on key radio frequency metrics, specifically the Received Signal Strength Indicator (RSSI) and the Signal-to-Noise Ratio (SNR). The experimental results demonstrate the practical boundaries of the implemented hardware configuration and evaluate the sub-noise reception capabilities and overall robustness of the LoRa modulation when subjected to severe urban interference and industrial noise.**

***Index Terms*—LoRa P2P, ESP32, Low-cost Alarm System, Wireless Propagation, RSSI, SNR, Field Testing**

I. Introduction

The authors of this publication focused on wireless communication, specifically the Raw LoRa protocol, which is currently the standard for the Internet of Things (IoT) [1]. They decided to examine transmission speed and packet loss and answer the question: Can this technology provide fast, low-cost wireless communication and be used to transmit data packets from alarm systems sensors? The authors want to check the above-described solution in real, not laboratory, conditions.

LoRa operates in the unlicensed band below 1 GHz (868 MHz in Europe, 902 MHz in the USA) [2], using Chirp Spread Spectrum modulation [3] and Frequency Shift Keying [4], which makes it more resistant to interference during transmission over longer distances. The advantage of using this type of solution is low energy consumption [5], [6].

In terms of potential applications, LoRa is used in industry, education and communities for purposes such as industrial sensor communication, smart cities, smart buildings, remote environmental quality monitoring, smart meters and agriculture [7].

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One of the disadvantages of using low transmission power over long distances is a significant drop in transmission speed, which decreases with increasing distance [8]. The authors decided to test how the technology would perform in households and over longer distances, where the distance between the secured property and the receiver is several kilometres. The tests were carried out in urban and rural areas due to the number of obstacles to be overcome by the transmitted signal.

II. Construction of measuring stations

To carry out the necessary research, it was necessary to design prototypes of the transmitter and receiver. The devices must communicate with each other and measure communication time and packet loss. Additionally, the Lora cards used in the project can measure RSSI (signal strength in dBm) and SNR (signal to noise ratio in dB).

A. Transmitter

The principle of event detection is simple: the magnet is placed on the door or window, and the reed switch is placed on the door frame. When the magnet is in the immediate vicinity of the sensor, the electromagnetic field affects the contact surfaces inside the reed switch, thus completing the electrical circuit. When the magnet moves away and the electromagnetic field no longer affects the reed switch, the contact surfaces inside the sensor open.

Changes in the circuit state are registered by the microcontroller, and then the signal from the transmitter to the receiver is sent via the Raw LoRa module. The authors wanted to test the range of their low-budget version of the alarm, so they decided to use the antennas included in the module kit. This was done to check whether this solution is sufficient for communication in small and medium-sized households.

Due to the above assumptions, a prototype transducer was designed, based on the ESP32 microcontroller with a connected switch imitating a reed sensor. Thanks to the extensive capabilities of the microcontroller, it is possible to implement software that measures the signal transmission time, which, combined with the reception time, gives a difference representing the packet transmission delay (shown in Figure 1). The prototype is powered directly by 5 V DC, providing a