Lopy2Lopy and Lopy2GW

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VERSION 1

Report - Project

Comunicações Móveis (CM)

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Abstract

In an era defined by the rapid evolution of wireless communication technologies, LoRa (Long Range) has become a transformational force that is changing the field of long-range, low-power communication. This technology holds immense potential for diverse applications within the Internet of Things (iot) environments. Unlike its competitors, LoRa's technology has the ability in providing range as well as minimizing power consumption. By the integration and confirmation of the effectiveness of LoRa's technology in real life this project, "*LoPy2LoPy*", this project emerges as an exploration into the core of LoRa's communication. To address these challenges, it was used LoPy devices. In conclusion, the goal of *LoPy2LoPy* project is to perform experiences and tests to evaluate overall performance of LoRa technology, by addressing challenges like long range, low-power communication by providing a direct communication between the different LoPy devices. This project also aims on testing different environments, surfaces, communication scenarios, accounting for various disturbances (for example noise), and also to understand how factors such as frequency, bandwidth and spreading factor can affect communication, providing a comprehensive evaluation of the LoRa network's adaptability and resilience.

Chapter 1

Introduction

In this report will be discussed and analysed the impact of various parameters on the performance of *LoRa* Wireless Communication adaptability, resilience and performance. With the intention of studying the LoPy devices functionalities it was consulted the official tutorial Website[1]. To achieve this, the project incorporates bilateral communication involving interchange of data between devices/nodes, with Node A transmitting an array of sixteen elements, starting from “0 to 15“, and Node B validating the complete reception of the array while checking for potential lost packets. Aditionally, it was also developed a communication between LoPys involving LED status exchanges, coupled with *GPIO* integration. This integration extends to hardware components like a breadboard and a temperature sensor, enhancing the project's capabilities to gather and exchange data between LoPy devices. This multifaceted approach not only ensures robust communication but also introduces monitoring through the temperature sensor, making the project versatile and suitable for various applications.

[1] `https://docs.pycom.io`

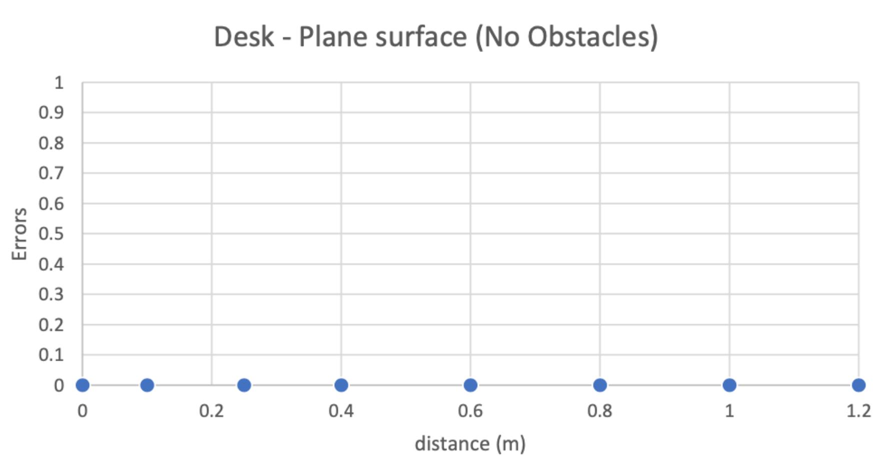
Chapter 2

Lopy 2 Lopy Communication - Lost Packets

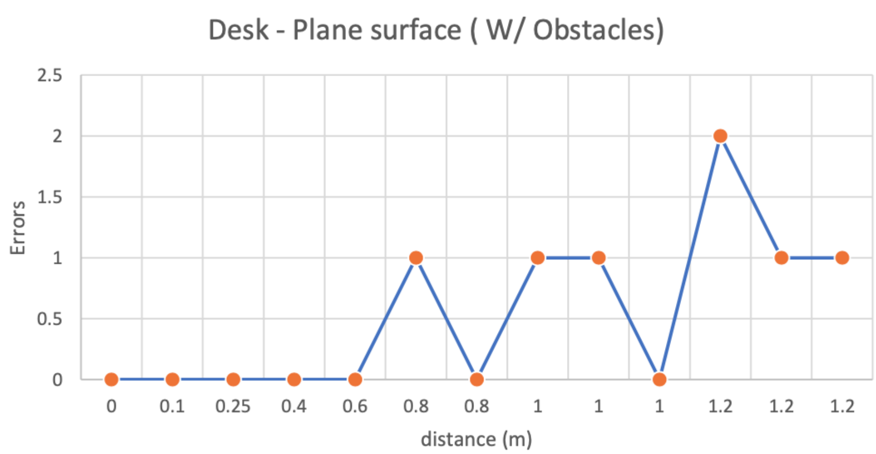
2.1 Testing without Antenna

In order to study LoRa network's adaptability and performance was necessary to test different environments, surfaces, and communication scenarios, whether involving obstacles or not, utilizing the LoPy antennas or not, and accounting for various disturbances. For the first study, it was not used the provided antenna for the lopy, to check low distances performance. The following figure (Fig.2.1) illustrates error/lost messages, whether involving obstacles or not, as the distance is increased.

As it is possible to observe, the reliability of sent messages is affected not only by increasing the distance between the two devices but also by introducing obstacles (in this case it was introduced an headphones case).



(a) Plane surface desk with no obstacles



(b) Plane surface desk with obstacles

Figure 2.1: Plane Surface Results (Distance Vs Error Vs Obstacles)

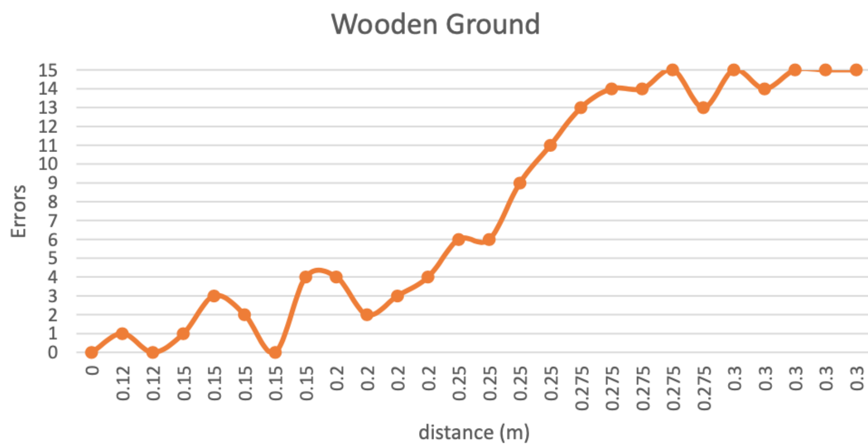
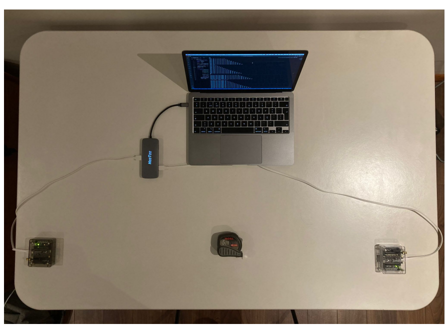
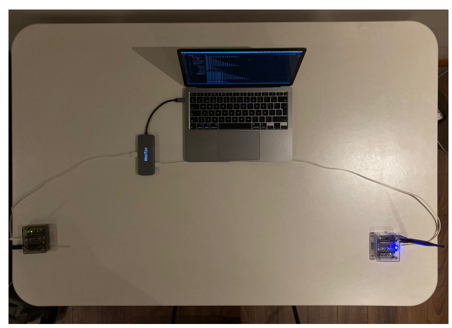


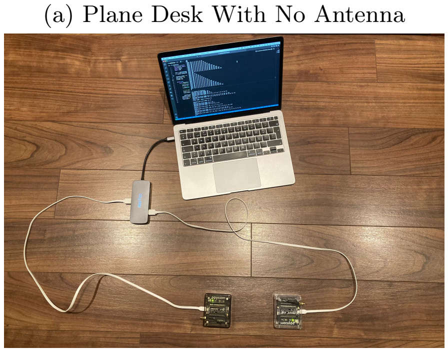
Figure 2.2: Wooden Ground (Distance Vs Error)



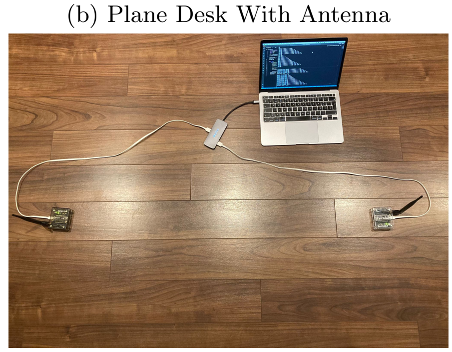
(a) Plane Desk With No Antenna



(b) Plane Desk With Antenna



(c) Wooden Ground With No Antenna



(d) Wooden Ground With Antenna

Figure 2.3: Different environments and scenarios for testing

In this study case, the surface/environment where both LoPys are positioned has been altered to a wooden ground characterized by various holes and flaws (with no obstacles). As it it presented in the previous figure (Fig. 2.2), it is presented a very notable difference in results between these two different surfaces/environments, where it is possible to acknowledge a worse communication behavior between the two devices, comparing to the previous results, since the lost messages start being noticeable already at 0.12m of distance between them. Comparing the ground and the plane desk it is recognizable that the surfaces and environments is an important evaluation parameter on LoRa's performance, at least when the study case is comparing both without using their corresponding antennas.

When introducing to loPys their antennas, the existing errors or lost messages will automatically be extinguished for this close range. The communication performance typically improves due to enhanced signal strength and reliability. The antennas optimize the transmission and reception of messages between the devices, reducing the chance of existing errors or lost messages. Without antennas, the communication range and quality might be limited, especially in environments with obstacles or interference.

The previous presented four pictures provide visual insights into the study case environments associated with the previously obtained results. (Fig 2.3) and Fig. 2.4 illustrates an example of client "0x000", which received correctly all the messages and a second one "0x001" that received incorrectly with a four error detection, meaning four loss messages.

```
>>> Looking for Requests!
Received from Client 0x000: [0]
Received from Client 0x000: [0, 1]
Received from Client 0x000: [0, 1, 2]
Received from Client 0x000: [0, 1, 2, 3]
Received from Client 0x000: [0, 1, 2, 3, 4]
Received from Client 0x000: [0, 1, 2, 3, 4, 5]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]
Received from Client 0x000: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]
Client 0x000 - Number of Errors: 0

Received from Client 0x001: [0]
Received from Client 0x001: [0, 1]
Received from Client 0x001: [0, 1, 2]
Received from Client 0x001: [0, 1, 2, 3]
Received from Client 0x001: [0, 1, 2, 3, 4, 5]
Error =  1
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6]
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7]
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7, 8]
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]
Error =  2
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]
Received from Client 0x001: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]
Error =  3
Client 0x001 - Number of Errors: 4
```

Figure 2.4: Error Detection Example - Receiver Side

In the pursuit of finding some other disturbances and parameters that could affect LoRa communication, the same tests were realized on an unusual noisy place called "University of Aveiro's Library", which is a place where it should be silent. Surprisingly, turned out to be just what the team needed to extract some valuable insights. Routers and devices certainly found their voice in this unconventional symphony of noise.

The obtained results are illustrated in the graphic (Fig. 2.5). As we can see, there is a bit of discrepancy on error detection this can be justified with the following possibilities:

- Signal Propagation / Reflection: Signal reflection, interference, or obstacles at 0.3 meters may contribute to a higher error count, while a more favorable signal path at 0.5 meters could lead to fewer errors.
- Signal Attenuation: The critical point of signal strength at 0.3 meters may make it more susceptible to interference, whereas a stronger signal at 0.5 meters could reduce errors.
- Environmental Changes: Dynamic environmental factors, such as the movement of people or electronic devices, might influence communication differently at 0.3 meters and 0.5 meters.

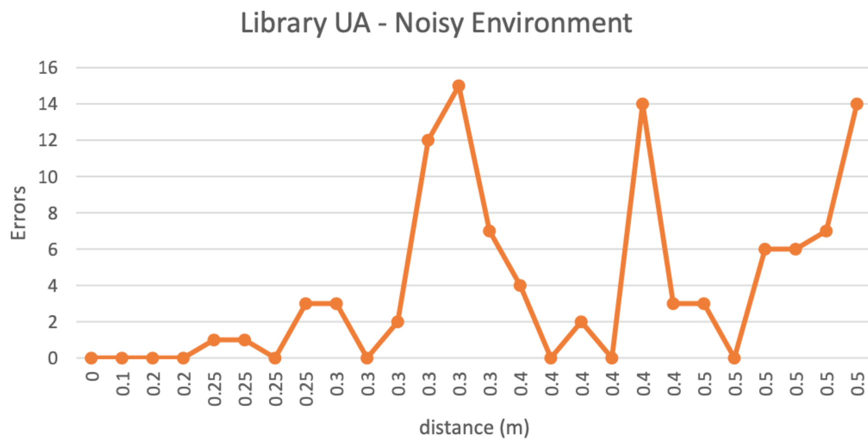


Figure 2.5: Library Noise Results

Concluding, with these results, we can tell that noise (unwanted, random, or disruptive signal interference that can distort or corrupt the transmission of information) is a crucial parameter influencing LoRa communication.

2.2 Testing with Antenna InDoors

To conduct a more comprehensive and accurate evaluation of LoRa's technology, the following tests were implemented. LoPys antennas were integrated into the LoPy devices, significantly extending the effective range of bilateral communication. By incorporating specialized antennas, we aimed to optimize the performance and reliability of LoRa communication. This strategic enhancement ensures a more robust testing environment and provides a clearer understanding of the technology's capabilities, particularly in terms of range and reliability.

The inclusion of these antennas is anticipated to yield more reliable and consistent results, allowing for an accurate assessment of LoRa's potential in real world scenarios. This improvement in hardware configurations aligns with the objective of obtaining precise insights into the technology's performance, ultimately contributing to a more informed evaluation.

In order to assess the performance of LoRa in environments with several obstacles (an important parameter on overall performance of LoRa), a new test was conducted within a closed environment (Ex: An house). In this scenario, an array of 16 numbers was transmitted every four seconds (first message: [0], second: [0,1] and so on...). The receiver then compared the expected values with the received ones, consequently calculating the packets lost in percentage.

As evident and observed on Fig. 2.6, on the same floor, all packets are received without any issues. However, as soon as obstacles are introduced within the communication, such as changing floors, the challenges that LoRa faces become evident. The difficulty it encounters in navigating through obstacles becomes noticeable in this context. Re forcing once more, the importance of range and obstacles as one of the most important parameters.

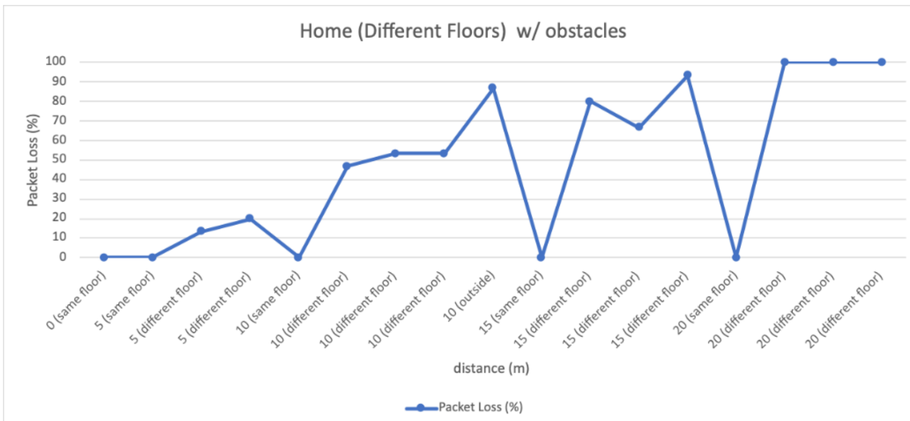


Figure 2.6: Evaluation of Testing Range in the Presence of Various Obstacles

Chapter 3

Temperature Sensor - GPIO Pin Integration

In order to make our project more complete and to explore the LoPys strengths and capabilities it was decided to integrate a temperature sensor with our LoPys.

The goal in this phase of the project was for the LoPy to read the real time temperature in Celsius provided by the temperature sensor. Subsequently, it would transmit a message to the other LoPy, including the temperature value (ºC). Depending on the temperature reading, the LED on the receiving LoPy would shift towards blue when the temperature is low and towards red when high.

3.1 Circuit Assembly

Using a breadboard, a circuit (Fig. 3.1) was implemented with GPIO Pin integration on one of the LoPys (Fig. 3.2). To assemble the circuit, we used the *LM335Z* temperature sensor, a *390Ohm* resistor and some jumper wires.

In order to develop this circuit successfully, the team consulted the *datasheet*[1] for the *LM335Z* temperature sensor. This datasheet provided crucial information and specifications necessary for the accurate integration and utilization of the sensor.

The team encountered challenges during this implementation from the use of outdated and unreliable wires to connect the LoPy with the breadboard. This resulted in unexpected temperature values and proved to be a time consuming process. Upon identifying this issue, the team promptly resolved it by obtaining new jumper wires. With this improvement, the temperature readings became more consistent and aligned with the expected values.

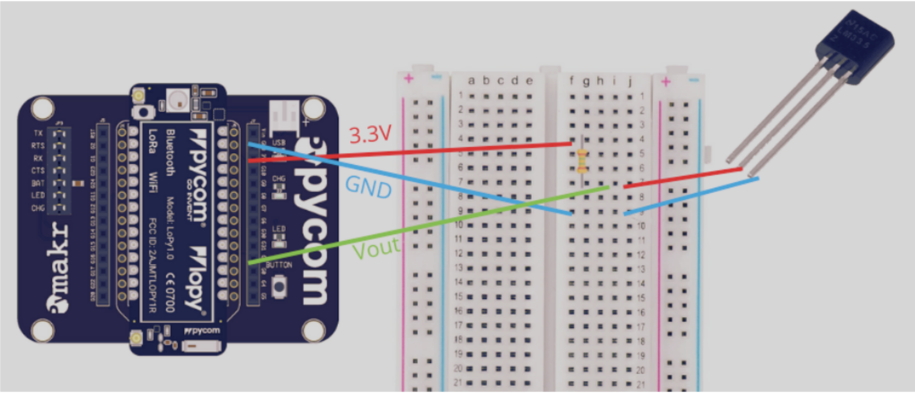


Figure 3.1: Circuit Assembly

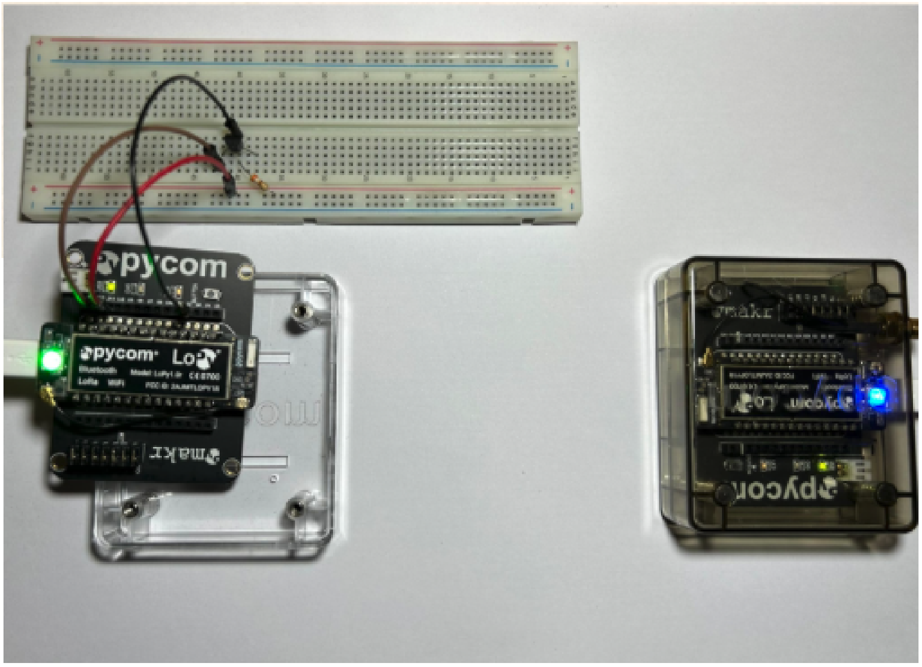


Figure 3.2: Temperature Sensor GPIO Integration Circuit

Chapter 4

Overall LoRa Performance Testing

In this chapter will be discussed the main parameters that affect significantly this technology overall performance. In order to test the accuracy of this parameters as well as Bilateral Communication and Range Testing (OutDoors), several tests were taken.

To assess the overall performance of the LoRa technology, the team conducted various tests (Figs. 4.2 and 4.3), outdoors. The following tests were executed at the Campus of the University of Aveiro (Fig. 4.1) with a simple technique consisting in sending 50 messages from Node A (sender) to Node B (receiver). The receiver will look for requests and new messages every 3 seconds in order to check if it received any message from the sender. At the end of the 50 messages $\times$ 3 seconds = 150 seconds, the receiver will perform an average of packets lost and received, retrieving the percentage of packet loss on this bilateral communication.

In the first test, conducted on a sunny day like December 15th, the aim was to evaluate the maximum communication range of the 2 Lopys provided by the professors. We positioned one team member in front of the UA library and another near the half-moon, close to the pedagogical complex. Surprisingly, at a distance of about 400m, no packets/messages were exchanged between the two devices. Consequently, the two o members had to get close to each other, and only at a distance of 135.81m it was possible to achieve a Packet Loss below 100%. This led us to conclude that, under these conditions, the maximum range was significantly lower than expected. The parameters affecting this performance will be discussed later. Interestingly, around the 100m mark, when one of the team members positioned himself behind an obstacle, the packet loss increased slightly, indicating that it is a parameter affecting the performance.

In a second test on a different day, colder and windier, we obtained results indicating a smaller maximum range (117.89m) compared to the previous day.

Figure 4.1: OutDoors Range Testing - Max Ranges

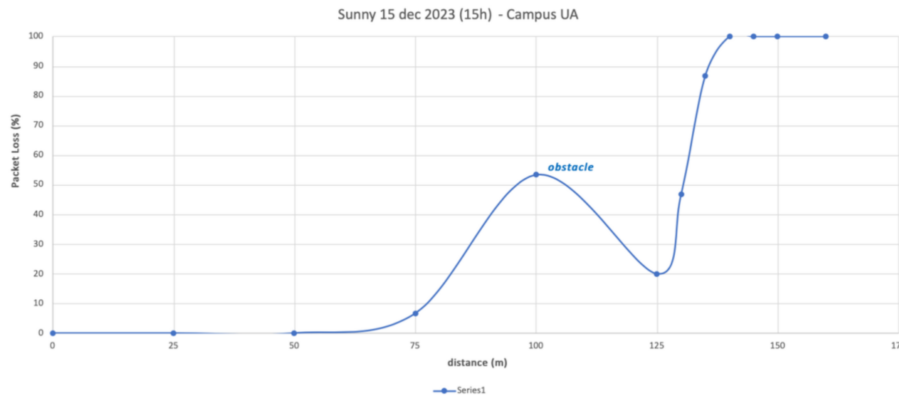


Figure 4.2: Campus UA (Distance Vs Packet Loss)

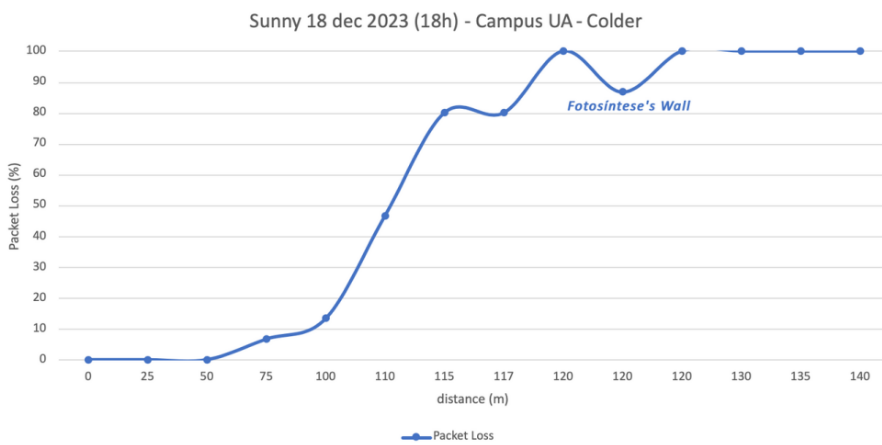


Figure 4.3: Campus UA (Distance Vs Packet Loss) Colder Temperature

4.1 LoRa Factors Testing

The following tests were conducted as part of our comprehensive exploration on the Pycom platform and LoPy devices, aiming to delve into the impact of critical parameters on LoRa communication **pycom**. Specifically, these tests focused on the implications of factors such as **frequency difference** between nodes, the interplay of **bandwidth** and distance, and the configuration of **spreading factor** [3].

The outcomes of these tests not only contribute to a deeper understanding of the LoPys capabilities but also provide crucial information for optimising

LoRa communication performance. By examining the relationships between frequency, bandwidth, and spreading factor, it is possible to take conclusions about the reliability of our LoRa networks.

4.1.1 Frequency Testing

The following tests for frequency took place at the Library of University of Aveiro (within a distance of 1 meter between the two nodes). Our goal was to find out how different frequency values affected the communication between nodes A and B, with a particular emphasis on packet loss.

Every LoRa parameter was kept at its default, with the exception of the region, which was left at EU868. Node B's frequency fluctuated from 868.035MHz to 868.037MHz, while Node A operated at a frequency of 868MHz (Note: the default provided by PyCom Website for frequency is 863MHz).

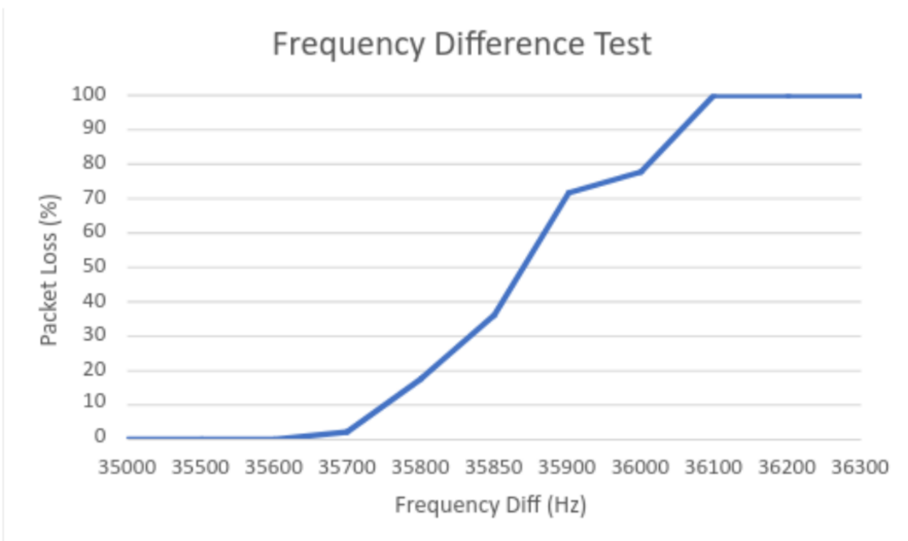


Figure 4.4: Impact of frequency difference between 2 nodes

The observed phenomenon of packet loss increasing from 0% to 100% in a nearly linear manner as the frequency of the Node B increases from 868.0356 MHz to 868.0361 MHz (while Node A frequency is set to 868MHz) provides crucial information that the chosen frequency range is critical for successful communication.

The initial frequency range of 35 kHz to 35.6 kHz indicates an ideal maximum frequency difference value with a packet loss of 0%. Within this range, the LoRa parameters are aligned with the environmental conditions, resulting in minimal interference and packet loss. The signal propagation and modulation settings are important to reliable data transmission.

As the frequency difference increases from 35.6 kHz to 36.1 khz, the LoPys devices may be less optimum for the particular environment since they are in a transition zone.

Crossing the 36.1 kHz frequency between the two nodes, the packet loss reaches the 100%, which means there is no communication between them. This is associated with a significant increase in interference or a mismatch between the modulation settings (frequency) of the nodes.

4.1.2 Bandwidth Testing

The following tests for bandwidth took place at the of University of Aveiro Campus. With a focus on packet loss in particular, we wanted to see how various bandwidth levels affected the communication between two nodes. Noting that the same bandwidth configuration needs to be applied to both nodes.

All LoRa parameters were left at their default values, except for the region, which remained at EU868. Three distinct bandwidth values (125 kHz, 250 kHz, and 500 kHz) were evaluated. We tested alternative distances between nodes (50, 75, and 100 meters) for each bandwidth value.

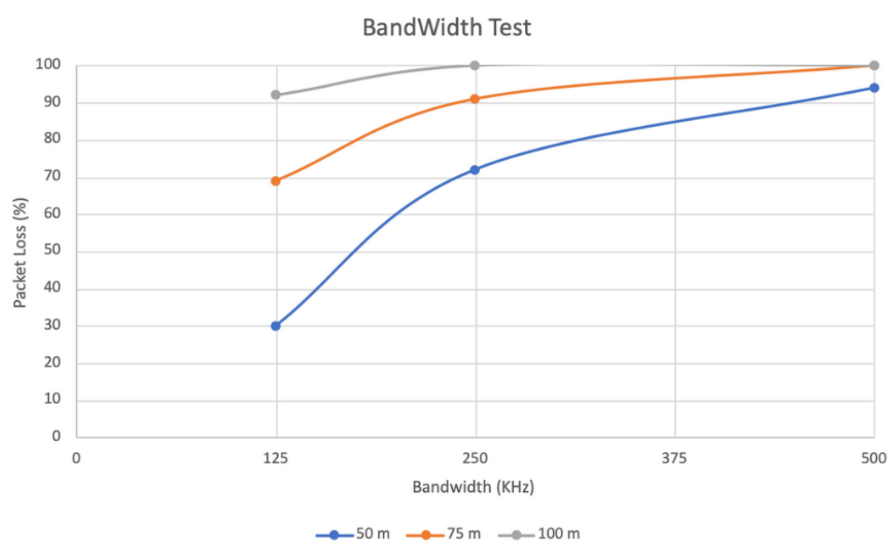


Figure 4.5: Impact of Bandwith Vs Distance

As we can see, the packet loss percentage tends to increase with bandwidth, especially when nodes are farther apart. On the other hand, reduced bandwidths result in reduced packet loss, making long distance communication more dependable.

4.1.3 Spreading Factor Testing

The following tests for Spreading Factor took place at the University of Aveiro Campus. Our goal was to find out how Spreading Factor levels affect the range in LoRa communication and also to discover what the maximum distance value would be for each level.

Except for the bandwidth, spreading factor, and the region (set to EU868), all other LoRa parameters were maintained at their default configurations. The bandwidth was specifically set to 125 kHz, and the spreading factor varied within the range of 7 to 12. It should be noted that the bandwidth and spreading factor settings for both nodes must match.

In theory, selecting a low Spreading Factor, for example 7, would allow a communication within a shorter range. On the other hand, choosing a higher Spreading Factor, for example 12, would provide a communication with an extended range.

In the following graph, we can confidently confirm this theory. Furthermore, we were able to extract the maximum distance value, which corresponds to Spreading Factor level 12 (as mentioned earlier) with a maximum distance of 243 meters.

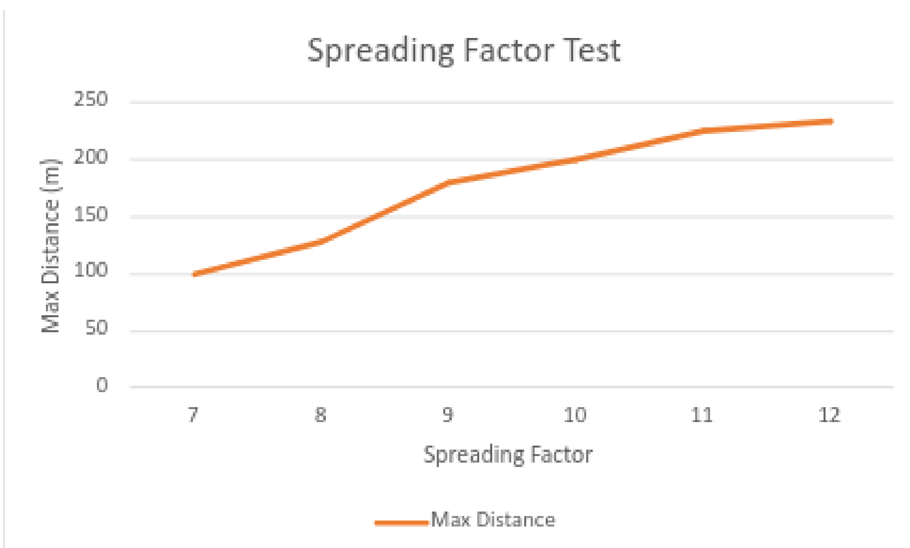


Figure 4.6: Spreading Factor Test

Chapter 5

Conclusion

In conclusion, the *LoPy2LoPy* project successfully explored and confirmed the effectiveness of LoRa technology for long range, low power communication using Pycom LoPy devices. This project conducted an evaluation of adaptability, and performance, along with tests on key parameters. The bilateral communication between LoPy devices demonstrated LoRa's real world effectiveness. Testing in diverse environments and scenarios, along with evaluations of frequency, bandwidth, and spreading factor, contributed to a deeper understanding of LoRa's capabilities. The integration of additional hardware components showcased the versatility of LoPy devices, enhancing their applications in IoT.

5.1 Contributions

- Eduardo Fernandes Lopes - 30 %
- João Afonso Ferreira - 30 %
- João Pedro Ferreira - 10 %
- Rafael Luís Curado - 30 %

Acronyms

ECT Engenharia de Computadores e Telemática

CM Comunicações Móveis

iot Internet of Things

Bibliography

[1] SGS-THOMSON Microeletronics, *Lm335z datasheet (pdf) - stmicroelectronics*, `https://pdf1.alldatasheet.com/datasheet-pdf/view/22761/STMICROELECTRONICS/LM335Z.html`, Accessed: December 2023.

[2] pycom, *Pycom introduction*, `https://docs.pycom.io`, Accessed: December 2023, 2023.

[3] Pycom, *Lorastats documentation*, `https://docs.pycom.io/firmwareapi/pycom/network/lora/`, Accessed: December 2023.