# Outdoor Localization and Distance Estimation Based on Dynamic RSSI Measurements in LoRa Networks: Application to Cattle Rustling Prevention

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IoT – from idea to reality

# Cattle rustling

- In Africa, particularly in Senegal, the practice of animal husbandry has always been and still remain farmers' livelihood and income
- Their main problems in this activity remain the cattle rustling and some families are put in dramatic situation after a theft

# Cattle collar for localization

- Cattle collars with GPS can provide real-time localization
- With appropriate design and based on period beacon, a collar can also alert when something goes wrong
- Tested in Cimel farm in Saint-Louis, Senegal

# 1 collar = 1 GPS?

- GPS-collar for each animal can quickly become very expensive in cost and energy even if the collar is energy efficient and designed with a low-cost spirit
- Most of solutions for LoRa localization are based on TDOA and need a large number of gateways as anchor nodes
- In rural areas, private LoRa deployments are the most common scenario with generally a minimal number of gateways due to cost and deployment constraints
- Many herdsman are also nomadic

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# Our proposition

- We propose a method that minimizes the number of collars with GPS and provide accurate localization of nodes without GPS
  - Based on RSSI
  - With a single LoRa Gateway
- But, it is also well-known that RSSI values are very fluctuant and give high localization errors
- We propose a dynamic RSSI mapping approach and take advantage of the GPS collars to increase accuracy of non GPS collar localization

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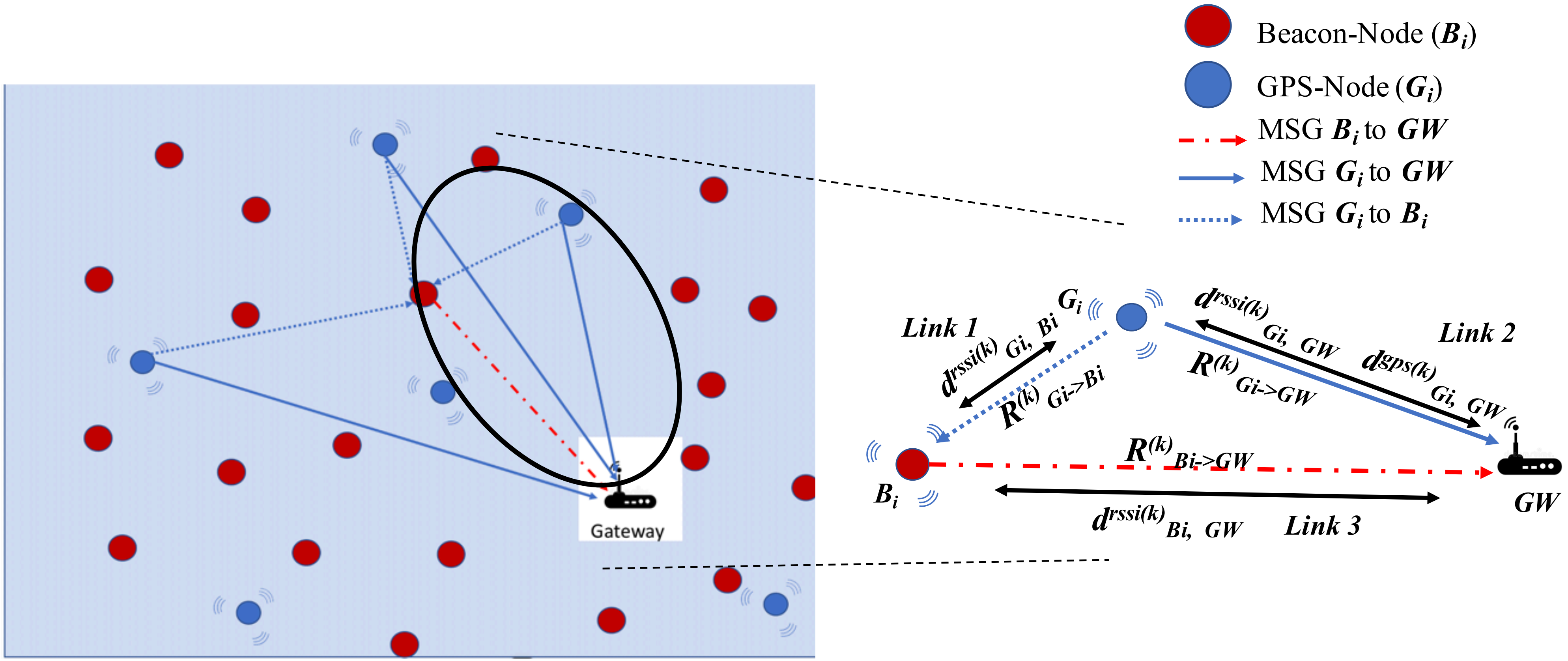
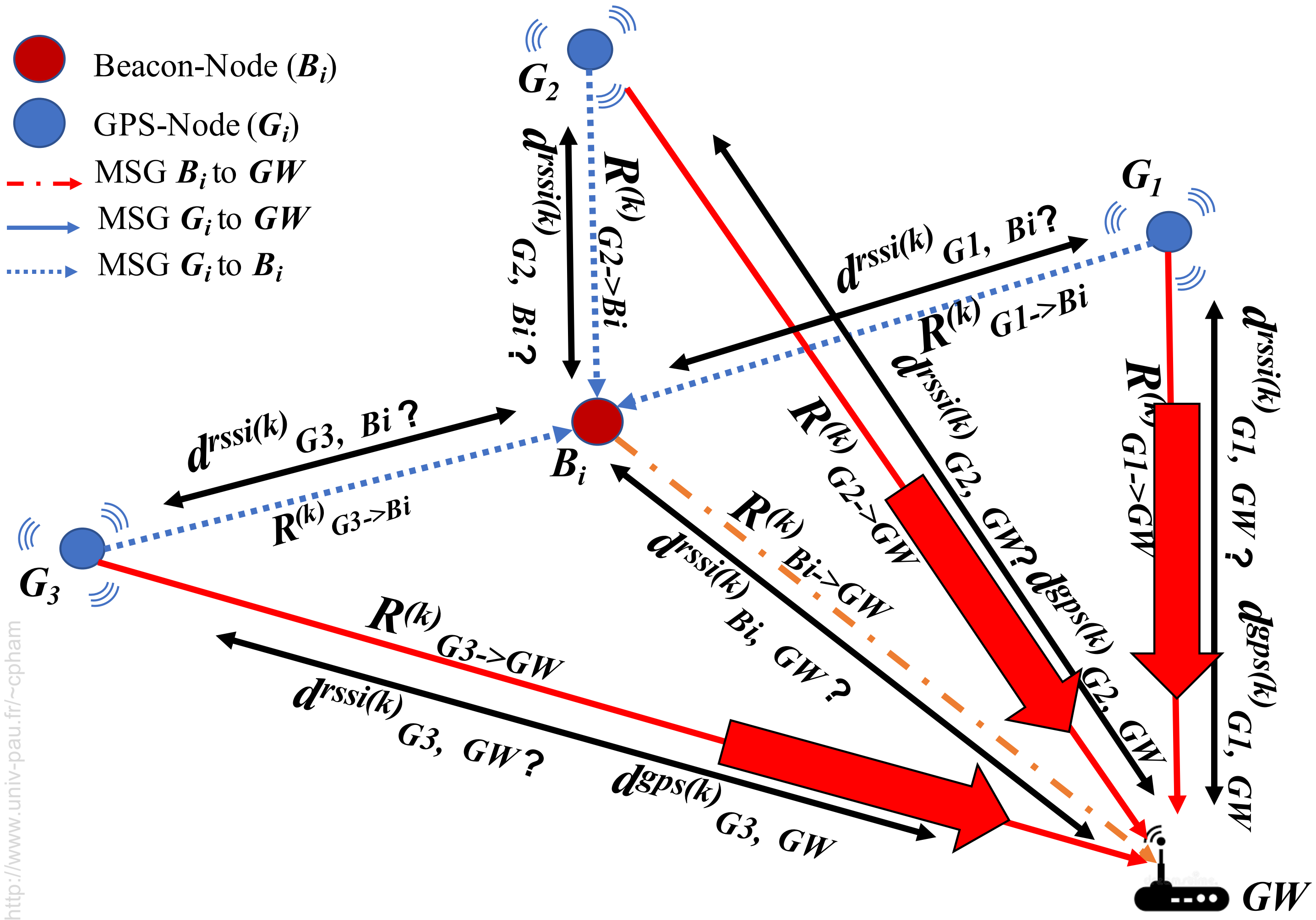
# System overview



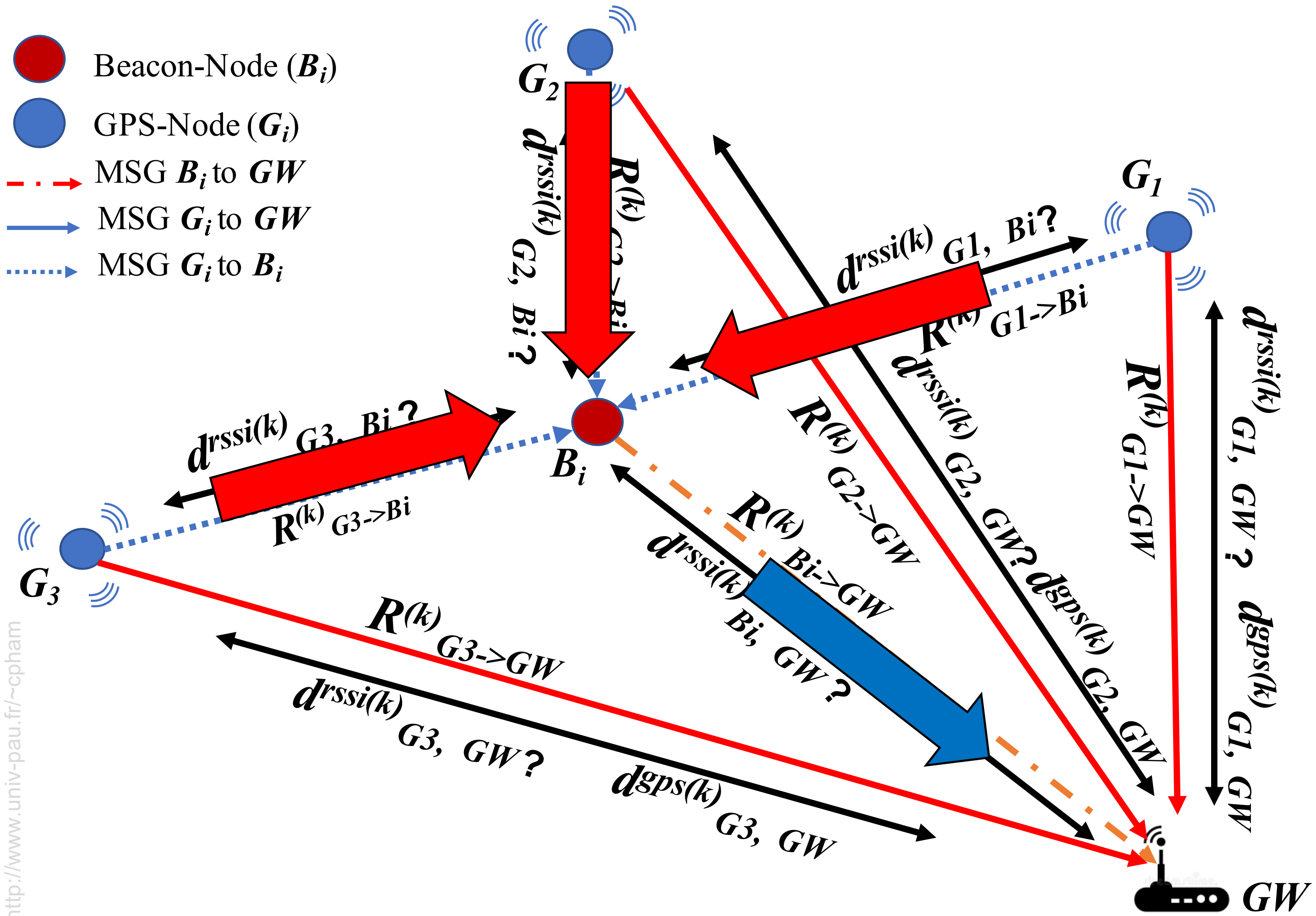

Network

# (1): GPS-node to GW at step k



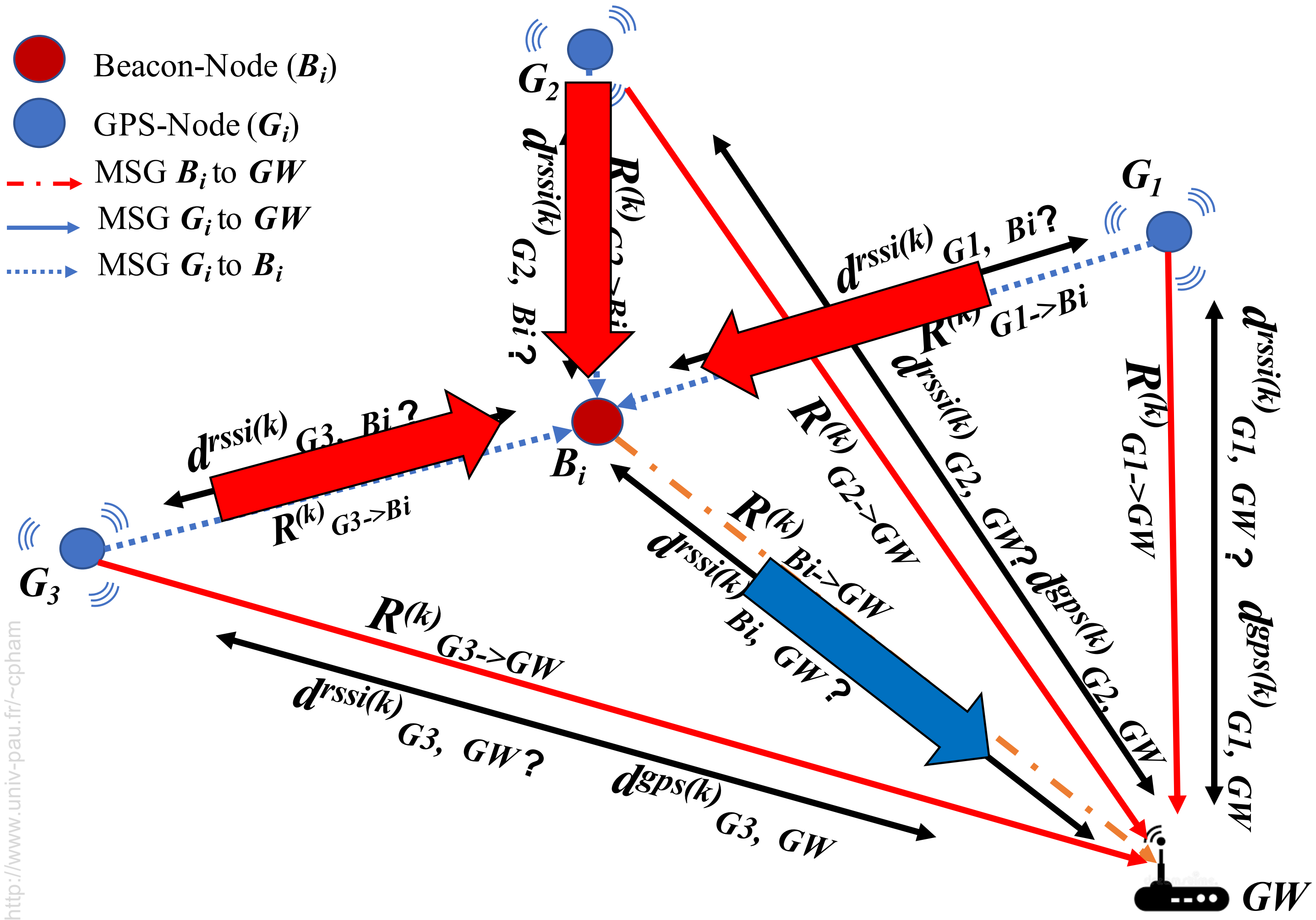

- GW updates a weighted RSSI-distance table based on received RSSI and computed GPS coordinates at step k
  - $d^{gps(k)}$ G1, GW
  - $d^{gps(k)}$ G2, GW
  - $d^{gps(k)}$ G3, GW
- The table will be continously filtered with a Kalman filter

# (2): GPS-node to Beacon node



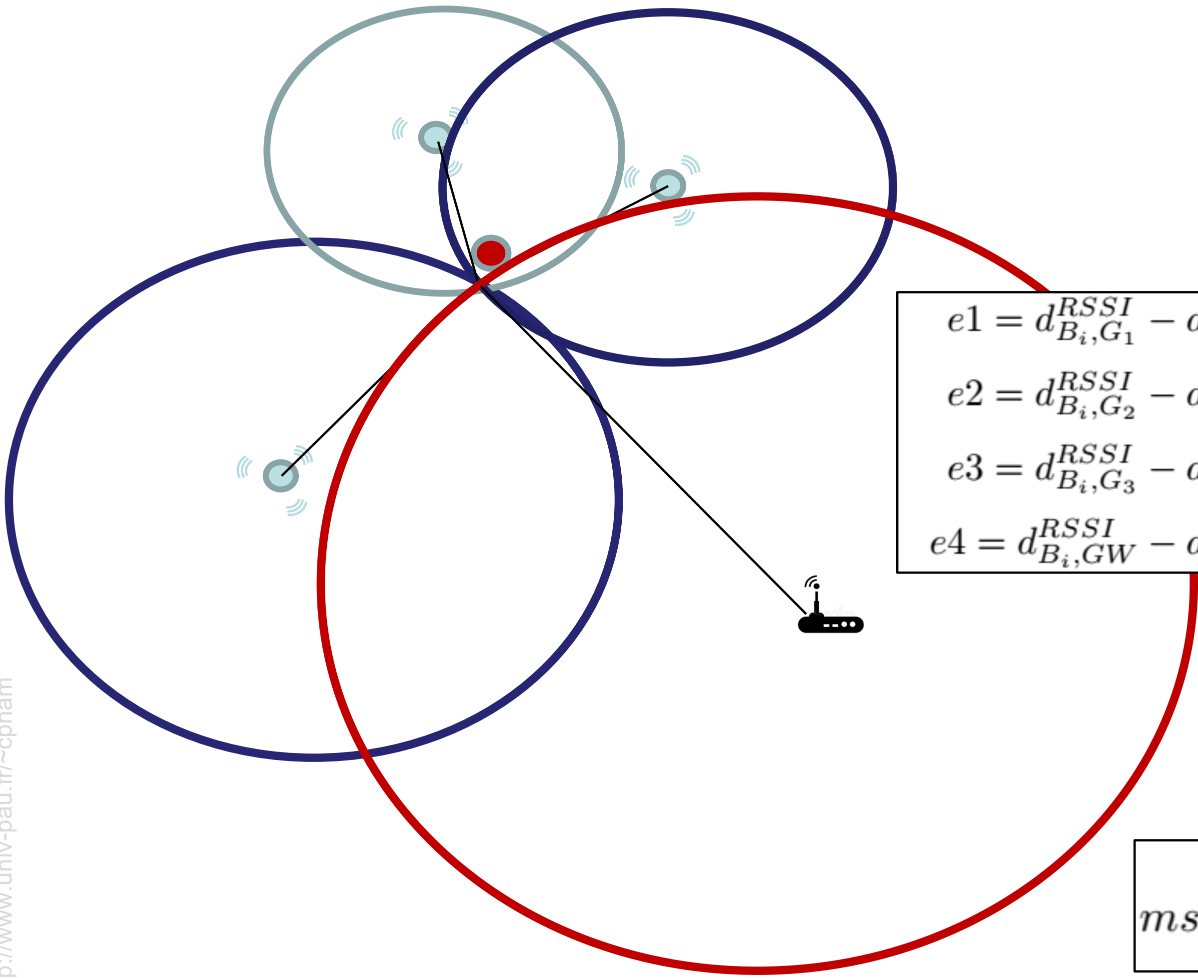

- Beacon node also receives from GPS-node
- Builds and sends a msg to GW, indicating the RSSI of msg from GPS nodes
- $G1_{RSSI,k}$, $G2_{RSSI,k}$, $G3_{RSSI,k}$

# Step 3: Distance estimation at GW




- GW uses RSSI-distance table to estimate
  - $d^{rssi}$ Bi, GW
  - $d^{rssi}$ Bi, G1
  - $d^{rssi}$ Bi, G2
  - $d^{rssi}$ Bi, G3
- Standard deviation σ and entry weights are used to determine the σ-closest entry
- Path-loss model is used if there is no entry (not enough samples)

# Step 4: Distance estimation at GW

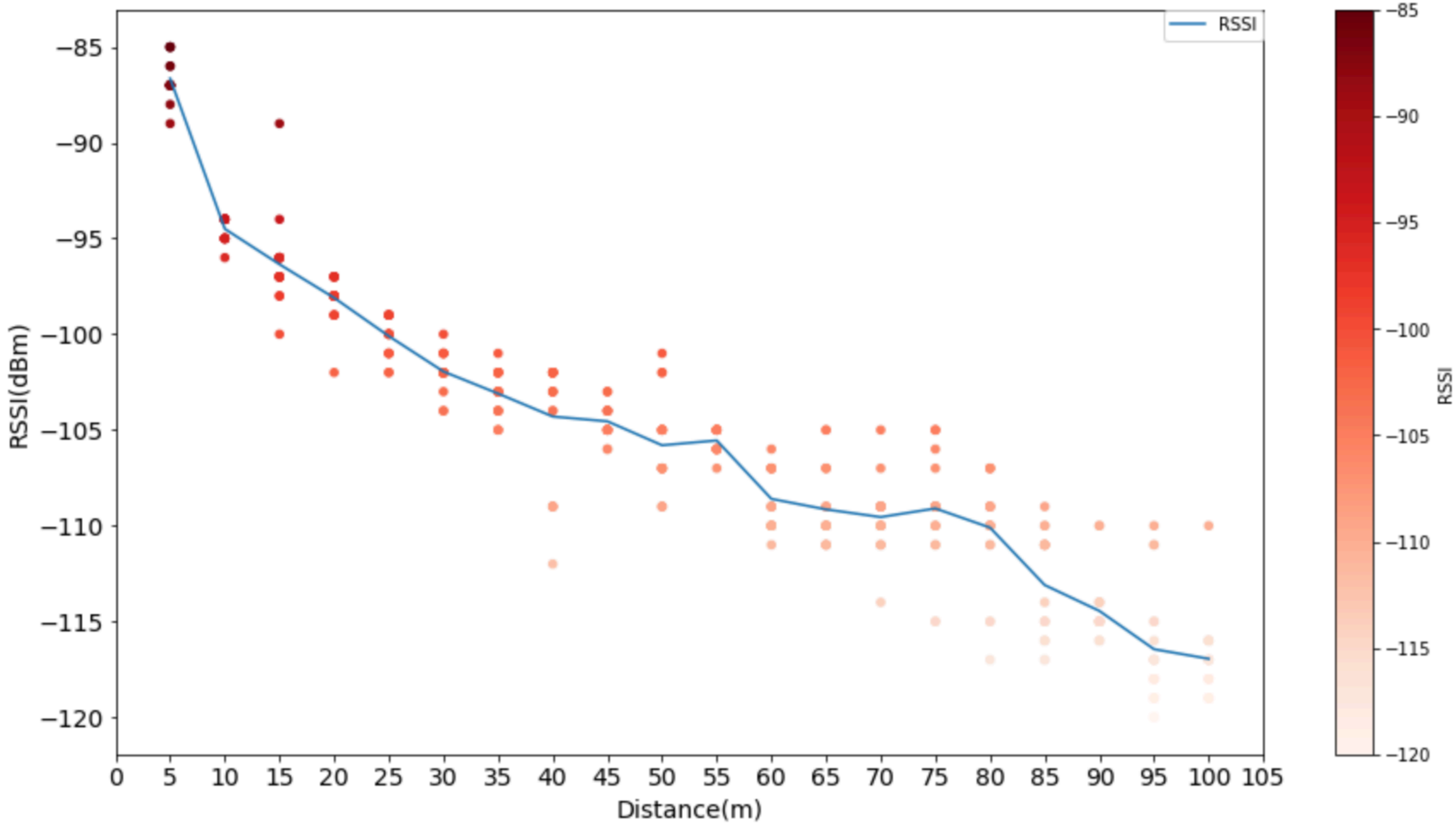


$$e1 = d^{RSSI}_{B_i,G_1} - d_{X,G_1}$$
$$e2 = d^{RSSI}_{B_i,G_2} - d_{X,G_2}$$
$$e3 = d^{RSSI}_{B_i,G_3} - d_{X,G_3}$$
$$e4 = d^{RSSI}_{B_i,GW} - d_{X,GW}$$

$$mse = \frac{\sum_{i=1}^{4} e_i^2}{4}$$

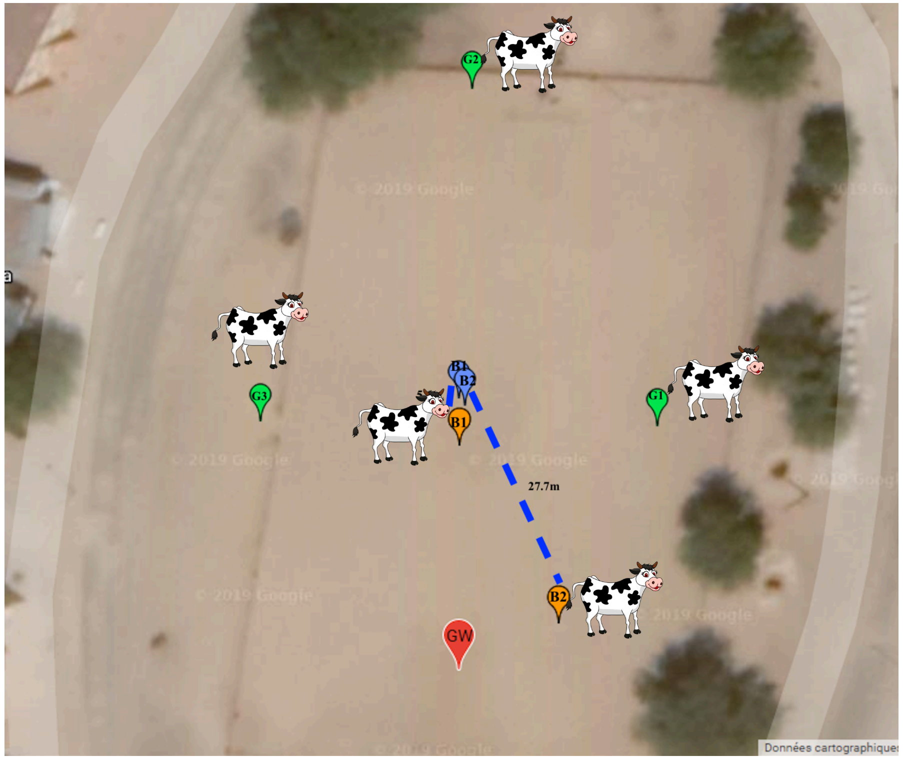
- GW uses RSSI-distance table to estimate
  - $d^{rssi}$ Bi, GW
  - $d^{rssi}$ Bi, G1
  - $d^{rssi}$ Bi, G2
  - $d^{rssi}$ Bi, G3
- Localization uses Non-linear Least Square Fitting method

# Preliminary RSSI-distance tests



# Tests and validation (1)

- In-situ deployment (1GW, 3 GPS-node, 2 Beacon nodes)




- When the number of RSSI-distance pairs is not sufficient, Path-Loss model is used – blue/orange markers shows estimated/real position of non-GPS nodes (Beacon nodes)

# Tests and validation (2)

- In-situ deployment (1GW, 3 GPS-node, 2 Beacon collars)


- After some rounds, RSSI-distance pairs will populate the RSSI-distance mapping table and accuracy of localization is greatly improved
- As animals are moving, additional RSSI-distance mapping will be available to cover the grazing area, leading to more accurate positionning

# Conclusions

- We proposed a dynamic and continuous RSSI-distance mapping mechanism on LoRa networks to localize cattle equipped with collars
- The objective is to accurately localize collars without GPS and minimizing the number of collars with GPS
- We proposed an original solution to improve the distance estimation scheme with adaptive RSSI-distance mapping algorithms that can refine the estimations at run-time
- The advantage of the proposed approach is to seamlessly take into account the impact of the physical environment as true RSSI-distance mapping are continuously collected as animal move in the grazing area

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