# A comparative study between LoRa and Zigbee transmission for racing car telemetry

Anderson G. de Almeida, Caio T. B. Costa, Vitória J. Baratella e Danilo H. Spadoti

***Abstract*— This paper presents a comparative study on the application of LoRa and Zigbee technologies for telemetry in Formula-SAE cars. It aims to evaluate the feasibility and effectiveness of both wireless communication in the telemetry transmission data from a F-SAE car to a monitoring system platform. The study evaluates the advantages and limitations of both technologies, considering range, reliability and handling of simultaneous telemetry transmissions. The transmitted data provide insight into LoRa and Zigbee performance for F-SAE car telemetry, helping teams make decisions to optimize performance and data acquisition in real time.**

***Keywords*— Telemetry, LoRa, Zigbee, Formula SAE.**

## I. Introduction

Wireless telemetry systems play an important role in the optimization, performance and reliability in many domains, including the dynamic world of motorsposrt [1]. This study explores the application of LoRa and Zigbee technologies for telemetry in Formula-SAE cars, focusing on their ability to transmit vehicle data to a monitoring system. With the aim of extracting maximum performance and improving decision-making processes, telemetry allows real-time monitoring of crucial parameters such as engine performance, suspension dynamics, aerodynamics, brake systems, among others[2]. By comparing the feasibility, advantages and limitations of LoRa and Zigbee in the context of FSAE cars, this study aims to provide insights for racing teams, engineers and automotive enthusiasts looking to optimize their telemetry systems and propel their vehicles to new heights of success.

## II. Development

The subsequent section delves into the technologies employed to conduct this study, providing a comprehensive overview of the tools utilized.

### *A. Radio techonologies*

LoRa and Zigbee are wireless communication protocols that have gained significant attention in various domains [3]. LoRa (Long Range) is a low-power protocol known for its long-range capability and low energy consumption. It operates in unlicensed frequency bands, enabling long-range communication with minimal power requirements. LoRa is well-suited for applications that involve transmitting small amounts of data over extended distances.

Zigbee, on the other hand, is a low-power wireless mesh network protocol designed for short-range communication. It operates in the 2.4 GHz frequency band and utilizes a mesh topology, allowing devices to form a self-configuring network.

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### *B. LoRa telemetry overview*

In the conducted study, a point-to-point connection was established using ESP32 Wi-Fi LoRa Heltec V2 [4] development boards. These boards, equipped with ESP32 microcontrollers and integrated SX1276 LoRa transceivers, allowed long-range communication between the racing car and the ground station [5] .

To ensure the confidentiality and integrity of the transmitted sensor data, AES (Advanced Encryption Standard), was employed. AES is a widely adopted symmetric cipher that performs a series of substitution, permutation, and linear operations transform the data securely [6]. In the present work, a 128-bit key was implemented using the DavyLandman Arduino Compatible AESLib [7] library on both the transmitting and receiving development boards. Following, the, RSSI (Received Signal Strength Indication) information was collected from the SX1276 module at the ground station to evaluate radio performance and assess the strength and quality of the wireless connection. In addition, the study included the measurement of transmission latency to assess the quality and feasibility of using the systems in a real-time context.

### *C. Zigbee telemetry overview*

Another point-to-point connection was established between the vehicle and the ground station using two XBee-PRO S1 development boards. XBee is a brand of wireless communication modules based on the Zigbee protocol offering a reliable and low-power wireless solution, operating in the 2.4GHz frequency band [8]. XBee modules are widely used in various professional applications that demand efficient and secure wireless communication, including industrial automation, remote monitoring, and sensor networks [9].

Similar to the LoRa technology, in this study, RSSI and latency data were collected to evaluate radio performance in the racing car telemetry system, and AES encryption was used.

### *D. Acquisition and Transmission Module*

The acquisition and transmission module for the telemetry system consisted of an ESP32 Wi-Fi LoRa Heltec V2 module, a Zigbee-PRO module, and a GPS module.

The GPS module plays a crucial role in accurately determining the distance between the receiving and transmitting systems, to properly analyse both communication systems.

### E. Ground station design

The ground station developed in the telemetry system was equipped with Heltec ESP32 LoRa V2 modules and Zigbee modules. The received data were then processed for further analysis, including storage of RSSI and latency data.

The ground station played a vital role in capturing and analyzing the telemetry data. By recording latency and RSSI values, important insights into the performance of the telemetry system were obtained. This data enabled comparisons between the LoRa and Zigbee technologies and the evaluation of their suitability for racing car telemetry applications.

### F. Transmission Parameters Collection

To evaluate the RSSI and Latency parameters for both LoRa and Zigbee technologies, a Test Car was utilized on a flat 1,5km asphalt track, and utilizing the GPS location to determine the transmission distance. By systematically varying the distance between a test car and the telemetry monitoring station, the relationship between distance and corresponding RSSI and Latency values were established. The Test Car was driven along the track while telemetry systems wirelessly transmitted data to the monitoring station, enabling the assessment of signal strength and reliability at different distances.

The telemetry transmissions were operated at 100 samples per second, with a UART speed of 9600 bits per second. This setup allowed for real-time monitoring and analysis of the car's parameters during the test runs, providing a sufficient amount of data for evaluating its performance [10].

## III. Results and discussion

To present the data collected for analysis, two Figures were generated using the Microsoft Excel. In the Figures, the x-axis represents the distance, which was derived from the GPS NMEA coordinate data. The distance between coordinates was calculated using the Haversine formula, and the calculated distance was then offset from the first coordinate to establish a reference point. Figure 1 presents the received signal strength being the y-axis the RSSI values of both systems. On the other hand, Figure 2 depicts the latency of both systems, indicating the time delay in transmitting the data.

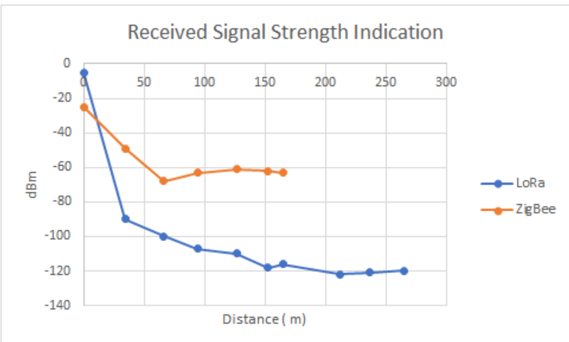


Fig. 1. RSSI Measurements

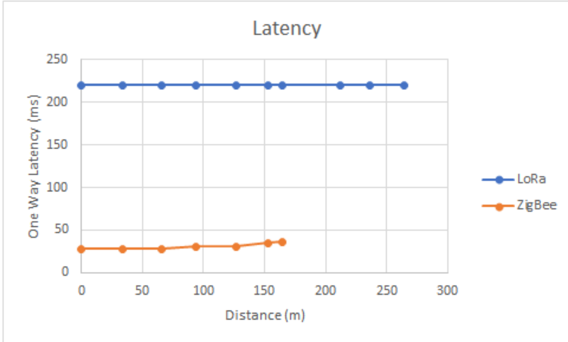


Fig. 2. Latency Measurements

## IV. Conclusion

In conclusion the given results and analysis from the experiment indicate that LoRa technology is more suitable over Zigbee for this application. Figure 1 and Figure 2 demonstrate that LoRa was able to establish communication at all examined distances, whereas Zigbee experienced packet losses over 160m. The evaluation, considering both received signal strength indication and transmission range, consistently demonstrates that LoRa outperforms Zigbee by maintaining a more stable signal, due to its lower package losses, particularly at extended distances. Additionally, it is noteworthy that both radio technologies exhibited stable latency, with LoRa averaging a latency of 220ms and Zigbee averaging 31ms. These findings underscore the suitability of LoRa for racing car telemetry, ensuring reliable and uninterrupted transmission of sensor data with enhanced accuracy and real-time monitoring capabilities.

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