Geolocalisation in Internet of Things with LoRa technology

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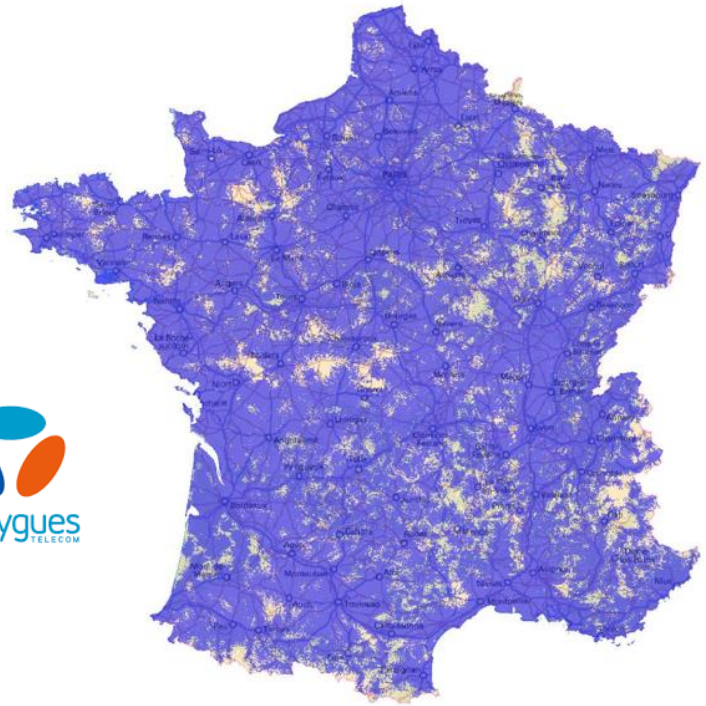
Introduction to Organization and Business

Objenious is a subsidiary from Bouygues Telecom dedicated to the IoT

We roll out 4200 LoRa GTW to provide a nation wide Coverage :

- 93% of population
- 84% of the surface



The network is deployed, engineered, exploited by Bouygues Telecom

Bouygues Telecom is French mobile and ISP operator.

More than 13M Mobile subscribers and 3M fixe lines

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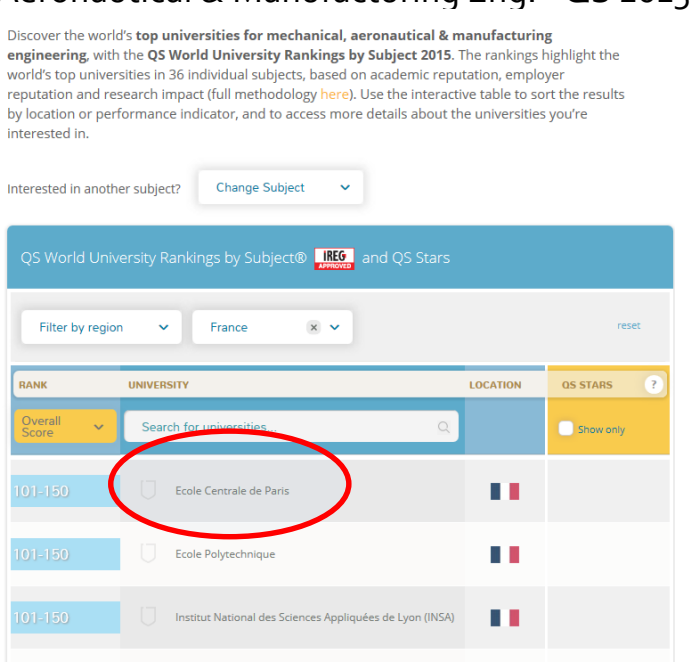
Introduction to Organization and Business

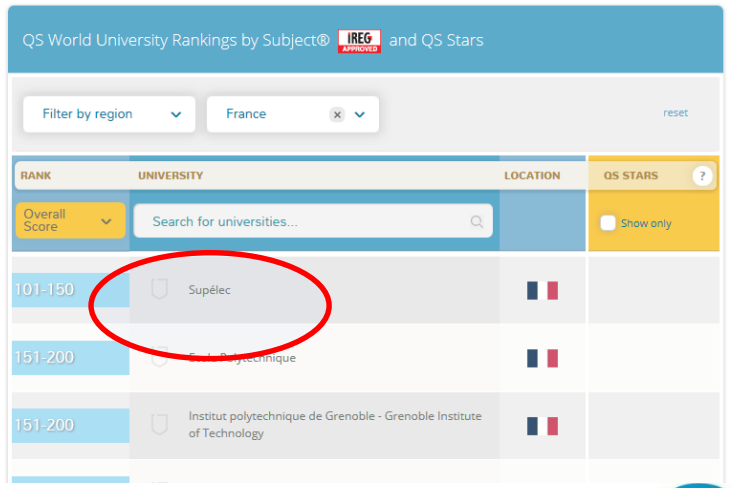
CENTRALESUPELEC

Result from the merging in 2015 between Ecole Centrale Paris and Supélec, leading engineering Grande Ecole in France.

Centrale ranks 1st in France on Mechanical, Aeronautical & Manufacturing Eng. - QS 2015



Supélec ranks 1st in France on the domain of Electrical & Electronic engineering - QS 2015.



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Why geolocation is needed ?

Uses cases

New services

Decrease the loss / robbery

Asset tracking

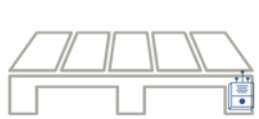
Monitor the usage of your assets (nb / length of rotation)

Geofencing

Alerting

Inventory

...



the key points

Accuracy

Where geolocation is available outdoor / indoor / Which surface ?

Power consumption

Coverage

Price of the device

The cost of the service

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Innovation Challenges and Achievements

Geolocation is crucial for the IoT use cases

More than 50% of IoT uses cases needs geolocation (with several level of accuracy)

Eg : Logistic, Tracking, Security :

Many different technologies exists :

- Cell location
- GPS location
- Location triangulation TDOA
- Localisation beacon
- Localisation BLE
- Localisation via sniffing wifi
- …

Now, LoRa is the best IoT LPWAN technology for localisation with good accuracy without GPS, low power consumption, indoor, outdoor and cost service.

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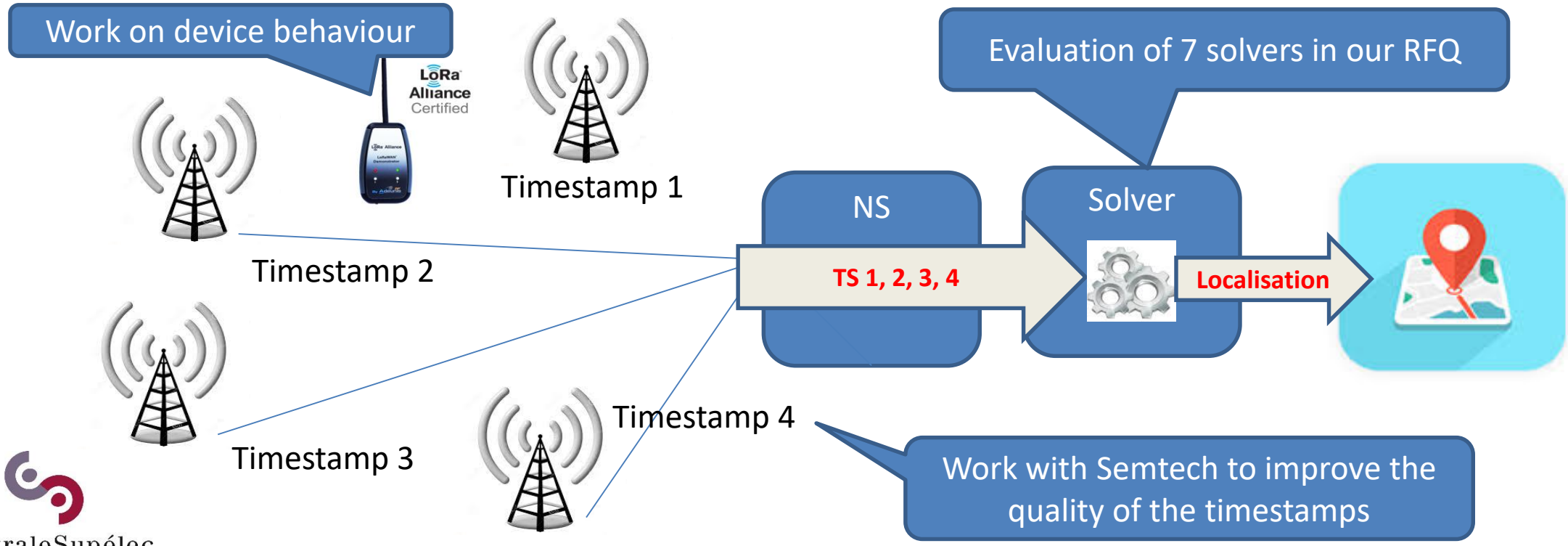
Localisation with TDOA

We aim to open the service this summer

We test TDOA since 8 months on 3 larges test fields (between 10 and 20 LoRa GTW)

To deliver the best TDOA experience we work on :

devices behaviour, on timestamps, on solver



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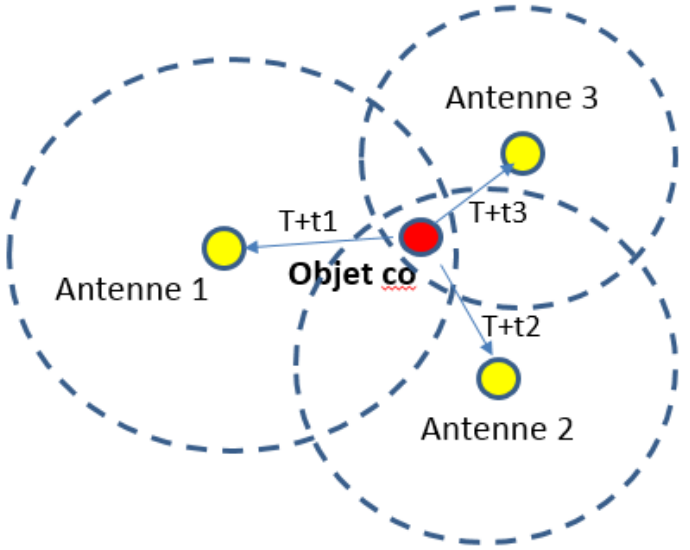
The mathematical challenge

To calculate the best position for the target (P), we use the TDOA method

Input :

- The position of 3 antennas : A(x_A,y_A), B(x_B,y_B),C(x_C,y_C),
- The differential time of arrival :

$$\Delta TOA_{12} = T_A - T_B$$
$$\Delta TOA_{13} = T_A - T_C$$
$$\Delta TOA_{14} = T_A - T_D$$



- Resolve this 3 equations for calculate the minimum

$$\begin{cases} \sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_B - x)^2 + (y_B - y)^2} - D_{12} = 0 \\ \sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_C - x)^2 + (y_C - y)^2} - D_{13} = 0 \end{cases}$$

$$\begin{cases} \sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_C - x)^2 + (y_C - y)^2} - D_{13} = 0 \\ \sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_D - x)^2 + (y_D - y)^2} - D_{14} = 0 \end{cases}$$

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How did we get there and leverage MathWorks

Because of the errors in the measurements and due to the noise, instead of solving the above equations which are not always exactly 0, we look for the minimum of the following equation:

$$\min_{X,Y,Z} \sum_{i=1}^{N} \left| \sqrt{(X_i - X)^2 + (Y_i - Y)^2 + (Z_i - Z)^2} - \sqrt{(X_r - X)^2 + (Y_r - Y)^2 + (Z_r - Z)^2} - c * \Delta t_i \right|^2$$

To find the solution we have created and tested the algorithm using MATLAB.

- Grid Search method is an easy algorithm, however it requires to test the function to minimize on all the dots of a dense grid. So the computation complexity is high: for instance on a 4x4km square with a 1 m step it is 16.000.000.
- Another choice: Genetic Algorithm

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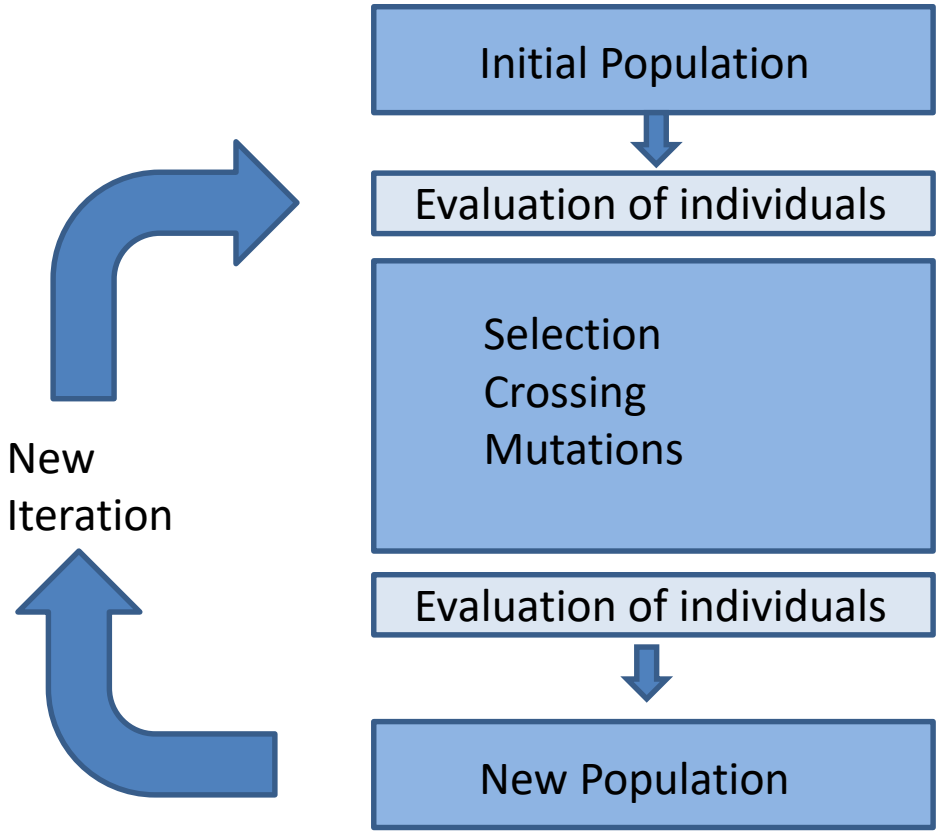
How did we get there and leverage MathWorks

Genetic Algorithm:



In our case individuals are positions

The evaluation is how much they minimize the function

Crossing is taking the baricenter between two individuals, with a random weight for each individual

Mutation is taking a new random position to randomly explore new arera

Use of the function ga in Matlab

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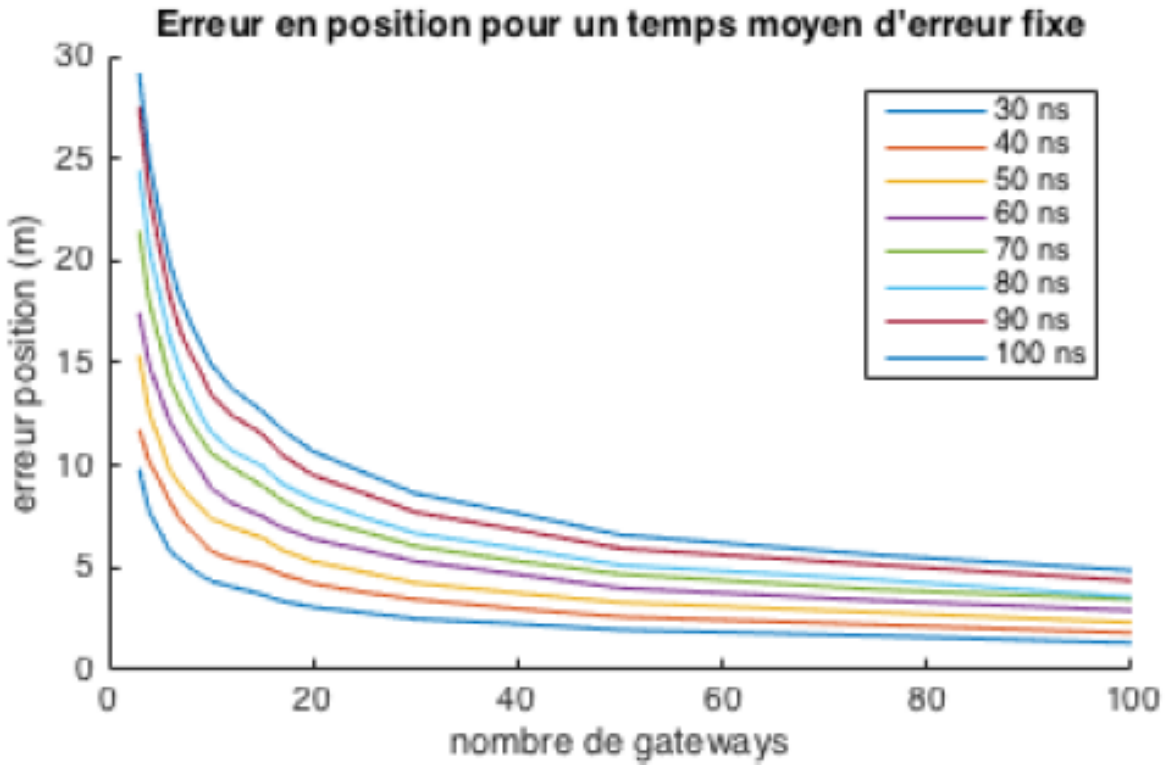
How did we get there and leverage MathWorks

The results are good:



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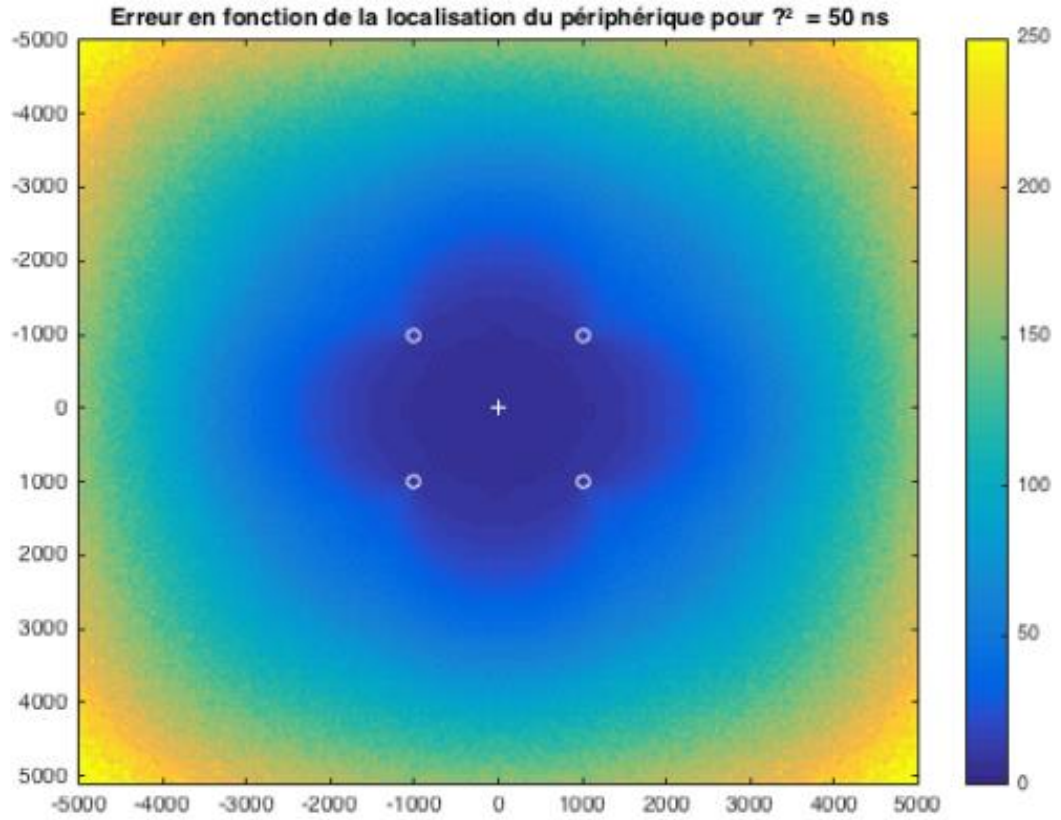
How did we get there and leverage MathWorks

Other kind of analysis that could be done thanks to the algorithms:
the positioning precision in function of the position of the object with respect to the gateways.



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First result

The location is calculated by the network :

- **Calculation is based on the time of arrival of a message on several gateways (at least 3)**

Low power consumption

- **location can be calculated on each uplinks**
- **It works for any LoRa devices**

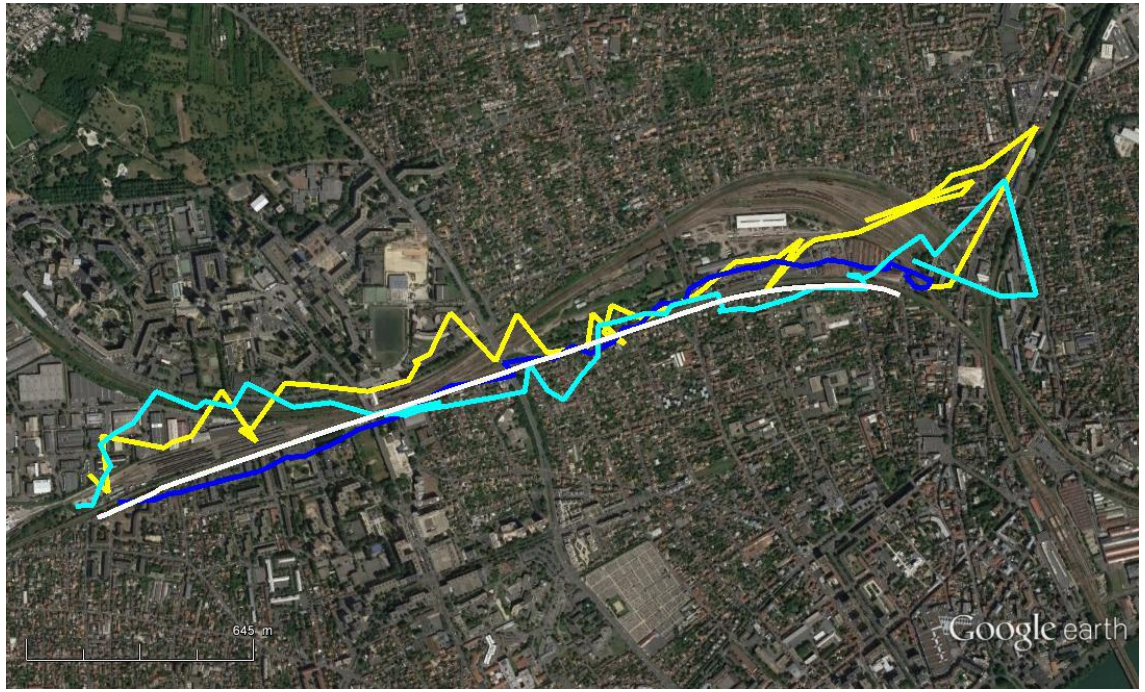
It works for indoors use cases

Not aivalable everywhere in the Objenious's network, we need at least 3 gateways

Accuracy varies between the use cases

- **Settings are different for fixed or motion use cases**
- **For fixed use cases, we observe accuracy under 100 m in 80% in dense area. Accuracy is good because we can filter.**

3 TDOA traces in a car



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Innovation Challenges and Achievements

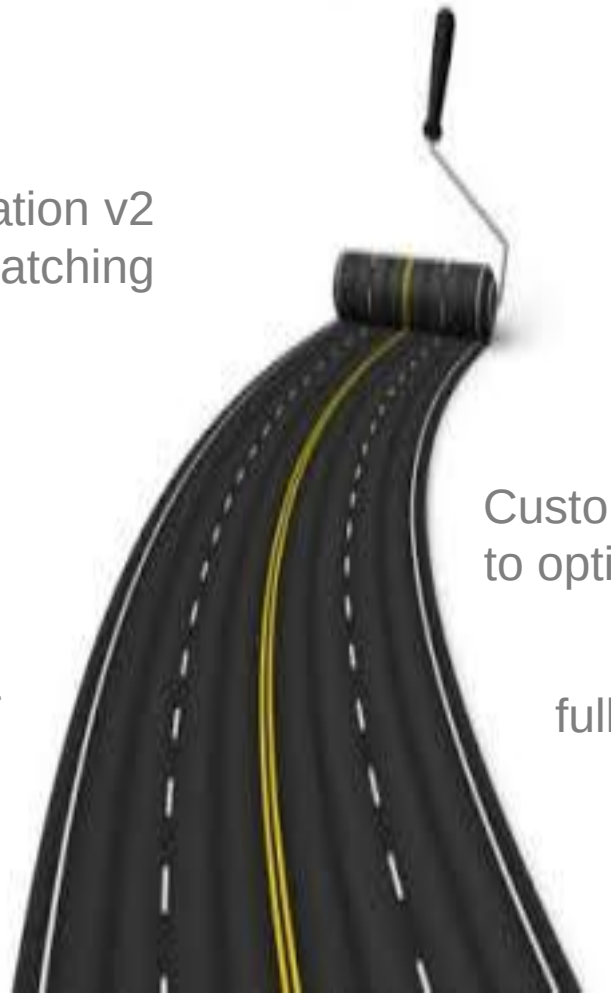
What's next for geolocation

Launch of TDOA geolocation v2
data fusion / Finger printing / map matching

TimeStamp improvement

Launch of TDOA geolocation v1

TDOA testfields



Wifi sniffing

Indoor location solution
(with beacon)

Customize device behaviour
to optimize TDOA calculation

full Mv2 network

GPS geolocation

4200 LoRa Gateways

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Next steps

The service will open 1st July

Still a lot of work to improve the accuracy : filtering, data fusion,…

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