Geolocalisation in Internet of Things with LoRa technology

Philippe COLA
Senior Core Network Architect
Technical direction
Bouygues Telecom
pcola@bouygues Telecom.fr

Jocelyn FIORINA
Professeur
Département Télécommunications et Laboratoire LSS
CentraleSupélec
jocelyn.fiorina@centralesupelec.fr

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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.
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.
**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
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.
Localisation with TDOA

We aim to open the service this summer.
We test TDOA since 8 months on 3 large test fields (between 10 and 20 LoRa GTW).
To deliver the best TDOA experience we work on:
- device behaviour,
- on timestamps,
- on solver.

Work on device behaviour

Evaluation of 7 solvers in our RFQ

Work with Semtech to improve the quality of the timestamps
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:

\[
\Delta T O A_{12} = T_A - T_B \\
\Delta T O A_{13} = T_A - T_C \\
\Delta T O A_{14} = T_A - T_D
\]

- Resolve this 3 equations for calculate the minimum:

\[
\begin{align*}
\sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_B - x)^2 + (y_B - y)^2} - D_{12} &= 0 \\
\sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_C - x)^2 + (y_C - y)^2} - D_{13} &= 0 \\
\sqrt{(x_A - x)^2 + (y_A - y)^2} - \sqrt{(x_D - x)^2 + (y_D - y)^2} - D_{14} &= 0
\end{align*}
\]
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
How did we get there and leverage MathWorks

Genetic Algorithm:

- Initial Population
- Evaluation of individuals
- Selection
  - Crossing
  - Mutations
- Evaluation of individuals
- New Population

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 area

Use of the function ga in Matlab
How did we get there and leverage MathWorks

The results are good:
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.
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 available 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.**
Innovation Challenges and Achievements

What’s next for geolocation

- Launch of TDOA geolocation v1
  - TDOA testfields
  - TimeStamp improvement
- Launch of TDOA geolocation v2
  - data fusion / Finger printing / map matching
- 4200 LoRa Gateways
- GPS geolocation
- Wifi sniffing
- Indoor location solution (with beacon)
- Customize device behaviour to optimize TDOA calculation
- full Mv2 network
Next steps

The service will open 1\textsuperscript{st} July
Still a lot of work to improve the accuracy: filtering, data fusion,…