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Universidade Federal de Pernambuco

Workshop MoDCS 2021

A LoRaWAN Analysis for Reliability

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Overview

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4. Computational Geometry
5. Analyzing the LoRaWAN protocol
6. Energy Consumption of a LoRaWAN Network

1. Introduction

Introduction

LoRa technology and the LoRaWAN protocol, one of the most widespread in the field of Internet of Things (IoT) and also some of the main development kits available on the market.

The development of embedded systems for IoT solutions in broader areas, such as smart cities, precision agriculture and sensing Ind. 4.0, is a field in which LoRa, along with other technologies, has a special role.

2. Research Scope

Objective

The objective of this research is to propose a new mathematical model of computational geometry for reliability in LoRaWAN networks using convex hull.

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Research objective

To **Analyze the Reliability** in a LoRaWAN network using Computational geometry algorithms, taking into account the Energy consumption, Packet Delivery, Coverage and Availability.

3. Definitions and Concepts

Considerations in LoRaWAN

Definitions and concepts

For the development of the research, it is necessary to know the technology on which this content is focused.

LoRa (Long Range) (LoRa Alliance®, 2021), is the type of radiofrequency modulation, therefore it is the physical layer of the LPWAN network known as LoRaWAN. LoRaWAN (Long Range Wide Area Network) is a network protocol that uses LoRa technology to communicate and manage LoRa devices, therefore it is the medium access layer and is developed openly by the LoRa Alliance

Considerations in LoRaWAN

Definitions and concepts

LoRa is an IoT-oriented modulation technique that uses the ISM band (Semtech Corporation), although it can operate at any frequency below 1 GHz. LoRa uses a single-hop star-shaped network. On the other hand, LoRaWAN, being the network protocol, is divided into three classes Class A, Class B, and Class C. Each class represents a balance between reception capacity and consumption.

Considerations in LoRaWAN

Definitions and concepts

In LoRaWAN (Semtech Corporation) a security mechanism is established, which uses 128-bit AES encryption which is activated through Over The Air Activation (OTAA), its main advantage is security since the section is created at the time of sending data and is renewed every time the device loses connection.

Considerations in LoRaWAN

Definitions and concepts

1. Orthogonality

$$A * B \rightarrow \int_{t_1}^{t_2} f_a(t) * f_b(t) dt = 0$$

$f_a(t)$ is orthogonal with $f_b(t)$ if $f_a(t) = \cos(nwt)$ and $f_b(t) = \cos(mwt)$. How $cos\alpha * cos\beta = \frac{1}{2}[cos(\alpha + \beta) + cos(\alpha - \beta)]$ then

2. Code Rate

$$R_b = \frac{BW}{2^{SF}} * SF[bits/seg]$$

with coding:

$$R_b = \frac{\frac{4}{4+CR}}{\frac{2^{SF}}{BW}} * SF[bits/seg]$$

Considerations in LoRaWAN

Definitions and concepts

3. Shannon Theorem

$$C = B * \log_2\left(1 + \frac{S}{N}\right)\left[\frac{bits}{seg}\right]$$

The Equation can be rewritter as: $\frac{C}{B} = 1.43 * \frac{S}{N}$

4. Link Budget

If you want to set the link budget, this is determined by

$$LinkBudget = MDS - MTP[db]$$

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Considerations in LoRaWAN

4. Link Budget

$$FSLP = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) \; [dB]$$

And considering $f = 900$ MHz, then

$$FSLP = 32.45 + 20\log(d) + 20\log(f) \quad [dB]$$

LoRaWAN creates a packet format, which shows that the greater the error correction, the longer the packet will be for a given payload. The emission time of a LoRaWAN package is given by:

$$T_{packet} = T_{preamble} - T_{payload} \quad [Sec]$$

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Considerations in LoRaWAN

4. Link Budget

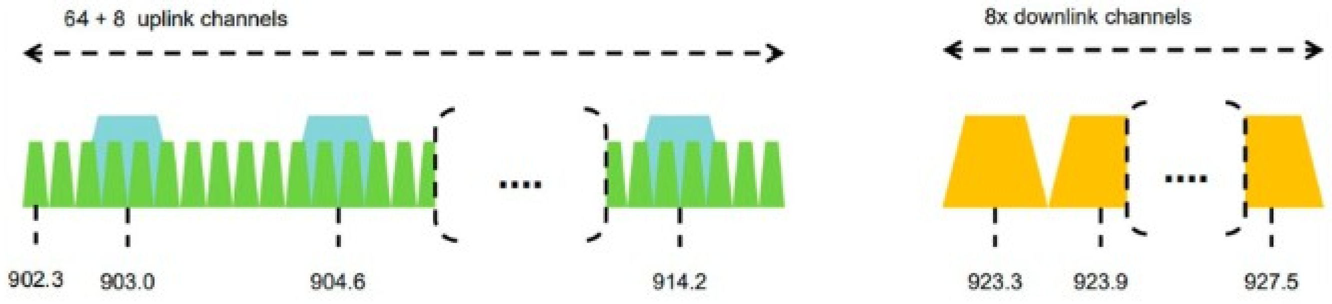
a. $$T_{preamble} = (n_{preamble} + 4.25)\,T_s \quad [sec]$$

$$T_s = \frac{1}{R_s}[sec], \quad R_s = \frac{BW}{2^{SF}}$$

b. $$T_{payload} = PL_{Symb} * T_s$$

c. $$T_{packet} = (n_{preamble} + 4.25 + PL_{Symb}) * \frac{2^{SF}}{BW}$$

5. Signal propagation



LoRa Alliance, LoRaWAN regional parameters, 2019

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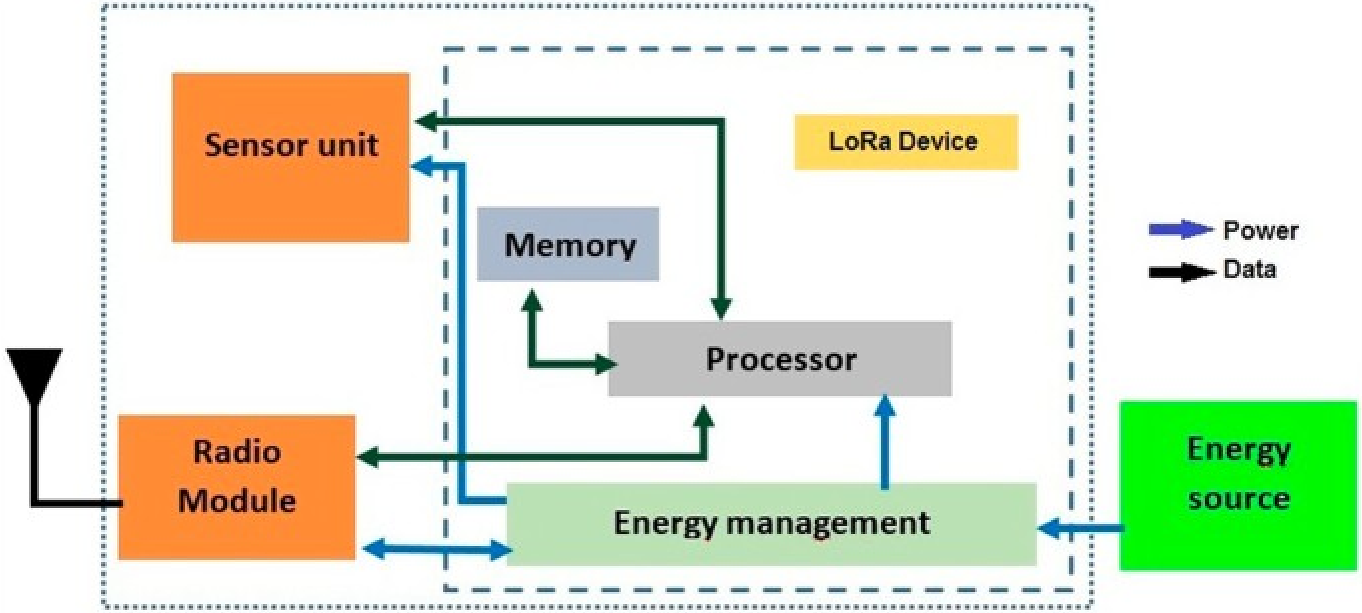
Sensor and consumption

The hardware of a sensor node can be broken down into five main parts: the processor, the sensor, the storage module, the transmitter and the power supply. As it can be seen in the Figure, all the elements of the sensor are using the power supply simultaneously.



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Definitions and concepts

6. Time Free

$$T_{off} = \frac{TimeOnAir}{DutyCycle_{subband}} - TimeOnAir$$

8. Energy Consumption

$$Battery\ Life\ [h] = \frac{Battery\ Capacity\ [mAh]}{Charging\ Current\ [mA]}$$

7. Channel Activity Detection

$$I_{Dect} = I_s + 2I_{SW}$$

9. Spreading Factor

$$SF = \log_2 \frac{R_c}{R_s}$$

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4. Computational Geometry

Computational Geometry

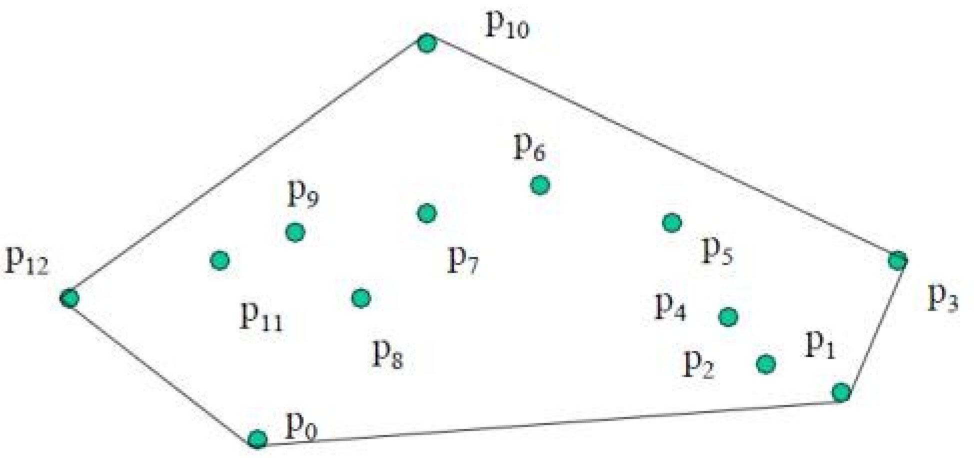
Computational geometry studies both classical geometric problems, as also problems motivated by several areas of computing such as Computer Graphics, computer aided design (CAD / CAM), robotics, geographic information systems, computer vision, combinatorial optimization, **image processing**, **theory graphs**, integrated circuit design, machine learning, GPS, etc.

Computing the **convex hull** means that a non-ambiguous and efficient representation of the required convex shape is constructed. The complexity of the corresponding algorithms is **usually estimated in terms of n, the number of input points, and sometimes also in terms of h, the number of points on the convex hull**.

Convex hull Algorithm

Algorithms that construct convex hulls of various objects have a broad range of applications in mathematics and computer science.
In computational geometry, the algorithms are proposed for computing the **convex hull of a finite set of points**, of which will be taken into account:

- **Gift wrapping, Jarvis march — O(nh)**
- **Graham scan — O(n log n)**



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Computational Geometry

The Computational geometry systematic study of algorithms and data structures for geometric objects, included computer graphics, computer vision and others.

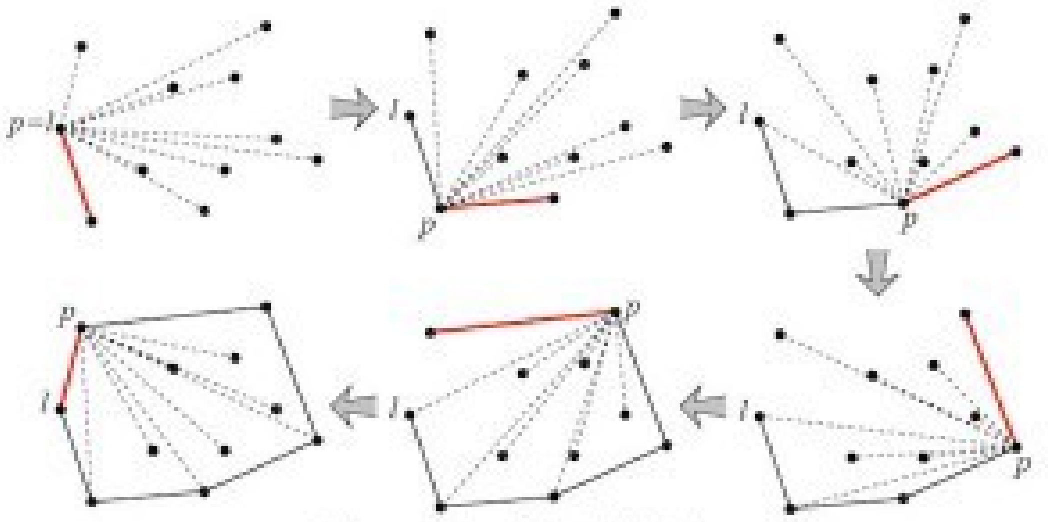
Theorem 1. *Algorithm Graham's scan runs at time O(n log n).*
Test: The symbolization of the points (sensors) according to the x-coordinates provided in these scenarios with the LoRaWAN protocol.

Theorem 2 . *Jarvis March Algorithm O(n).*
Jarvis march computes the CH(Q) by a technique known as gift wrapping or package wrapping. Consider first, a base point P (S1Detection) is selected.

5. Analyzing the LoRaWAN protocol

Jarvis Algorithm

Convex hull or convex envelope of a set of P points in a Euclidean plane is the smallest convex set that contains P. It is like wrapping the set of P points inside a boundary using the outermost smaller set of P points, as depicted in an illustration .



The execution of Jarvis's March.

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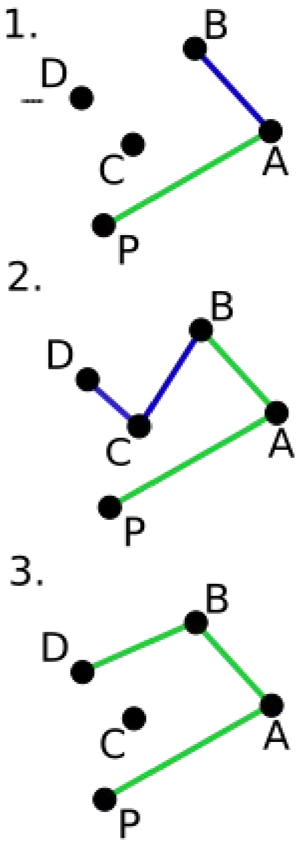
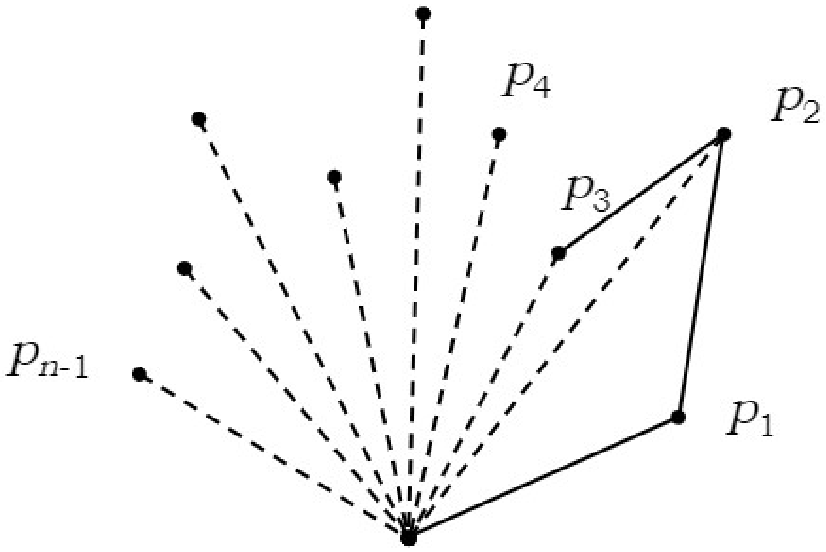
Graham Algorithm

Graham's method (Graham Algorithm) is a computational method of calculating the convex envelope of a finite set of points in the plane. The algorithm computes all vertices of the convex envelope ordered along the boundary. It can be easily modified to calculate the points that, without being vertices, belong to said envelope... (See Figures).





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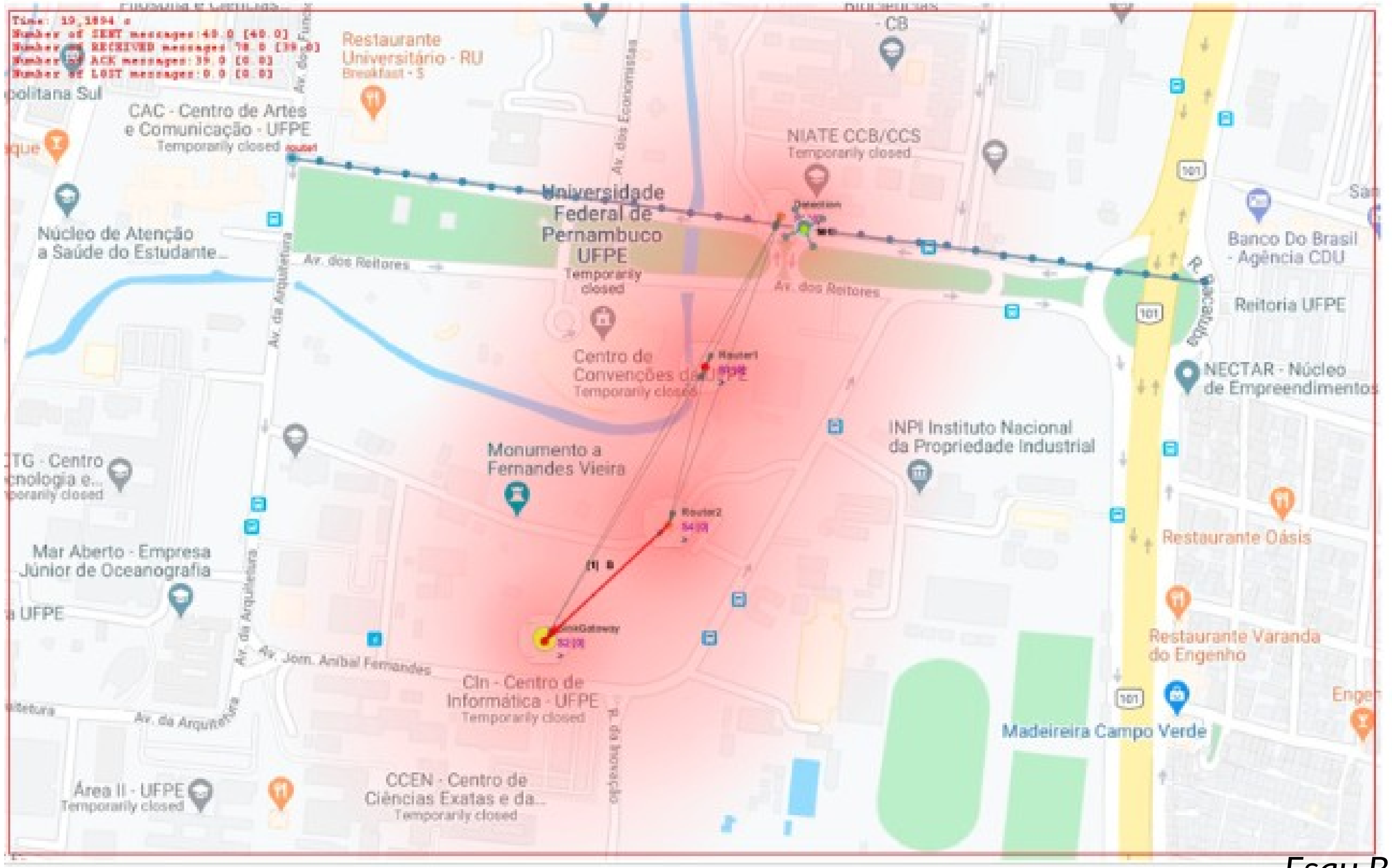
LoRaWAN Network



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Application in LoRa networks

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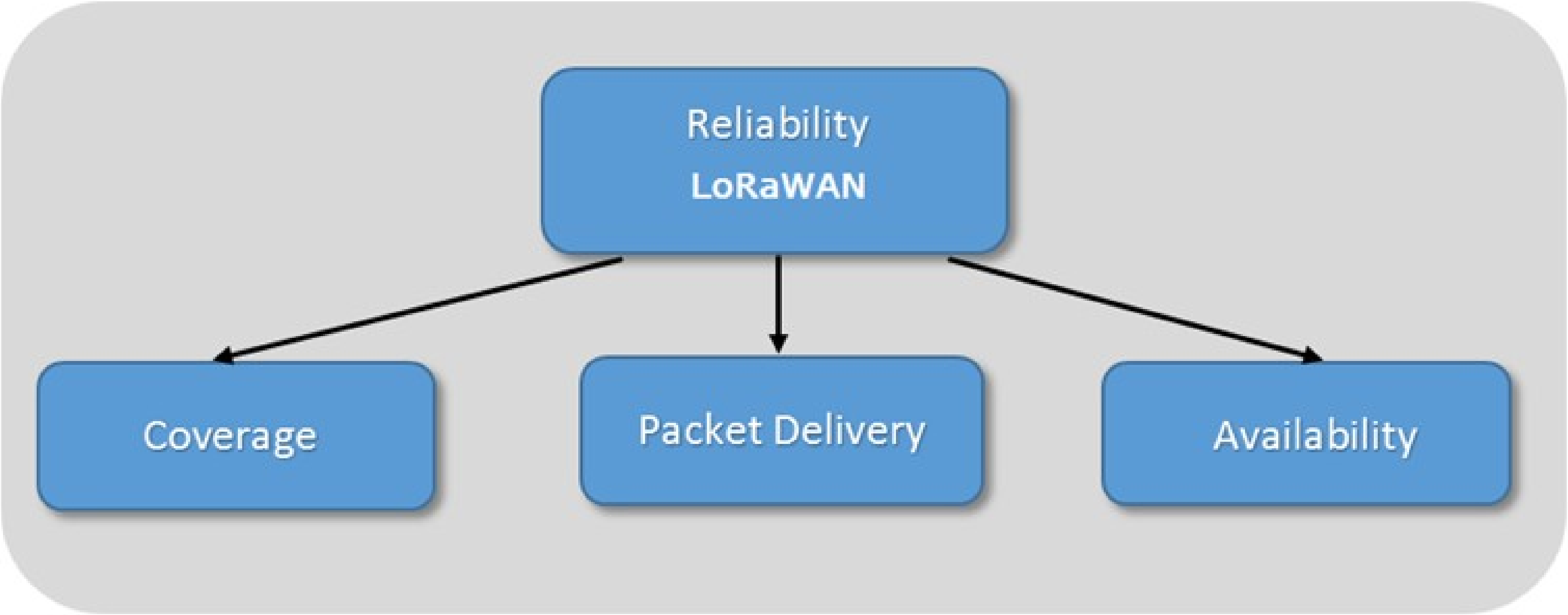
The same problems occur in the area of wireless networks, where it is necessary to develop solutions in terms of telecommunications in search of solutions for **sending packets, routing (graphs)** among others.

The focus will be to show how the algorithms they behave in this type of wireless networks, in order to obtain results that help improve their performance, **this from the graphs generated by the algorithms for their study and subsequent analysis.**

Test: The symbolization of the set points as (sensors) according to the x-coordinates provided in these scenarios with LoRaWAN protocol, for the location.

Jarvis march computes the CH(Q) by a technique known as gift wrapping or package wrapping. Consider first, a base point P (S1Detection) is selected.

Reliability in LoRaWAN



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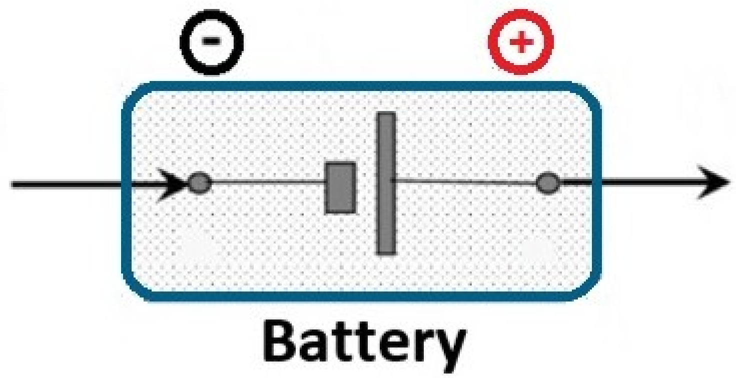
6. Energy Consumption of a LoRaWAN Network

Energy consumption

A peak of energy consumption at the sensor points is observed at the beginning.

But, over time this peak stabilizes and only when a request is made and the ACK is received does it return that peak to be displayed,



Definitions and concepts

10. Average Load

$$\bar{A} = \bar{C_{tx}} T_{tx}$$

where T_{tx} is the time when a node is transmitting and C_{tx} is the average current consumed in transmission mode .

11. Total consumption

$$P_{Tx} = P_{elec} + Kr^{\alpha},$$

we would obtain our improved research objective like this:

To **Analyze the Reliability** in a LoRaWAN network using Computational geometry algorithms, taking into account the Energy consumption, Packet Delivery, Coverage and Availability.

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Obrigado !

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Perguntas e Respostas

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