Project Report : Disaster Networking with LoRa

Maxime Bossant, Antonia Ivanova, Maxence Maury and Erwan Poncin

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1 Introduction

The planet is covered with networks relying on various technologies (cellular, telephony, satellites, electrical, etc.) that allow us to communicate quickly and efficiently with anyone in the world.

These different networks all operate in the same way: regular endpoints enabling the routing and retransmission of messages so they reach their destination. However, it follows that if one of these endpoints fails, a route is cut, and potentially an entire part of the network becomes unreachable. This is what happened during Cyclone Chido's passage over Mayotte in December 2024: 51 out of the 54 components of the island's mobile network failed, leading to difficult communication, which prevented authorities from relaying vital information to the inhabitants.

We can then wonder how this can be avoided, how to set up a network that would be resilient in the event of a natural disaster?

2 Project Objectives

2.1 Objectives

We decided to tackle the problem before any disaster occurs, at the time of setting up the network. Our goal is to provide a guide for those in charge of deploying the network so they can know in detail what specificities the network should have based on the different characteristics of the area to be mapped.

We will rely on LoRa (Long Range) technology, which offers several advantages: long range, low energy consumption, reduced cost, good building penetration, etc. Our objective is as follows: regardless of a location's characteristics, the deployed network must enable communication in extreme situations. To achieve this, we rely on the strong capabilities of LoRa technology and the principle of redundancy to ensure communication even with a certain number of machines out of service.

2.2 Deliverable

Our deliverable is a decision tree (Appendix 1), which allows installers to identify the type of terrain they are trying to cover and directs them to an adapted installation guide, including the technology to use, the topology, placements, etc.

The results we propose are based on tests (Appendix 2) that we conducted on the field and which allow us to justify the choices present in our decision tree.

3 Implementation

To communicate using LoRa, we have two possible frequencies: 433 GHz and 868 GHz. The differences between the two frequencies are interesting to exploit: 433 GHz is more effective in a dense environment but more energy-consuming, while 868 GHz offers better range in an open environment.

The equipment available to us for the two frequencies is: **433:** 4x T-BEAM Supreme (Lyligo)

868: 2x T-BEAM Supreme (Lyligo) 1x WiFi LoRa 32 (Heltec) 1x Wio-WM1110

The T-BEAM Supreme boards serve as endpoints, while the other two boards for the 868 GHz frequency serve as relays. All these boards run on Meshtastic firmware, which is an automatic mesh protocol working with LoRa technology and maintained by the community.

4 Tests Conducted (Appendix 2)

The tested criteria are as follows:

- Influence of height
- Influence of urban density
- Influence of temperature
- Influence of distance

Details for each test can be found in the corresponding file.

5 Results and Interpretations

5.1 Results

- Influence of height: The tests showed that the height of the antennas has a significant impact on the range and quality of the LoRa signal.
  - Urban environment: A height of 10 meters (3 floors) improves the range compared to a ground-level installation.
  - Rural/mountainous environment: The effect is less pronounced, but a height of 5 meters is sufficient to optimize coverage.
- Influence of urban density: The density of buildings and obstacles greatly affects signal propagation.
  - Dense area (city center): The 433 MHz LoRa signal penetrates obstacles well, unlike the 868 MHz LoRa signal.
  - Less dense area (suburbs): 868 MHz offers better range (up to 2 km more than 433 MHz in an open environment).
- Influence of distance:
  433 MHz: Effective maximum range of about 500 m in urban areas and 1.5 km in rural areas.
  868 MHz: Effective maximum range of 1.5 km in urban areas, but up to 5 km in rural areas.

5.2 Interpretations

The tests clearly demonstrate the importance of adapting the LoRa configuration to the terrain. In cities, 433 MHz at 10m height offers the best signal penetration, while in rural areas, 868 MHz at 5m enables long-range links. These results confirm the need for a differentiated approach depending on the environment, integrating antenna height, frequency, and node density to ensure a resilient network. Our operational recommendations rely on these observations to optimize deployments.

6 Challenges Encountered

We encountered several challenges during the project.

6.1 Choice of Approach

First, it was essential to define the problem and formalize it to find a suitable approach. The initial situation is vague, and the solution we propose is implemented before the disaster. Another possible approach would have been to see how to efficiently restore a failed network (just the essentials to ensure basic communication) or to determine what types of messages to send in case of a disaster.

The approach we ultimately chose is, in our opinion, the best because it precedes the others. Indeed, if the network is adapted to the terrain's characteristics and designed to withstand a disaster, there will be no need to restore it. Moreover, the choice of messages to send is irrelevant if the network did not survive the disaster. However, this question remains important and is addressed in section 7.

6.2 Flashing the Boards

Our goal was to use the Meshtastic protocol on the boards provided to us. For the T-BEAM Supreme boards, the protocol is native to the board. If we want a newer version, we can use the web flasher.

For other boards, flashing the Meshtastic firmware was more complicated. To flash these boards, we relied on the documentation (Appendix 3) and the help of classmates from the IESE program.

We wanted to ensure we could represent these two topologies:

- Endpoints in network communication
- Endpoints connected by relays

The boards we successfully flashed allow us to ensure these two topologies. We therefore decided to start the testing phase, which represents a significant part of our approach, rather than continuing to flash, which requires a lot of documentation time.

7 Possible Improvements

7.1 EWSS Messages

As mentioned in section 6.1, the choice of messages is important. We had the opportunity to combine our work with another project group working on EWSS messages (Early Warning System for Satellites). These are alerts used in the space domain to warn satellites of potential threats, such as space debris, collision risks, solar storms, or electromagnetic disturbances...

By adapting the logic used by these types of messages to natural disaster situations, they would have been good messages to send on our network.

This is a potential improvement.

7.2 Flash boards under STM32 architecture

This task is difficult because these boards don't have enough memory to support the Meshtastic firmware we use on the other boards.

The solution would be to chanage the firmware in order to make it compatible with STM32 architecture using RIOT-OS.

8 Project Management

To carry out this project successfully, we adopted a structured methodology divided into several phases:

1. Formalization of the topic and drafting of the specifications
2. Familiarization with the equipment
3. Flashing the boards
4. Test planning
5. Conducting test campaigns
6. Analyzing results and creating the decision tree

Our collaborative approach allowed us to leverage the complementary skills of each team member. Most tasks were performed as a group to encourage exchanges and maintain team cohesion. However, some transitions between phases were managed differently by splitting the group to work on multiple tasks simultaneously.

More specifically, during the transition between flashing the boards and test planning:

- Maxime Bossant and Antonia Ivanova, more comfortable with technical aspects, took charge of finalizing the flashing.
- Meanwhile, Erwan Poncin and Maxence Maury began detailed test planning.
- Antonia Ivanova joined the test planning team, bringing her knowledge of the terrain, which was useful for planning tests in rural and mountainous areas.

This fluid organization allowed us to maintain steady progress without downtime while ensuring each task was handled by the most competent members.

9 Appendix

Decision tree: `src/decision_tree/decision_tree.md`
Tests: `src/tests/Readme.md`
Documentation: `documentation/`