GNSS interference detection and localization in city

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Project introduction

Background of the Project

- The widespread RFI to GNSS navigation signal seriously affects navigation, positioning and high accuracy application of city.
- In order to solve this problem, a project was arranged in China.

Project : GNSS interference detection and localization in city.

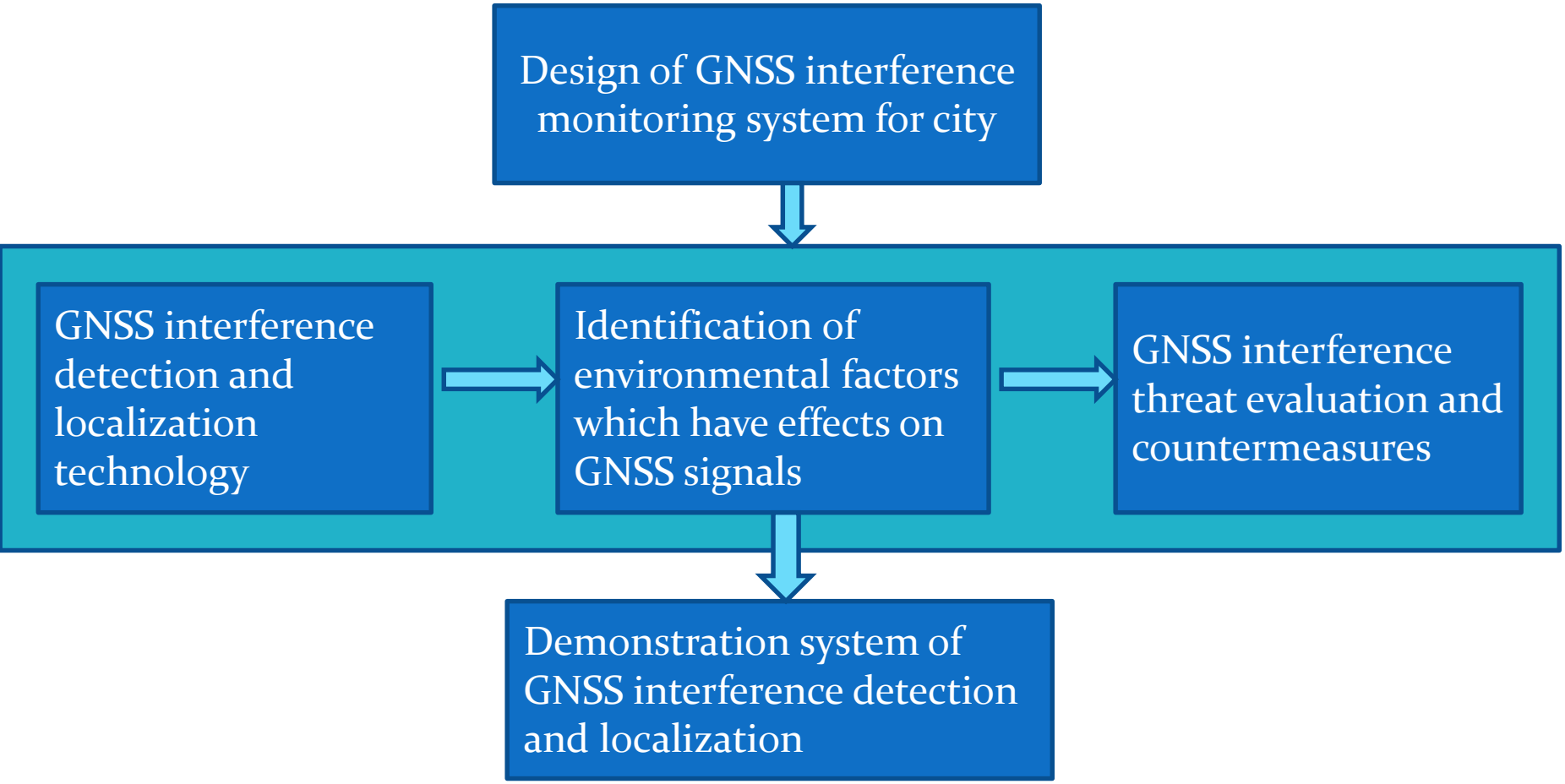
From: Ministry of science and technology

Participating units： Multiple institutes and Universities

project principal: Weimin Zhen

- This project aims to investigate the intentional and unintentional interference to GNSS, find suitable GNSS interference detection and localization technology for city. Demonstration system will also be developed.

Critical Research:



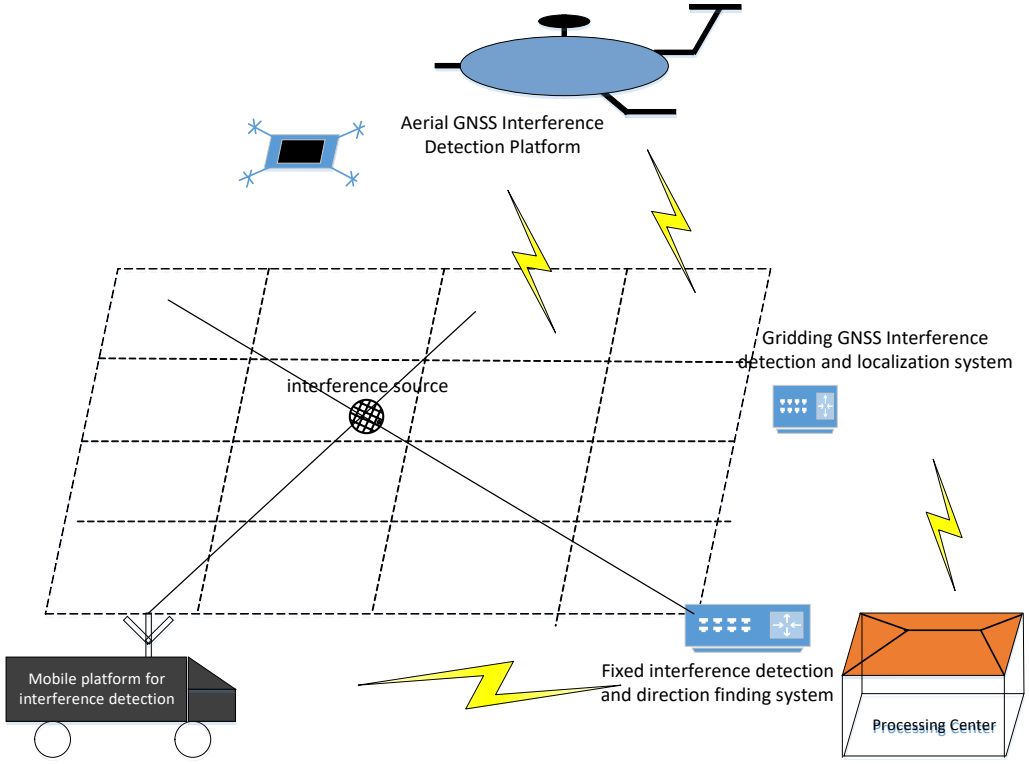
Typical cases investigation of GNSS RFI

- Investigation of GNSS RFI in Qingdao, Shanghai, Dongying etc.
- Typical scenario: airport, CBD(Central Business District),harbour, city road etc.

Demonstration system in Dongying Shengli airport

Demonstration system of GNSS interference detection in Dongying Shengli airport has been initiated.

Airborne view of Dongying Shengli airport



Demonstration system

GNSS interference detection and localization based on pattern recognition

Problem：

- Transmission of RFI in city maybe affected by reflection and refraction of buildings, which makes it difficult to localize the RFI source with traditional methods such as direction finding, TOA etc.
- It costs much for special direction finding device or clock synchronization in realize of traditional methods such as direction finding, TOA. which makes it difficult to realize interference monitoring in large area of the city.

This technology：

- Choose the carrier and noise ratio at the monitoring point as feature vector.
- Detection and localization of GNSS interference through feature study of carrier and noise ratio at the monitor node.

model of C/N0 variation with RFI power

Variation of C/No with RFI signal at the output of receiver :

$$C/N_{0_{eff}} = \frac{1}{\frac{1}{C/N_0} + \frac{J}{SQR_C}} \Rightarrow C/N_{0_{eff}} = C/N_0 - 10\log_{10}\left(\frac{C/N_0}{SQR_C}\right) - J_{(dBW)}$$

In which

- C/Noeff is effective carrier and noise ratio at the output of receiver with RFI;
- C/No is carrier and noise ratio at the output of receiver without RFI;
- J is power of RFI signal;
- S is power of real satellite signal;
- R_C is code rate of spread spectrum code; Q is quality factor of anti noise which is related with power spectrum density of signal and noise.

Transmission model of RFI power

- For line-of sight transmission, loss of RFI signal power are mainly related with distance and characteristics of RFI signal itself.

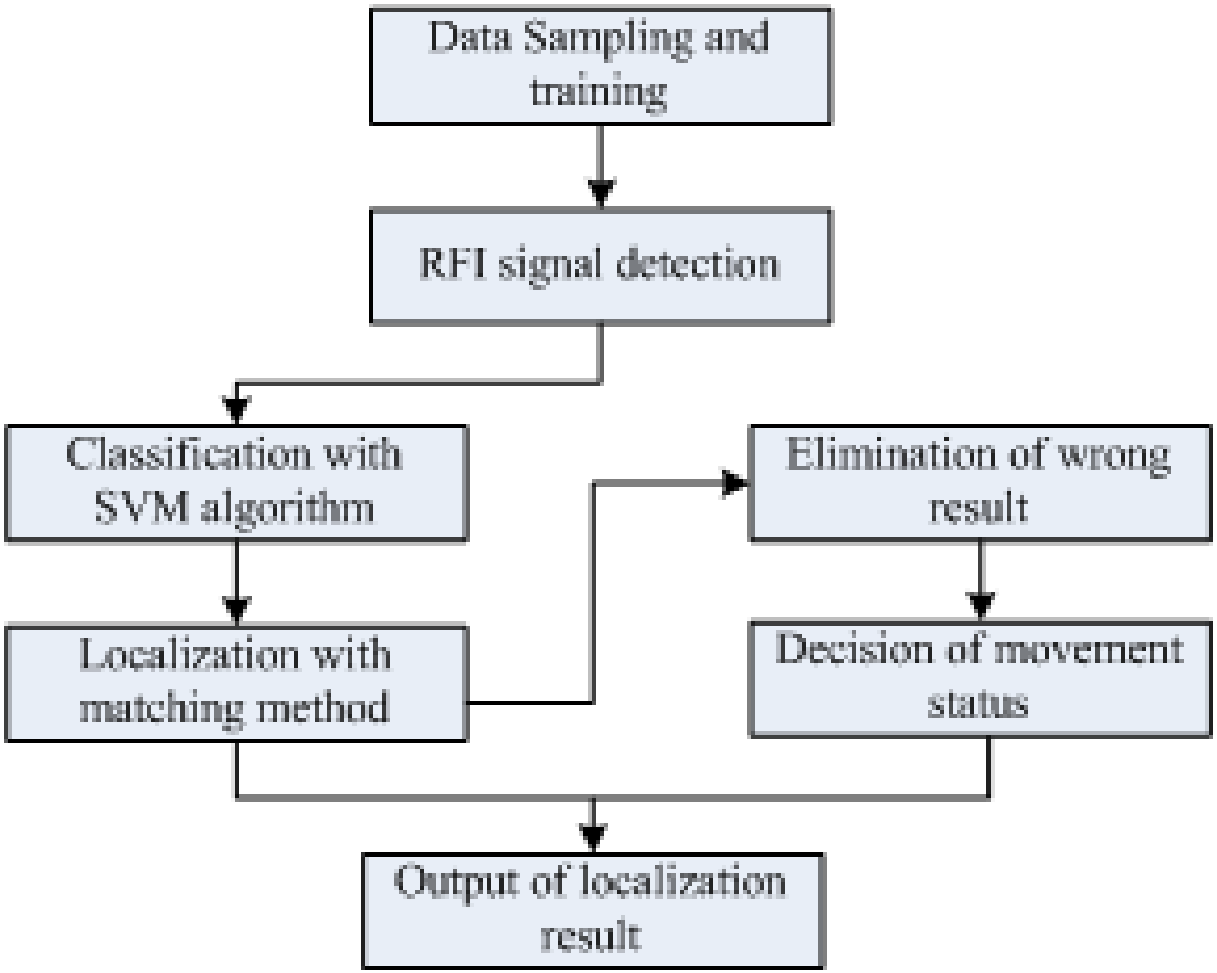
$$L_{Los} = L_{bp} + 6 + \begin{cases} 20\log_{10}\left(\frac{d}{R_{bp}}\right) & d \le R_{bp} \\ 40\log_{10}\left(\frac{d}{R_{bp}}\right) & d > R_{bp} \end{cases}$$

In which Lbp and Rbp are respectively basic transmission loss and distance of turning point.

- For non-line-of-sight transmission, models are different for urban canyon and residential region.

  - ✓ In urban canyon, loss of signal power are mainly caused by signal reflection and diffraction.
  - ✓ In residential region, loss of signal power are mainly caused by free space loss, diffraction from roof to street and multi-screen diffraction among buildings.

Process of RFI localization



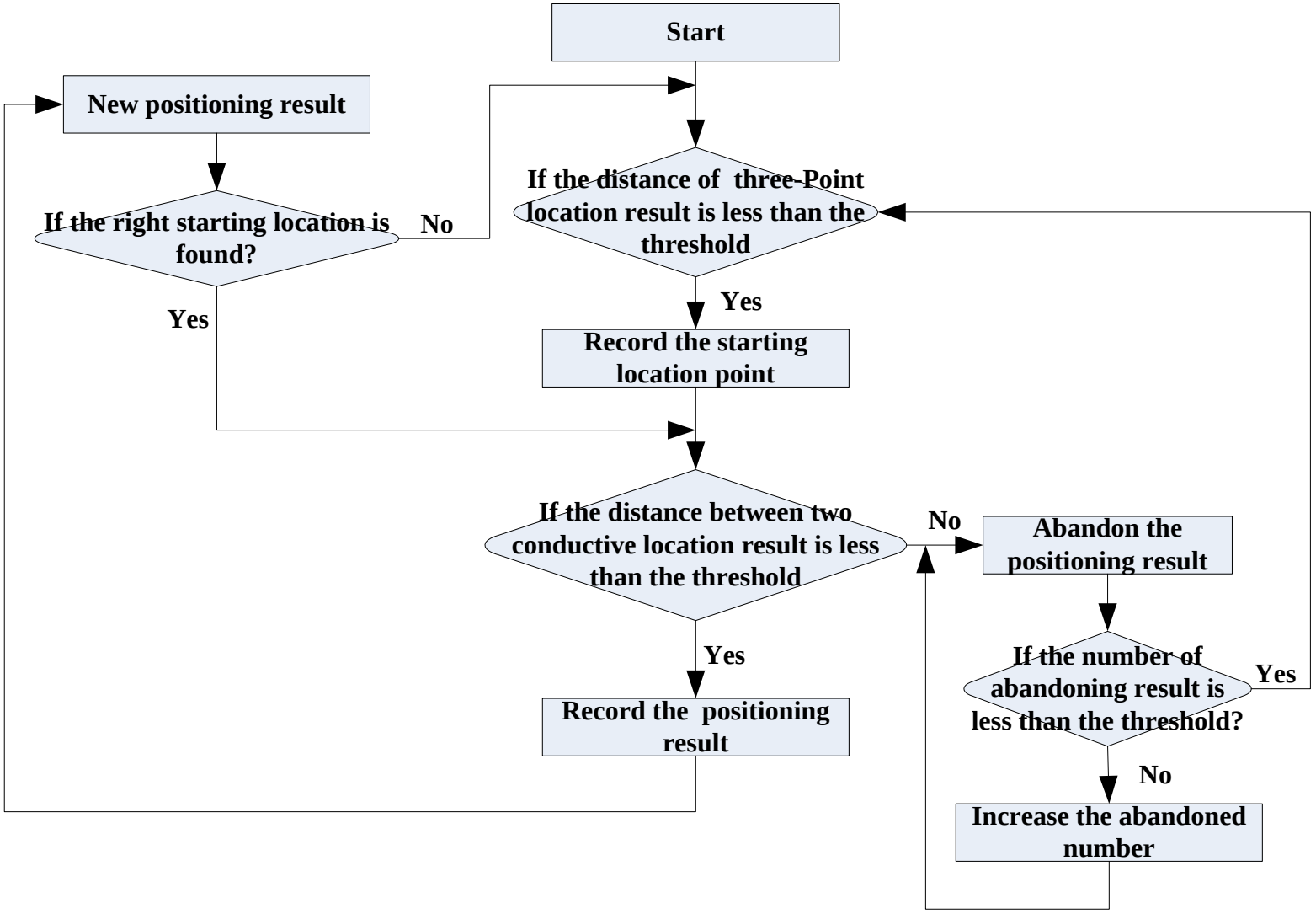
Data sampling and training

- Deploy the monitoring nodes and RFI sources with known characteristics and position in monitoring area.
- Sample C/No at the output of receiver of each monitor node as feature vector, and record values of each feature vector and its corresponding RFI source location.
- Classify data according to the Extension method of SVM(Support Vector Machine) classification

RFI signal detection and localization

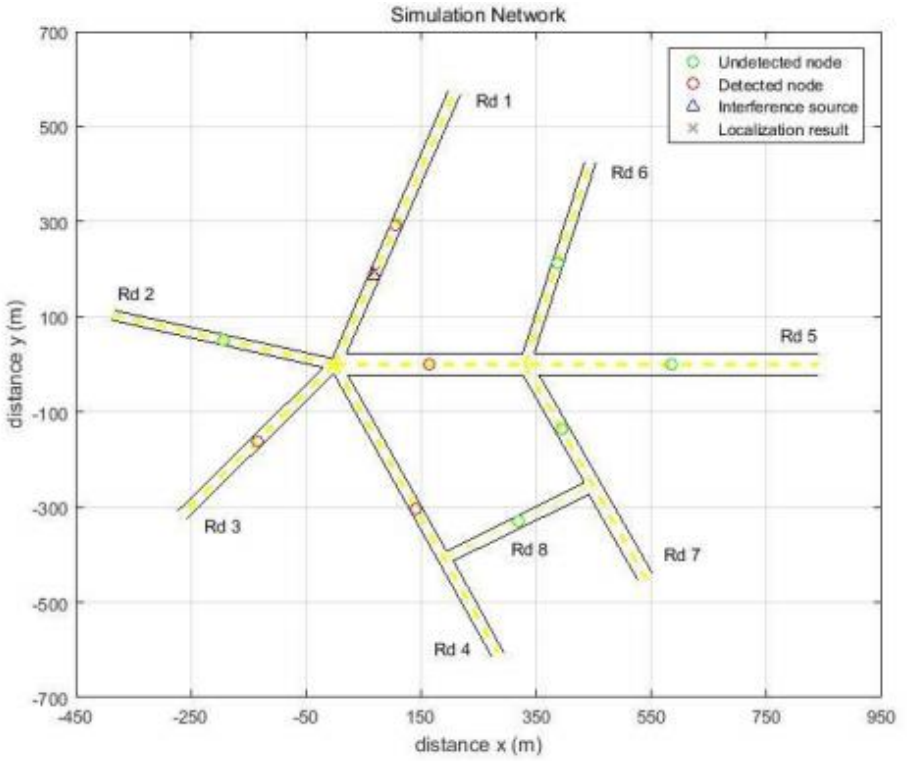
- Data is processed in central points .
- Compare real-time C/No with threshold at each monitor node.
- RFI source localization is decided by the decision function of extension method of SVM(Support Vector Machine) .

Elimination of wrong result and decision of movement status



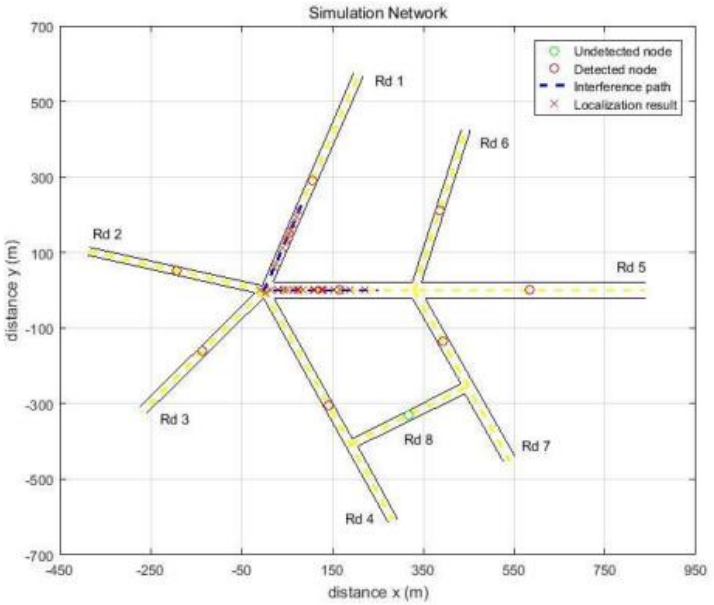
Experiment validation in urban canyon (Lujiazui, Shanghai)

- Area: 1km^2
- For static RFI
  - Correct positioning rate : 94%
  - Positioning error: 11.48m



Localization result of static interference source in urban canyon environment

- For moving RFI



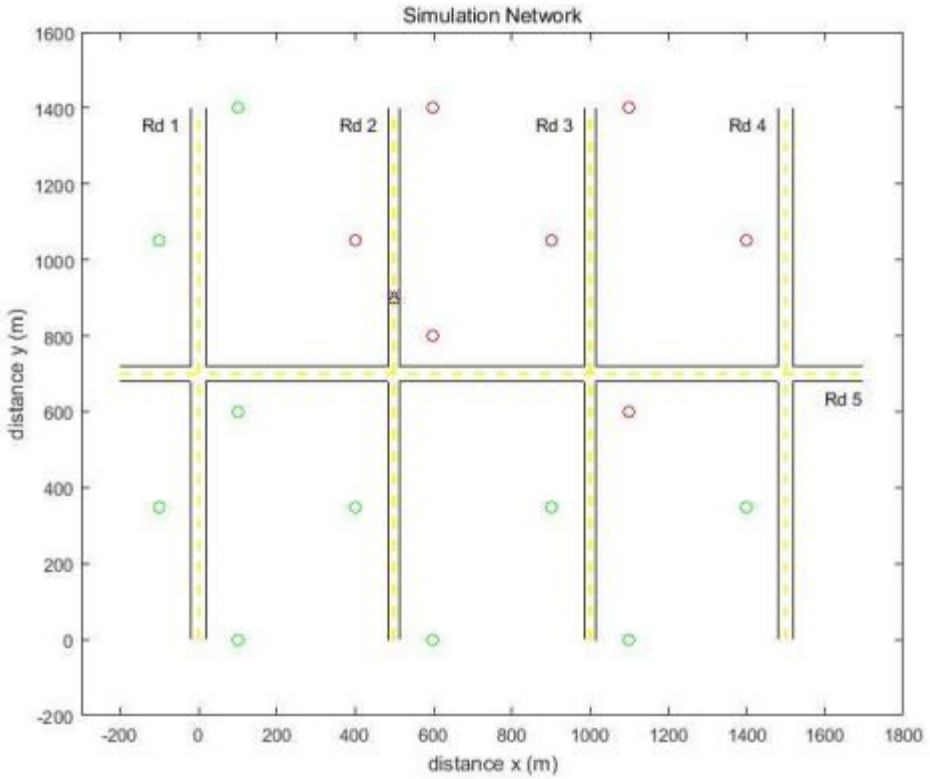
Route	Start (road No.)	End (road No.)	Velocity (m/s)	Correct positioning rate	Mean error (m)
1	1	5	10	90.00%	12.083
2	2	3	10	92.00%	13.947
3	3	1	5	94.57%	14.765
4	4	5	5	97.33%	9.782
6	6	7	20	92.00%	21.683
7	7	5	15	85.00%	19.931
8	8	7	15	88.89%	16.024

– Correct positioning rate : 90% when the velocity is low，
85% when the velocity is high.

– Positioning error: 15m when the velocity is low，
25m when the velocity is high.

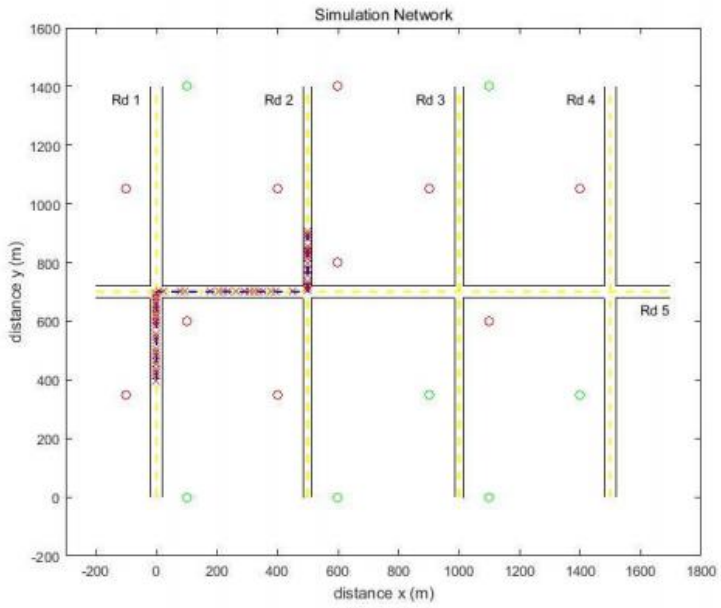
Experiment validation in residential area (Xinzhuang, Shanghai)

- Area: 1.5km^2
- For static RFI
  - Correct positioning rate : 90%
  - Positioning error: 15.63m



Localization result of static interference source in residential area

- For moving RFI



Route	Start (road No.)	End (road No.)	Velocity (m/s)	Correct positioning rate	Mean error (m)
1	1	2	10	70.00%	16.248
2	2	4	10	79.29%	19.963
3	3	1	5	55.31%	19.590
4	4	3	15	85.15%	17.475
5	5	3	20	41.67%	20.457

  - Correct positioning rate decreases ;
  - Positioning error: less than 30m.

Conclusion

- A project named GNSS interference detection and localization in city from the Ministry of science and technology is briefly introduced. Especially a critical technology called GNSS interference detection and localization based on pattern recognition is presented in detail.
- The project will be completed by the end of 2020. The technology will be applied in engineering of GNSS detection and localization in China.

Thank you!