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Drive Me Not - GPS Spoofing Detection via Cellular Network

Architecture, Models, and Experiments

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ACM WISEC 2019 – 17 MAY 2019

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Agenda

- Background on GPS
- GPS Security Issues
- Cellular Network
- Spoofing Detection Strategy
- Experimental Results
- Conclusions and Future Works

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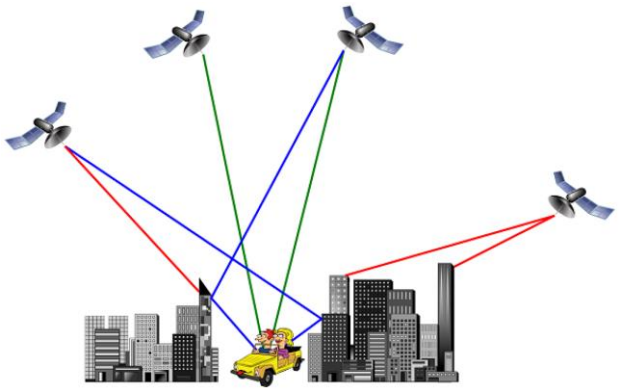
Global Positioning System (GPS)

- Satellite-based radio-navigation system owned by the United States government and operated by the United States Air Force.
- Global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.
- Obstacles such as mountains and buildings block the relatively weak GPS signals.
- Started in 1973 and enabled for civilian use in the 1980s.



- Precision: around 1m
- Number of satellites: 31
- Characteristics: MEO, about 20000Km.

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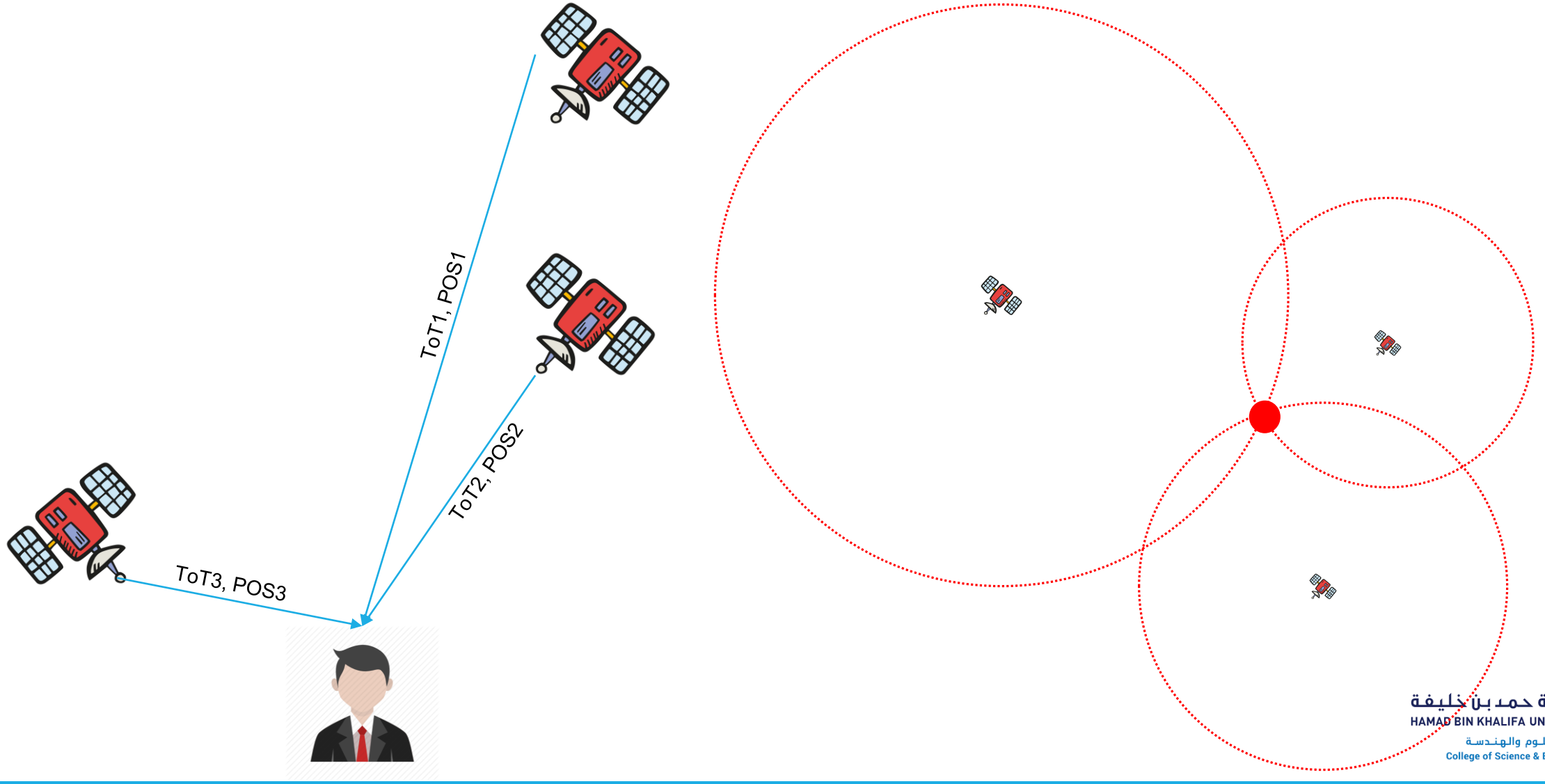
How GPS works?



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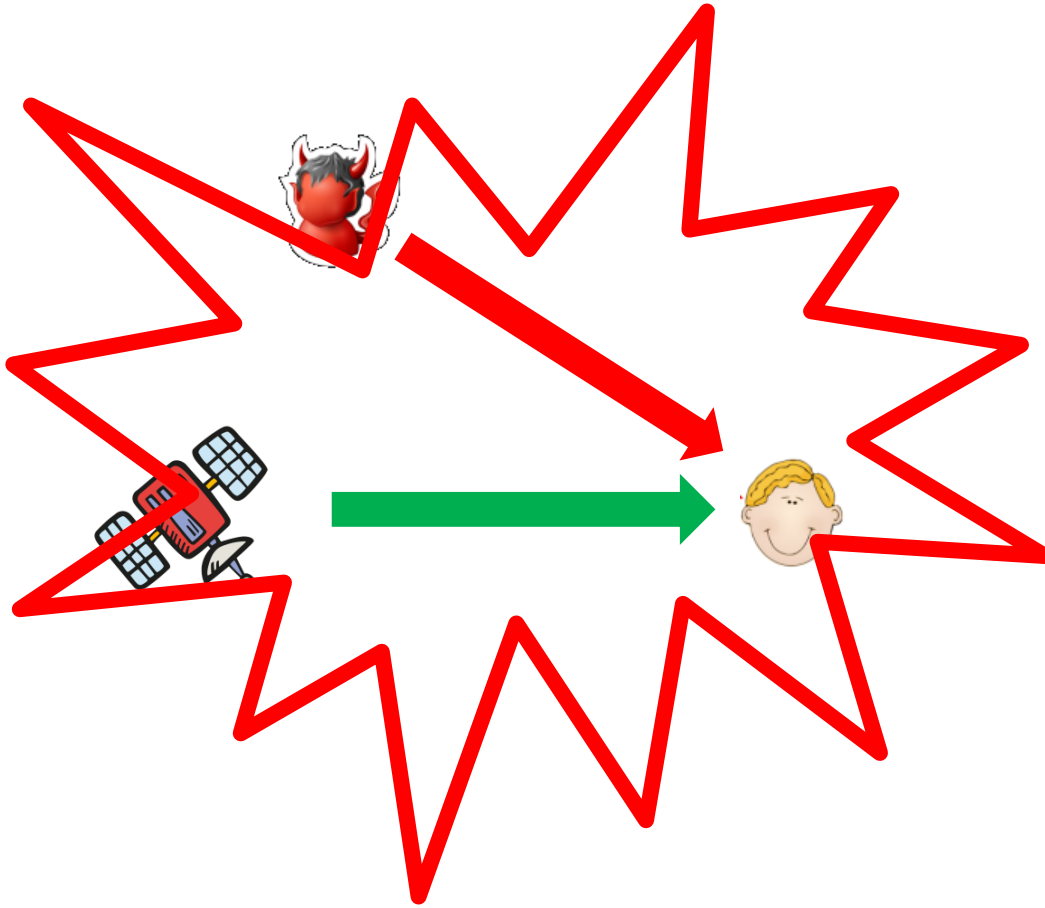
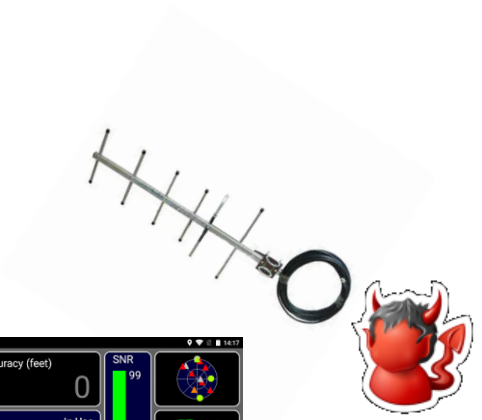
GPS (in)Security

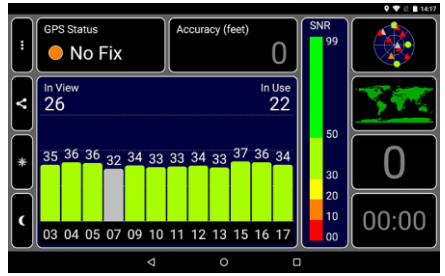
- **No Authentication**
  - The signal is not authenticated, i.e., source might be whoever
- **No Confidentiality**
  - Content of the transmitted message is in cleartext
- **Availability Issues**
  - The signal can be easily disrupted/jammed



GPS Spoofing Attacks

- Requirements
  - The adversary has to transmit with high power (e.g. be close enough to the target)
  - The number of fake satellites should be greater than the actual ones
- Implications
  - The GPS spoofer should be hidden (for attackers with low power tx capabilities)
  - Proper configuration of the software/hardware
- Caveat
  - Some GPS receivers are less prone to be cheated





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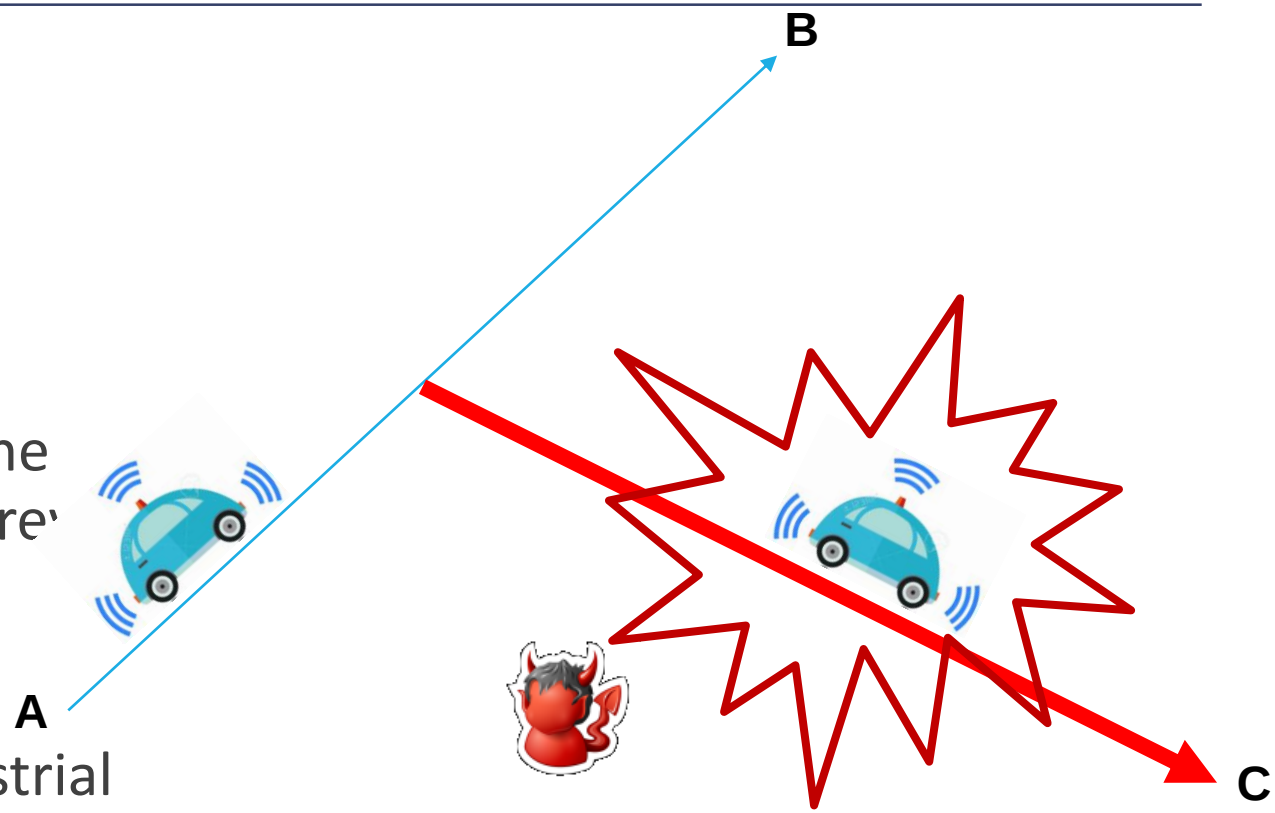
Scenario

- Components:
  - Car/Truck
  - GPS-based navigation
  - Path from A to B
- The adversary transmits a fake position to the car, and therefore the car can be driven where the adversary decides.
- This is a general problem that might affect:
  - Pedestrian, aircraft, self-driving cars, industrial devices (timing)…



- **How to detect the GPS spoofing attack?**

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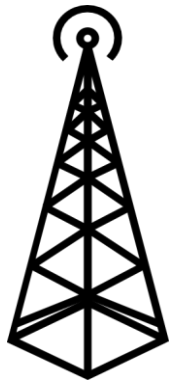
Cellular Network

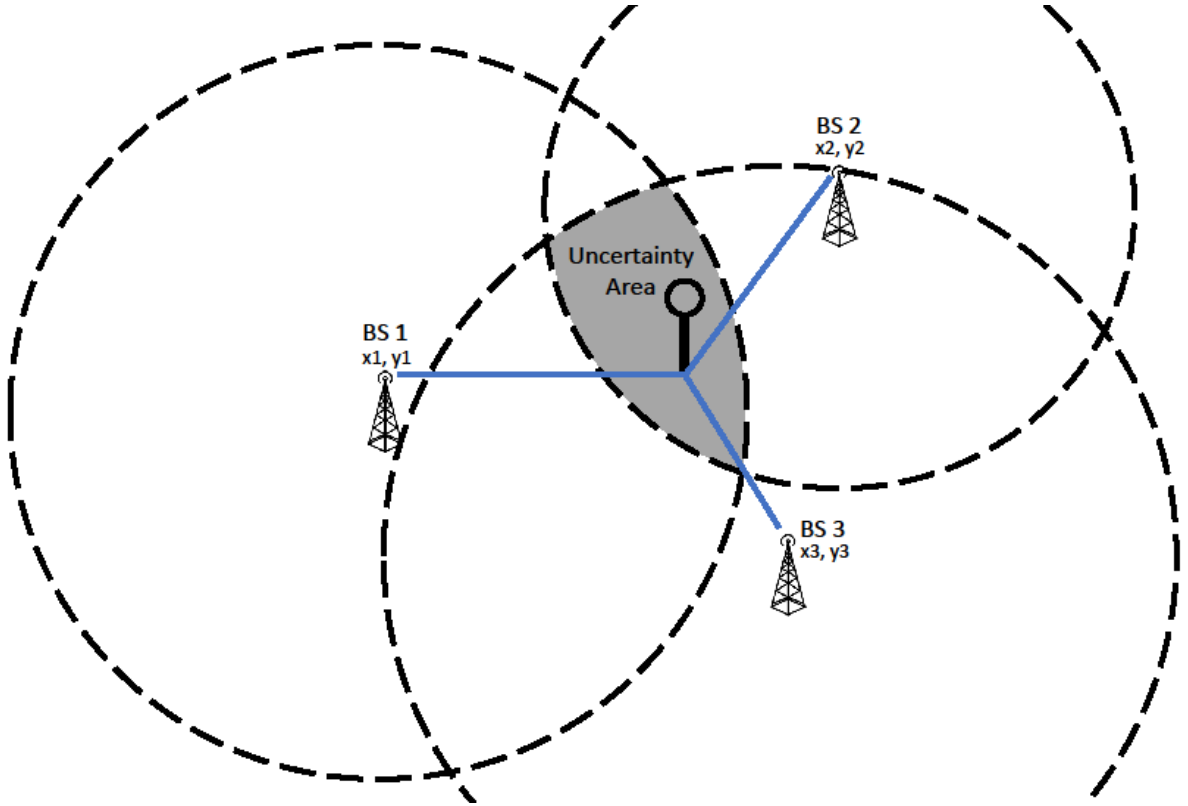
- Cellular Access Points broadcast a few information



- Cell ID (CID)
  - Unique number to identify each base station
- Location Area Code (LAC)
  - A "location area" is a set of base stations that are grouped together to optimise signalling.
- Mobile Network Code (MNC)
  - Unique identifier of the mobile network operator
- Received Signal Strength (RSS)
  - Received power associated to the received message and estimated by the user's device

Rough Localization via Cellular Network

CID, LAC, MNC	Latitude, Longitude
1, 1, 1	x1, y1
2, 2, 1	x2, y2
3, 3, 2	x3, y3



- User position estimation by averaging the anchors' position:

$$\left[\sum_{i=1}^{N} lat_{BS_i} \cdot w_i, \sum_{i=1}^{N} lon_{BS_i} \cdot w_i\right]$$

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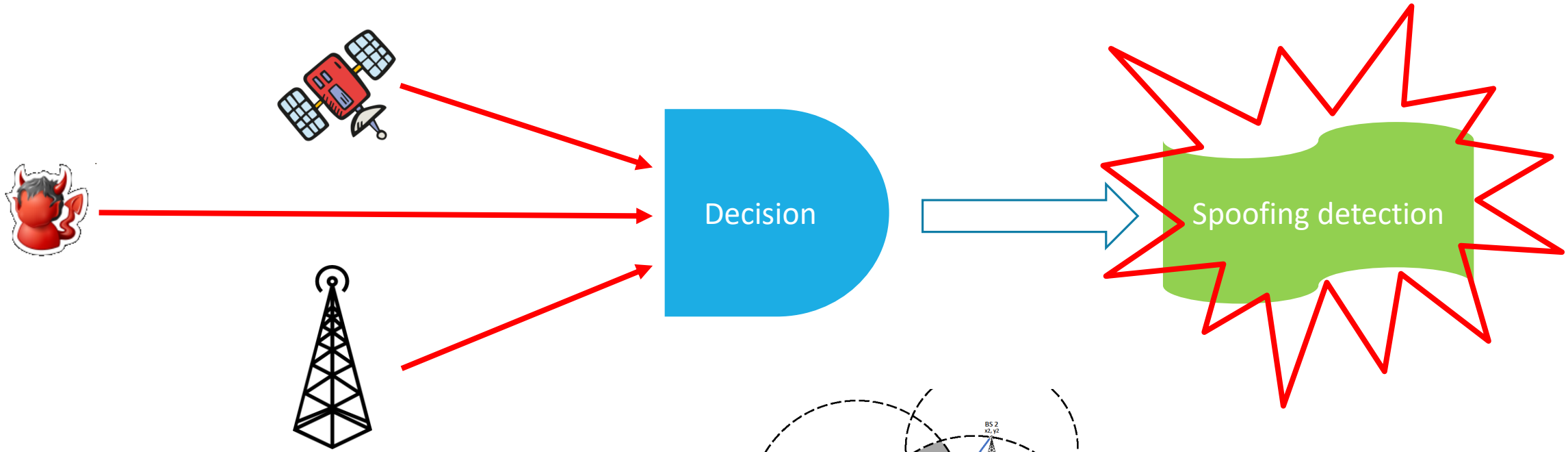
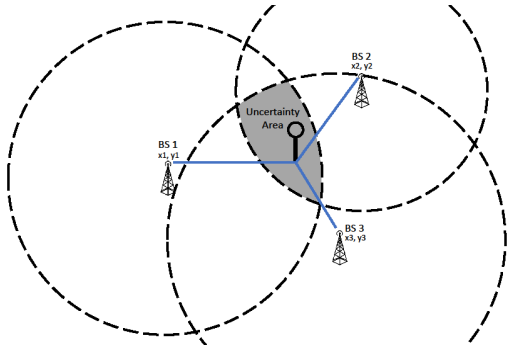
Our idea in a nutshell





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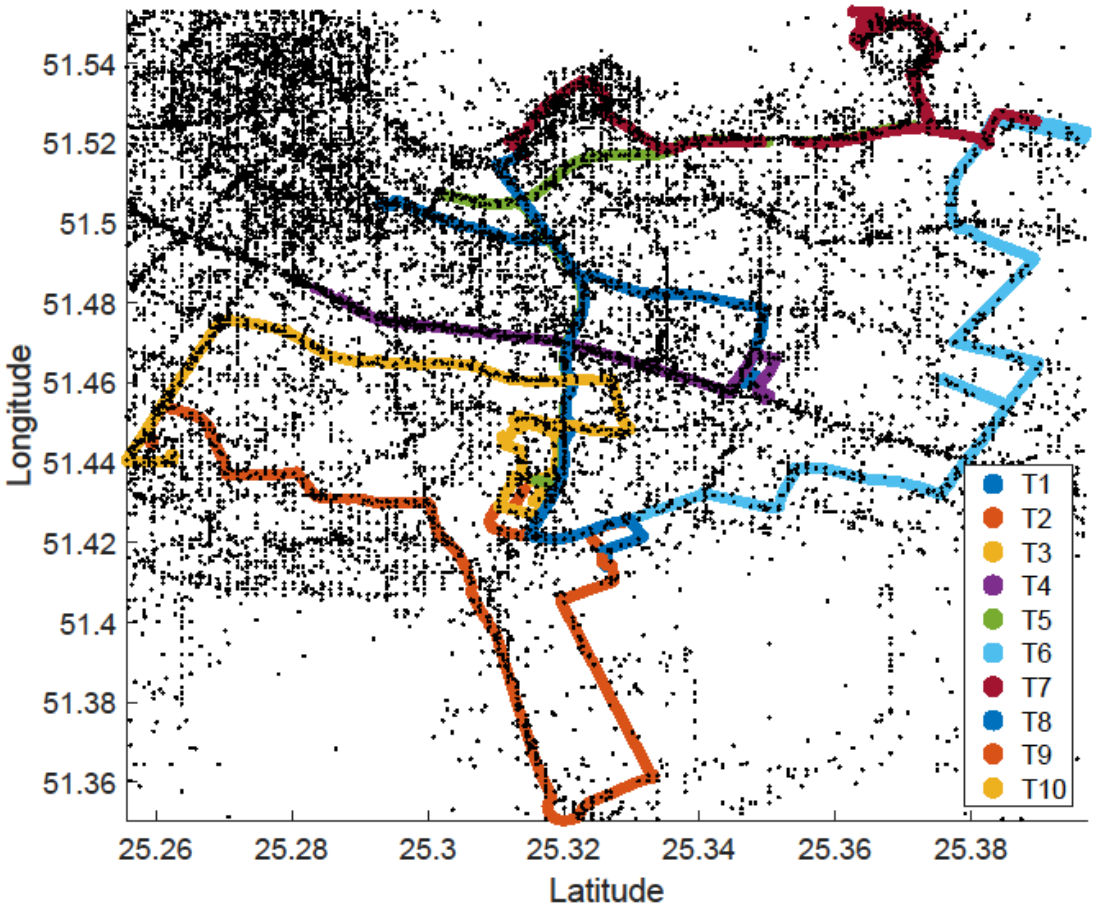
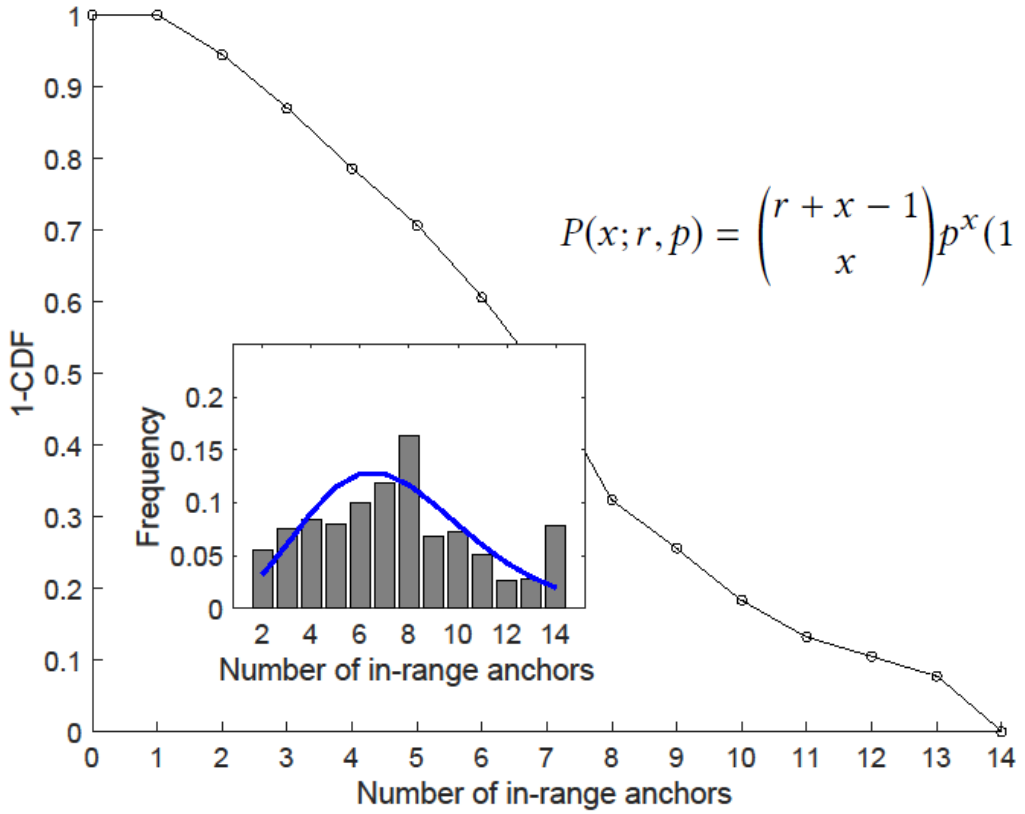
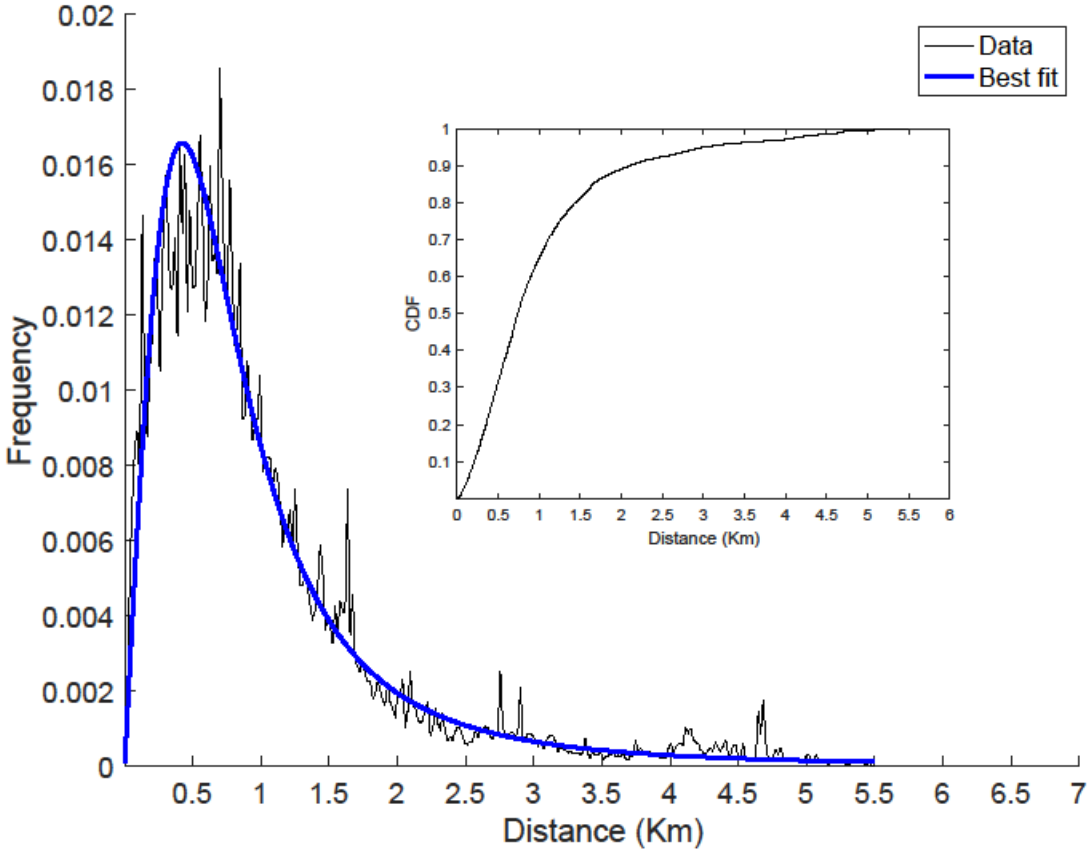
Base Stations (BS) Distributions





$$P(x;r,p) = \binom{r+x-1}{x} p^x (1-p)^r$$

BS-Node Distance Distribution



$$P(x;\alpha,\beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}$$

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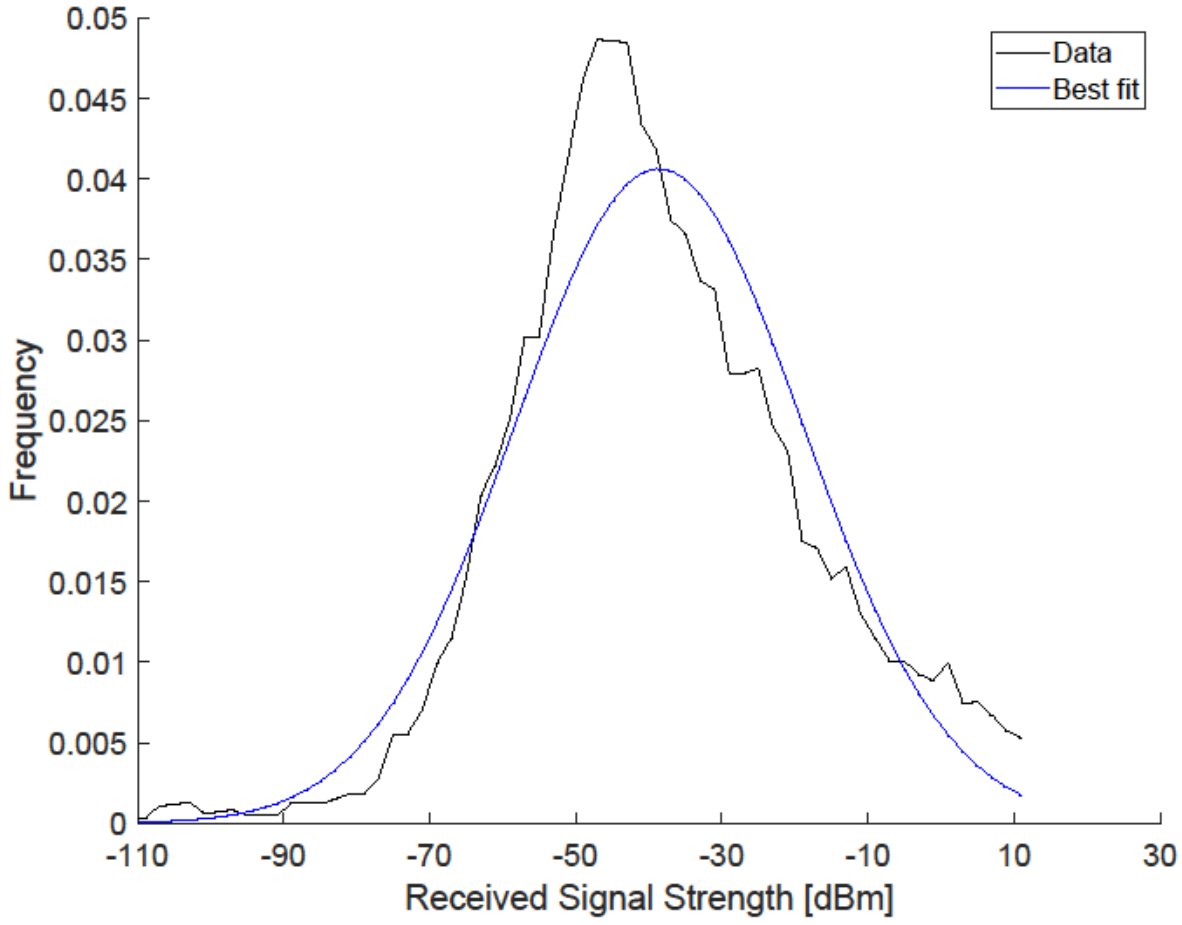
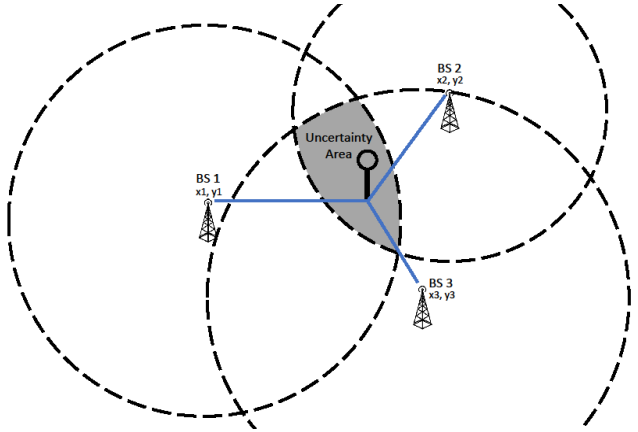
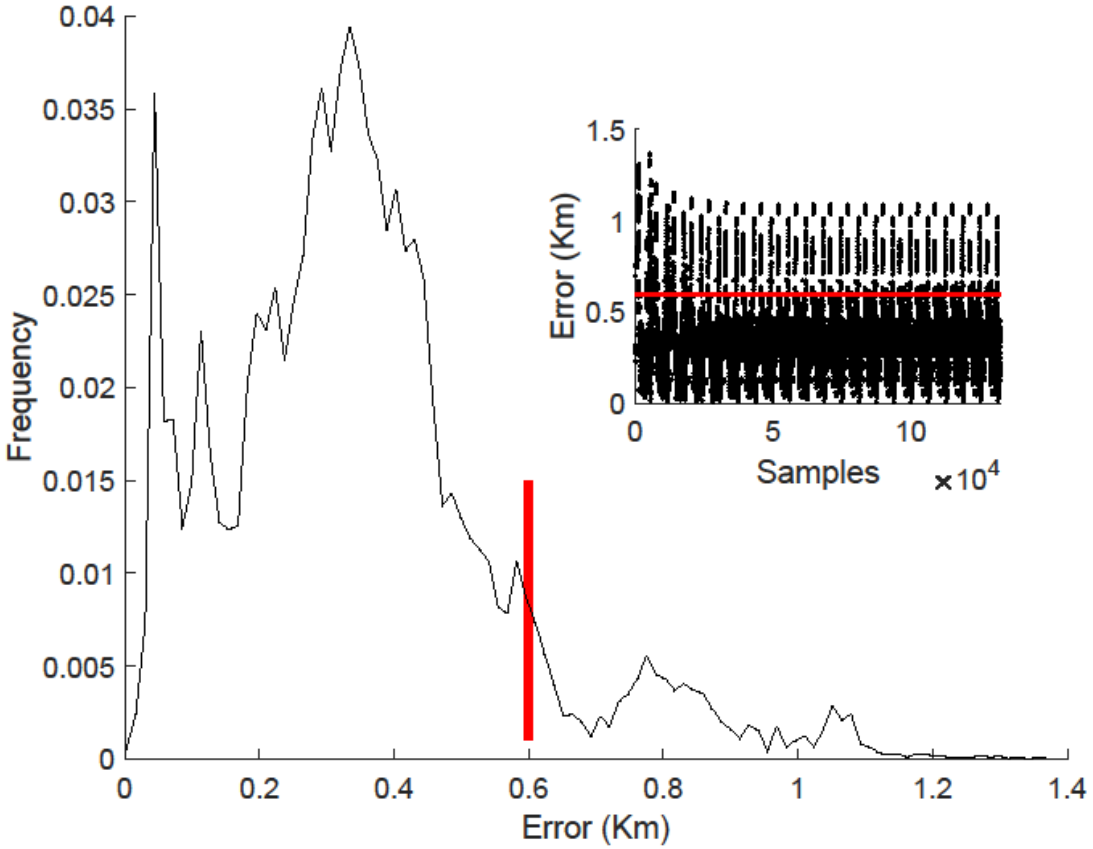
Estimated RSS at the user's side



$$P(x;\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}}$$

Position Estimation and Errors





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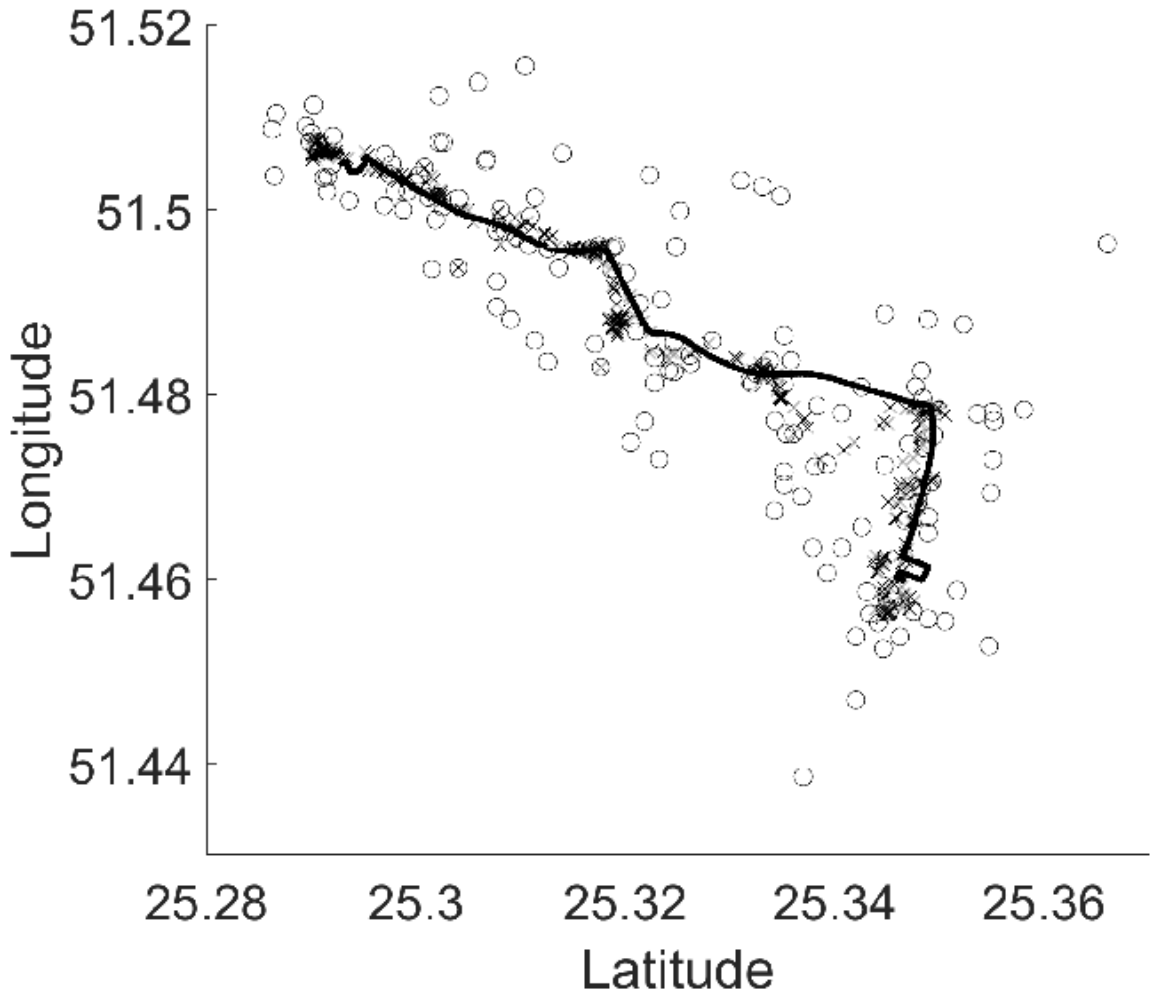
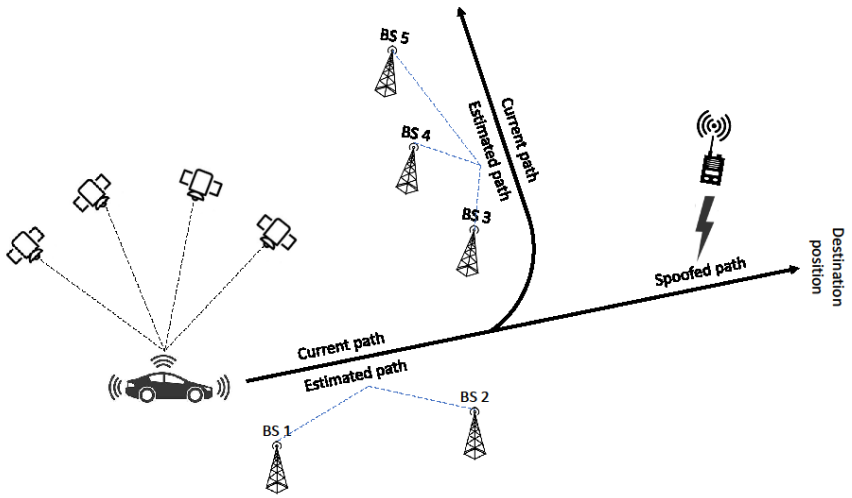
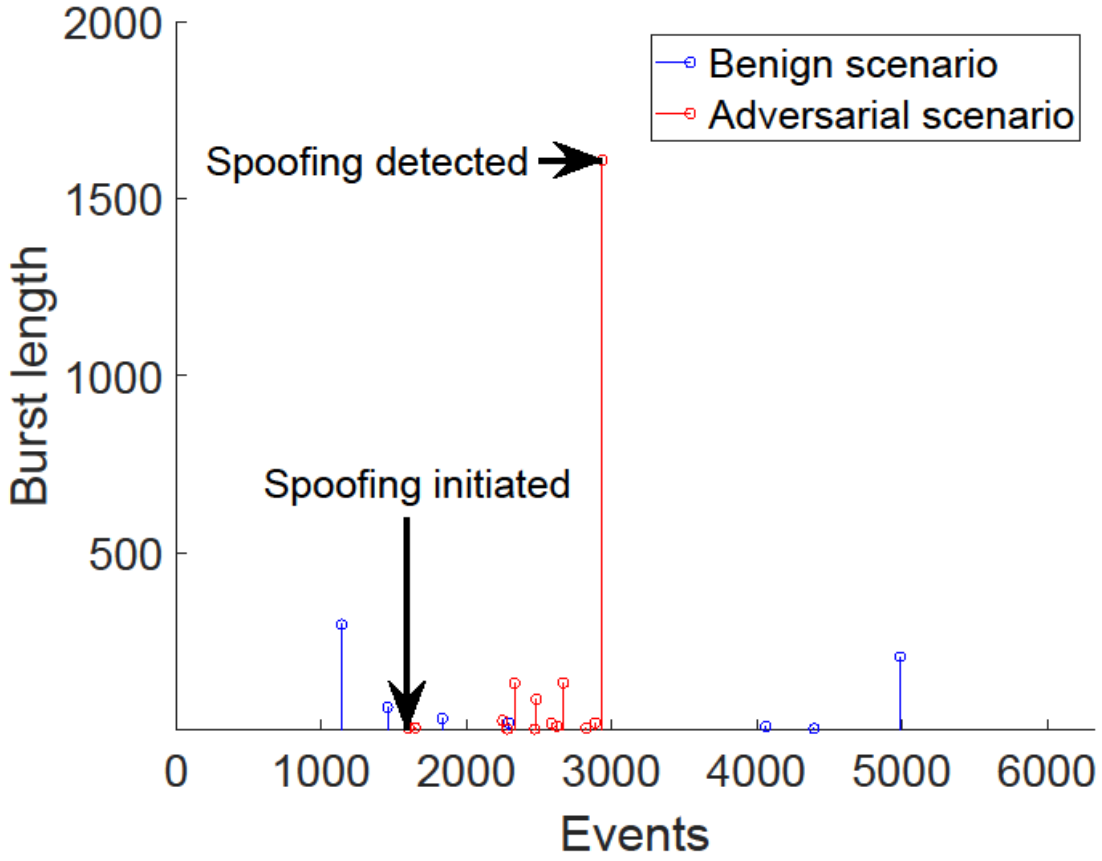
Baseline: Benign Scenario

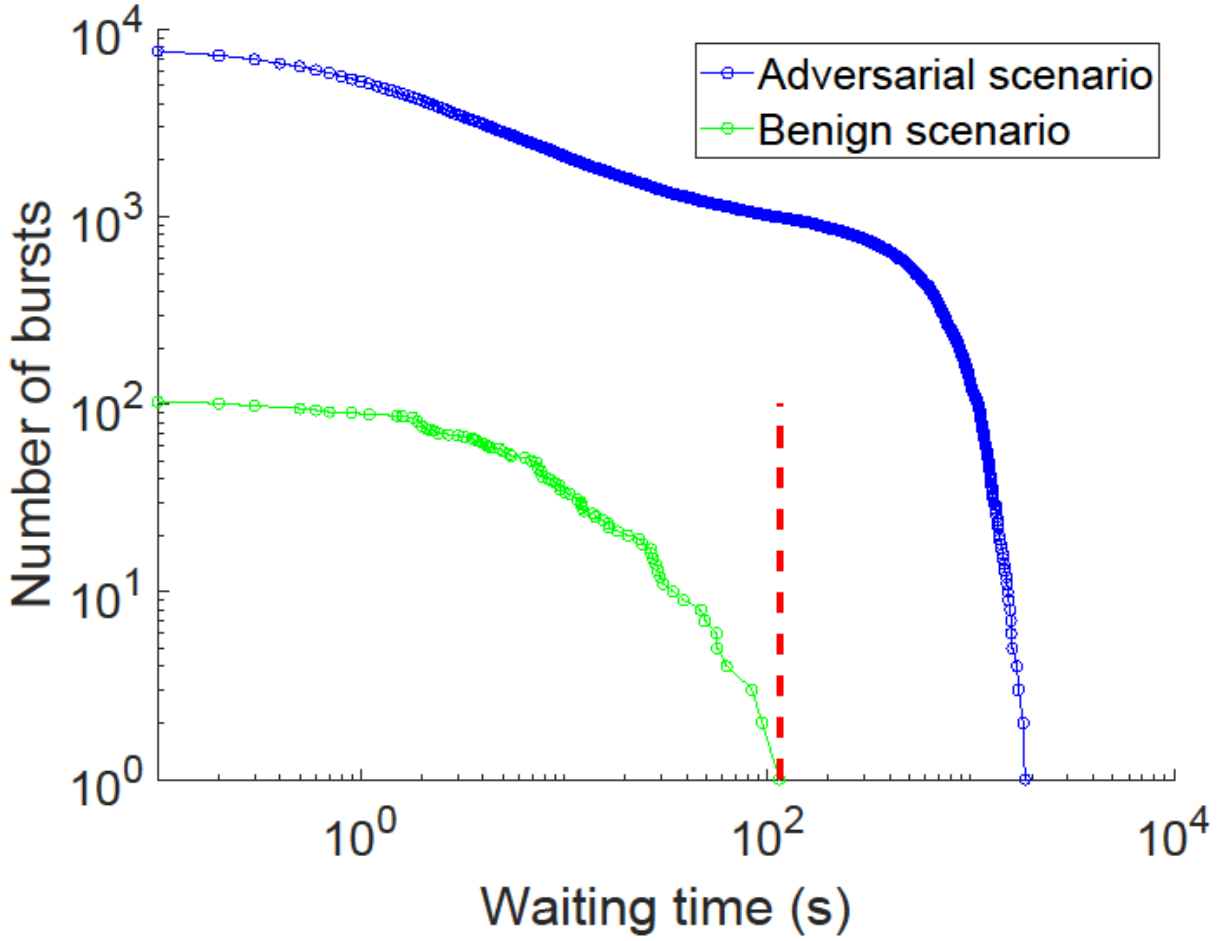


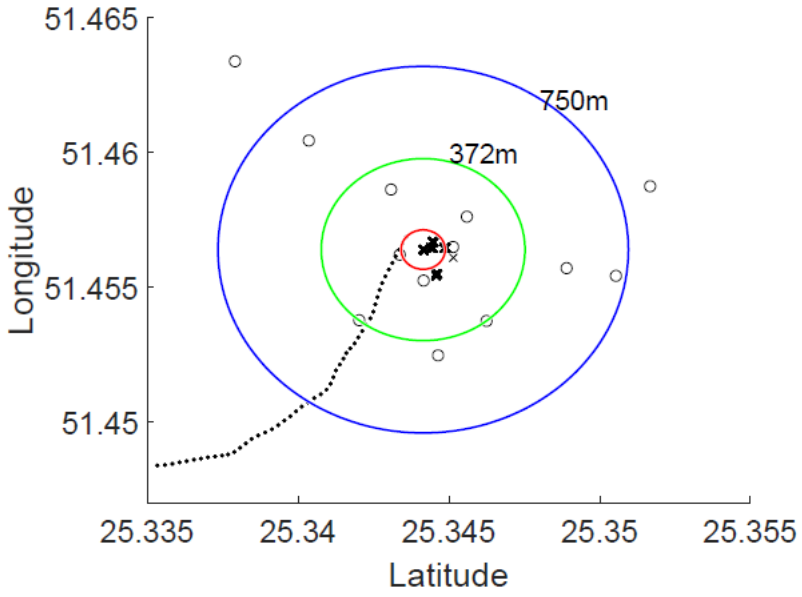
Mitigating False Positives





Spoofing Detection Performance





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Conclusions and Future Works

Take home message

- GPS is a pervasive technology widely adopted in different fields
- GPS is very easy to spoof
- Cellular Networks are a viable and not invasive option to detect GPS spoofing
- Our results can be considered as very general (applicable to other context as well)

Future Works

- Including other signal sources (WiFi, TV Broadcast, etc.)
- Robustness to fake Cellular Base Stations

Questions?

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