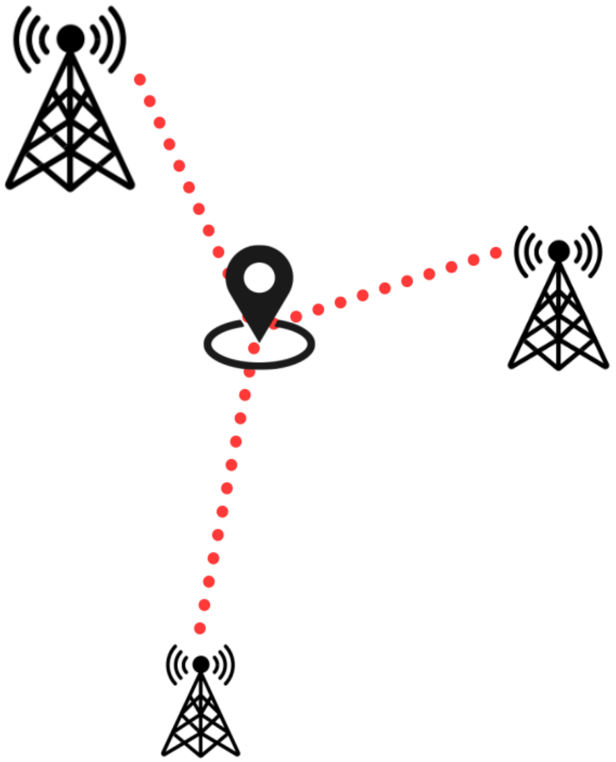
EXPLORING THE POTENTIAL OF 5G POSITIONING VIA RSSI, COMPARING ITS EFFICACY WITH GNSS-RTK POSITIONING



Akis G.K. Nestoras

Thesis Presentation - MSc Geomatics

CGI

TU Delft
Delft University of Technology

Introduction

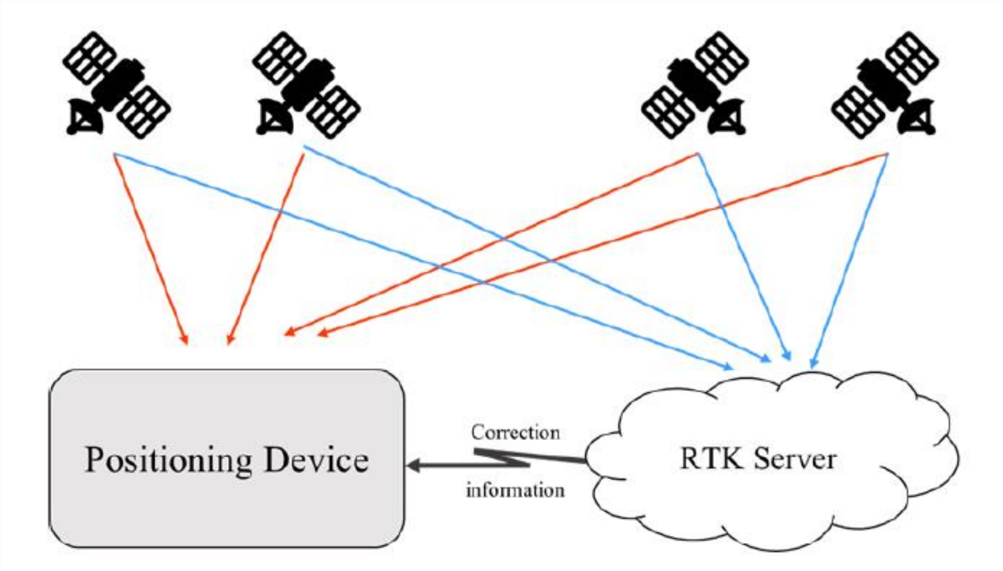
In a nutshell – why 5G?

- Higher accuracy (higher frequencies with wider bandwidths, Massive MIMO)
- Higher network capacity
- Lower latency

RSSI (Received Signal Strength Indicator)

- Measures Signal Power in wireless networks
- Scale: Typically -30 dBm (strong) to -100 dBm (weak)
- Applications: Wi-Fi, Cellular, Bluetooth
- Impact: Higher RSSI → Better Connection Quality

GNSS-RTK (Global Navigation Satellite Systems – Real Time Kinematic)



GNSS-RTK is a positioning technology that improves satellite-based position accuracy to the centimeter level by using real-time corrections from a nearby fixed base station.

Objective

Determine potential of 5G positioning using only RSSI measurements.

Practical Aspects

- Attach 5G modem to a laptop for signal reception.
- Use GNSS-RTK device for precise positioning validation

Positioning Algorithm

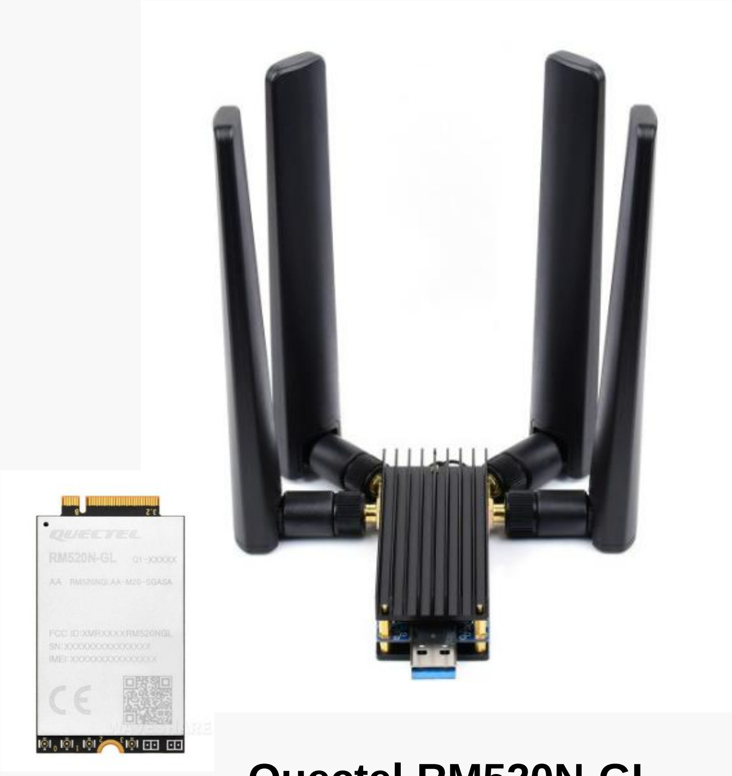
1) RSSI measurements

2) Estimation of distance between the transmitters and the user’s device through the FSPL model.

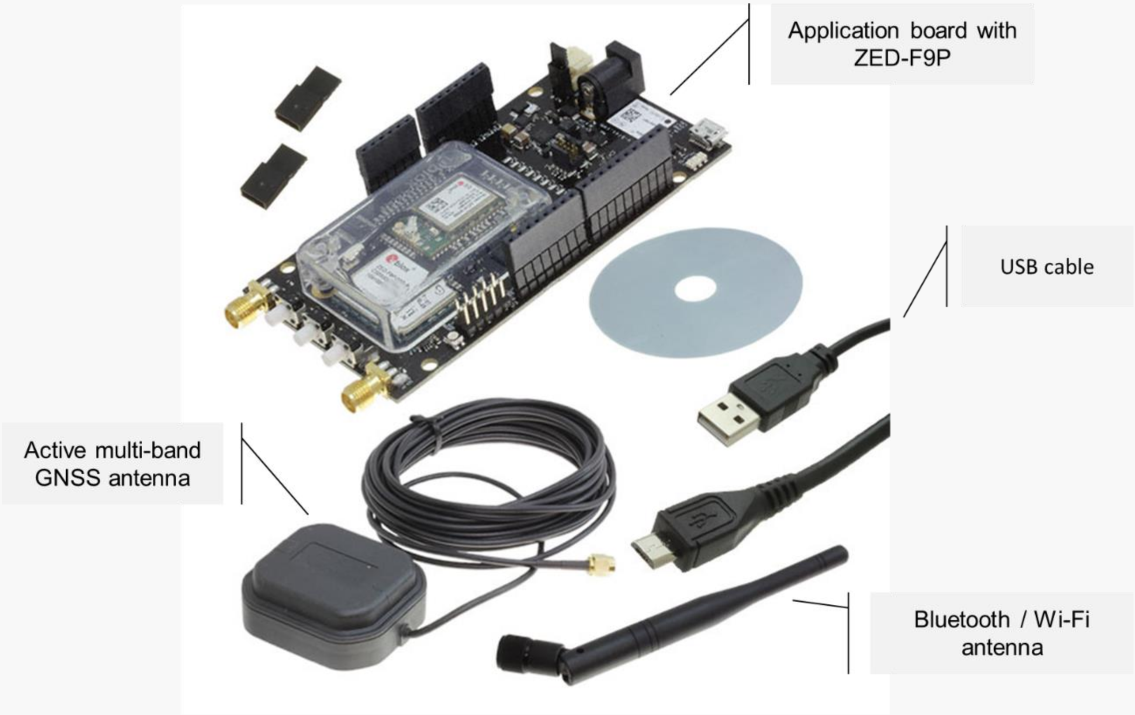
3) Trilateration based on these values.

4) Comparison of the measurements with GNSS-RTK ground truth.

Devices for real measurements



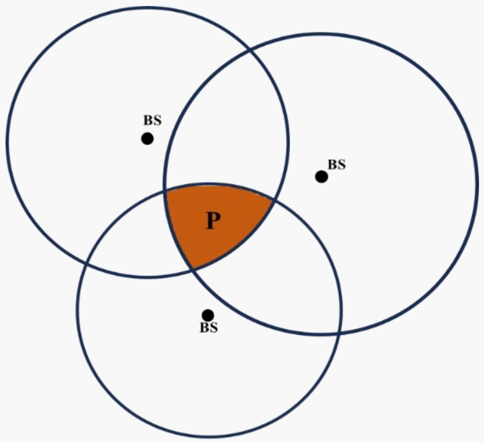
Quectel RM520N-GL (M.2 device)



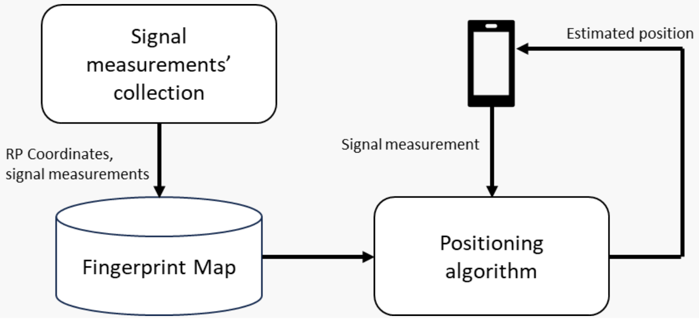
Ublox C099-F9P (GNSS - RTK device)

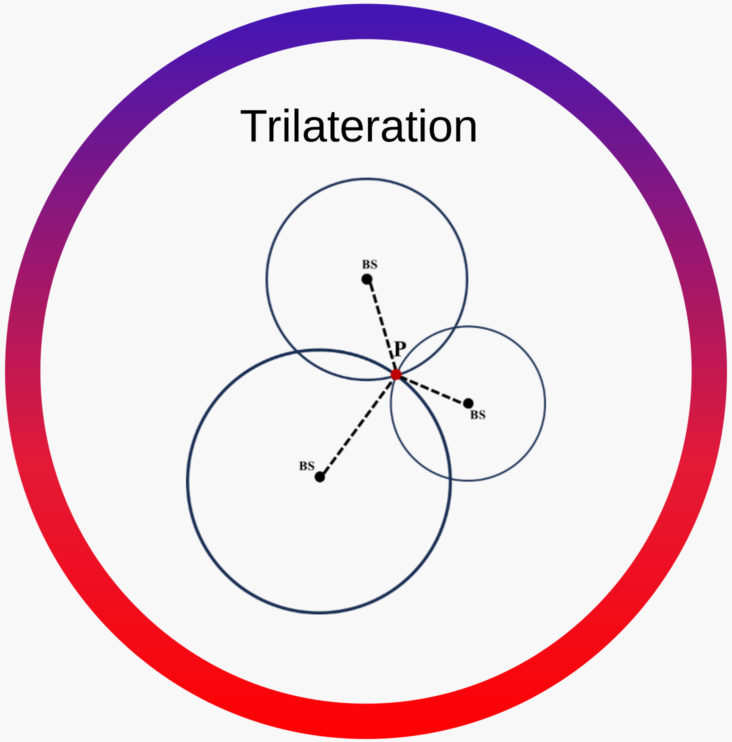
Positioning Methods

Cell identity



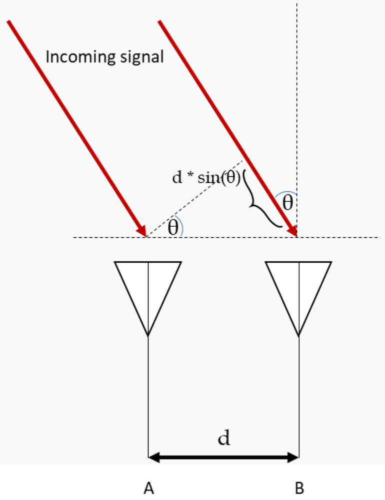
Fingerprinting





Time of Difference of Arrival

Angle of arrival/departure



Vodafone Ziggo Cell Towers in Delft

Received Signal information for each PCI at the Observation Point (RSSI, RSRQ, RSRP, SINR**)**

Cell Towers Data (Physical Cell ID, Coordinates, Frequency, Tx Power)

Distance from Observation Point to Cell Tower

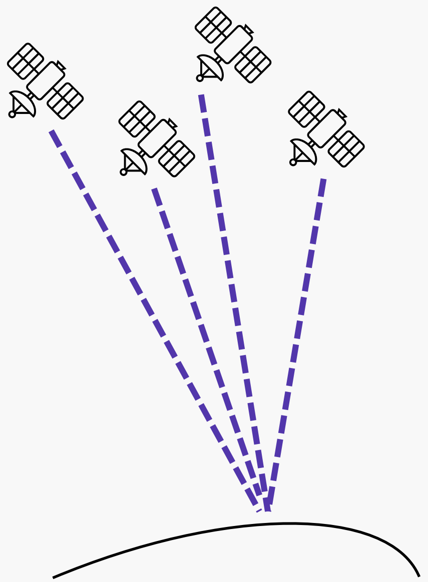
Free Space Path Loss

Reduction of the signal strength along a direct Line-of-Sight path through open space

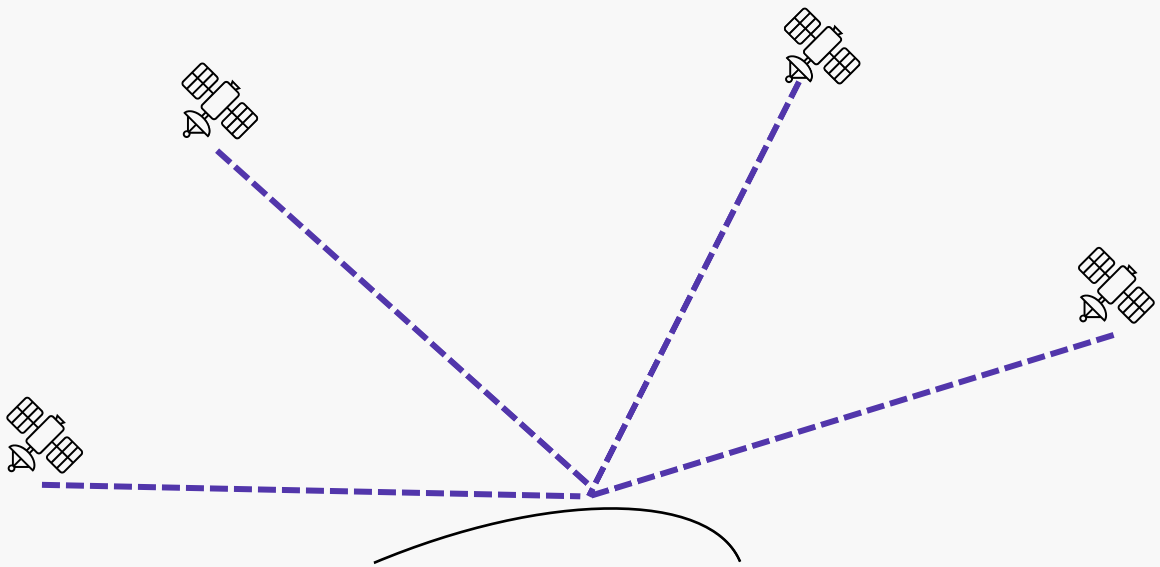
$$\mathrm{FSPL(dB)} = 20\log_{10}(d_{\mathrm{km}}) + 20\log_{10}(f_{\mathrm{GHz}}) + 92.45 - \mathrm{G_t} - \mathrm{G_r}$$

$$\mathrm{RSSI(dB)} = \mathrm{Tx\_Power} + \mathrm{G_t} + \mathrm{G_r} - \mathrm{FSPL} \longrightarrow d_{\mathrm{km}} = 10^{\left(\frac{\mathrm{Tx\_Power}+\mathrm{G_t}+\mathrm{G_r}-\mathrm{RSSI}-20\log_{10}(\mathrm{f_{GHz}})-92.45}{20}\right)}$$

DOP (Dilution of Precision)



High DOP
(Weak geometry)



Low DOP
(Strong geometry)

Research Objectives

"To what extent can the trilateration method for positioning, utilizing only the RSSI of the 5G network, serve?"

What is the potential accuracy of 5G positioning with the trilateration method in comparison to the ‘ground truth’ given by GNSS-RTK solution?

What is the impact of topographic factors (e.g., buildings, urban canyons) on the accuracy of 5G positioning?

How is the Position Dilution of Precision (PDOP) affected by the distribution of the 5G network?

Methodology

Methodological Framework

SIGNAL STABILITY ANALYSIS

Static Measurements

EVALUATION OF SIGNAL BEHAVIOR WITH DIFFERENT ANTENNAS

Multiple Antennas Testing

RSSI in LOS

FSPL Test (LOS)

- Continuous measurements
- Fixed intervals (50m steps)

DATA ANALYSIS

- Signal fluctuation, attenuation, obstructions
- 3D Visualization with QGIS (qgis2threejs), AHN4, 3DBAG

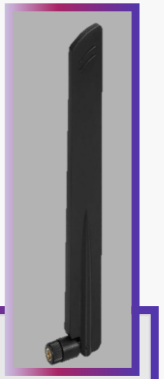
RESULTS

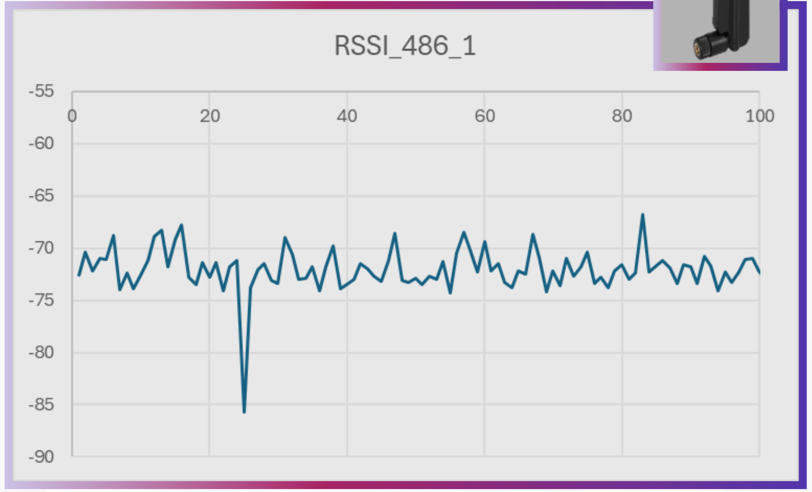
Trilateration through MOVE3 and validation based on GNSS-RTK ‘ground truth’

Results

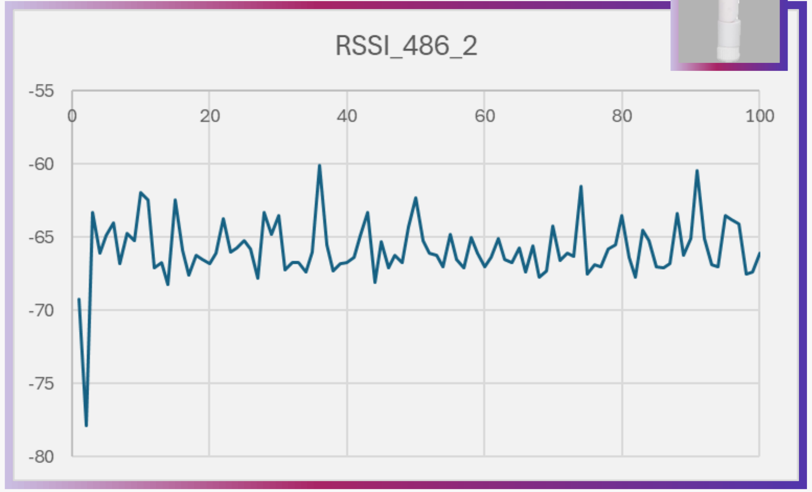
Multiple antennas testing

- Static measurements
- 100 first observations
- Distance to Cell Tower: 406 meters

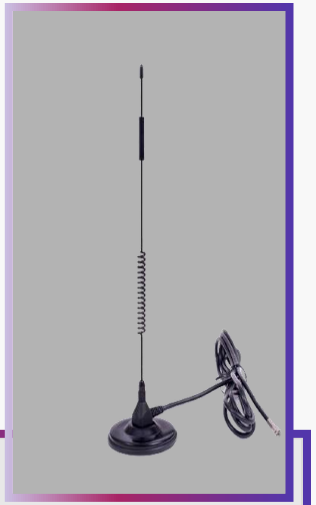


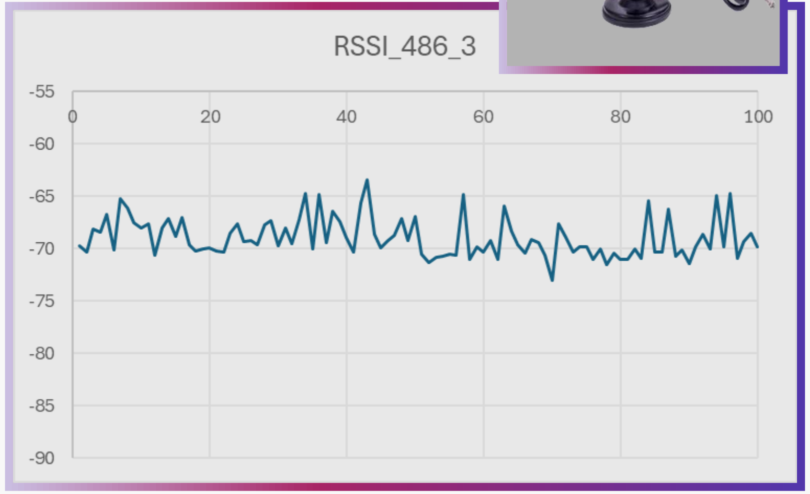


RSSI static measurements with antennas type 1 showing the variation of the RSSI.



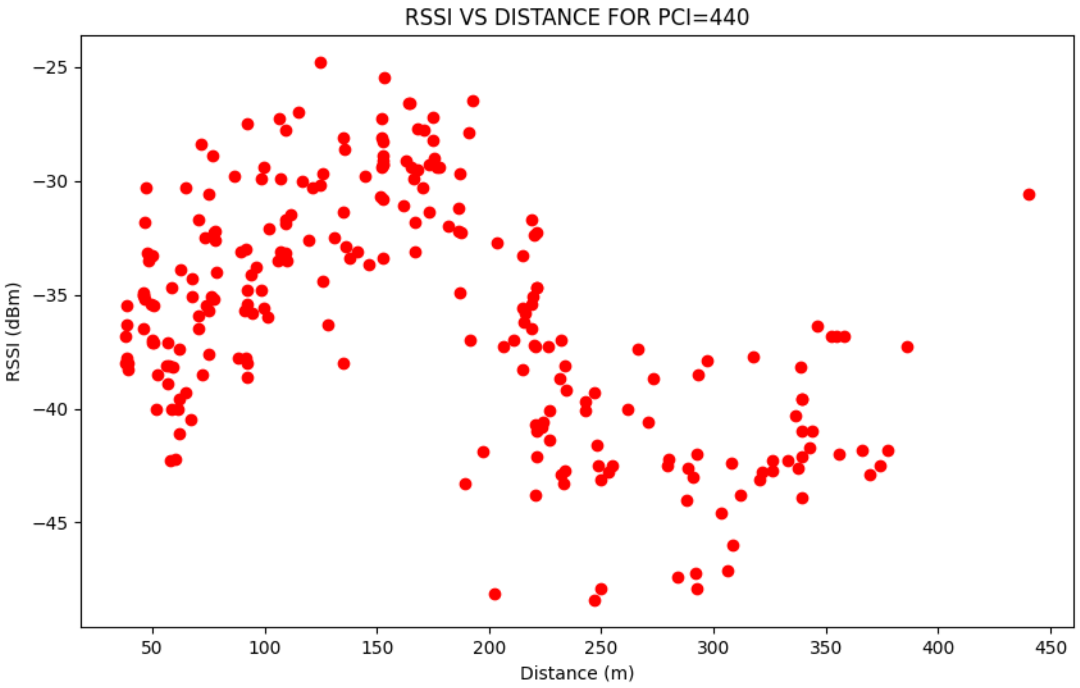
RSSI static measurements with antennas type 2 showing the variation of the RSSI.



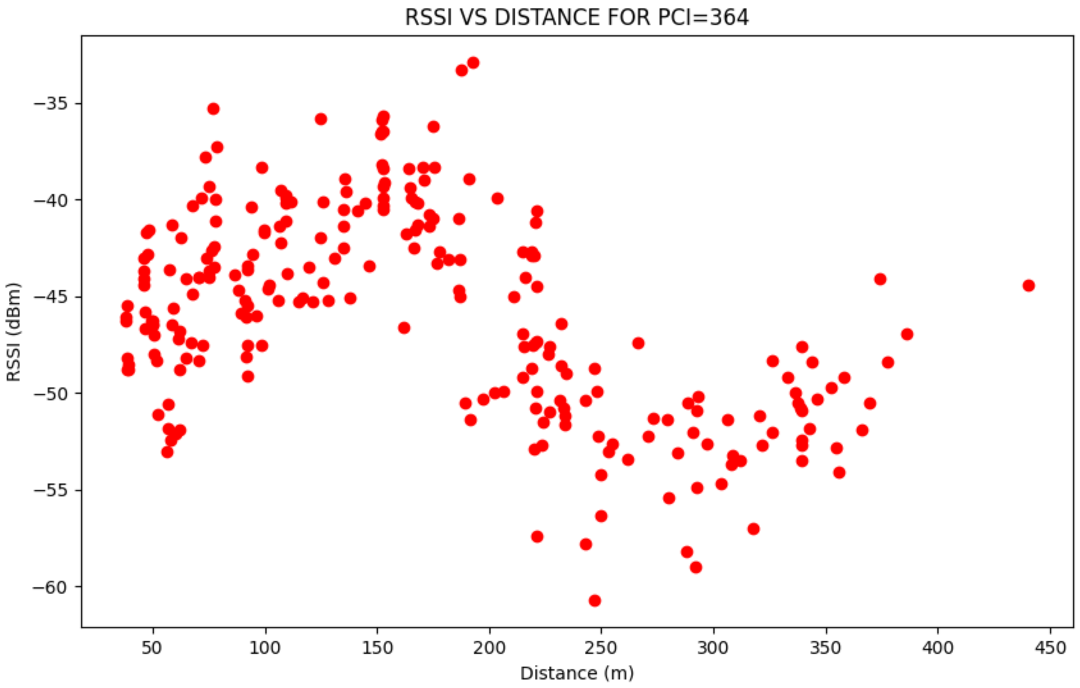


RSSI static measurements with antennas type 3 showing the variation of the RSSI.

FSPL along a direct Line-of-Sight of a specific transmitter

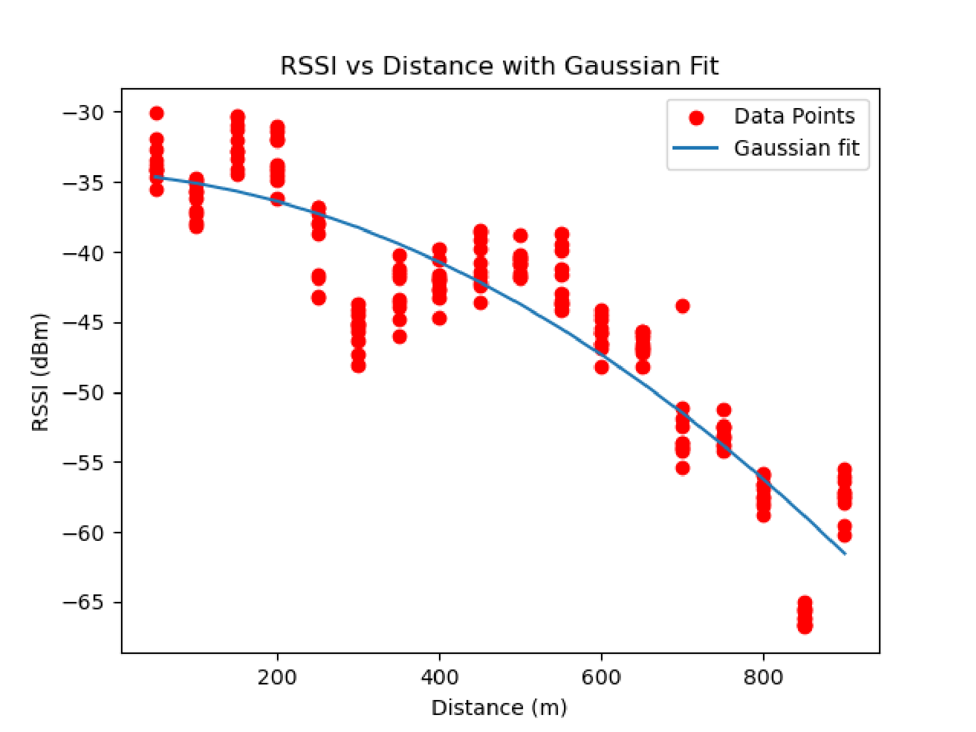


Continuous measurements of RSSI values in a direct LOS from cell tower with PCI 440.

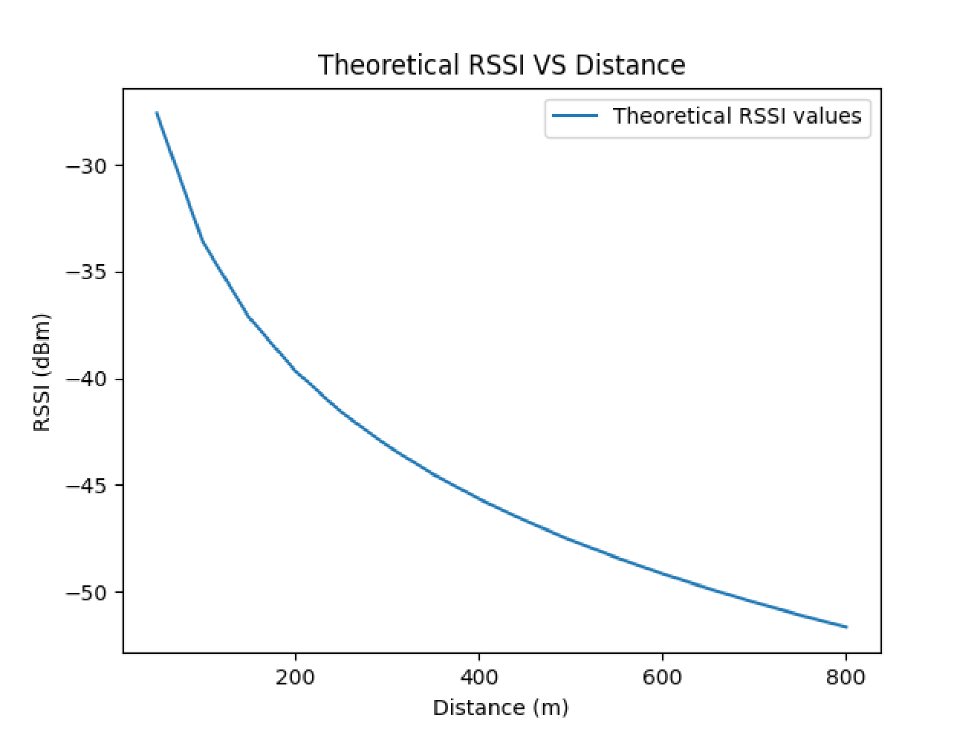


Continuous measurements of RSSI values in a direct LOS from cell tower with PCI 364.

FSPL along a direct Line-of-Sight of a specific transmitter



RSSI variation and Gaussian fit at 50-meter intervals (PCI 364).



Theoretical RSSI values along distance (PCI 364).

MOVE3 Steps

SETTINGS

Projection RD

INPUT

CSV file with distances from observation points to Cell Towers

Imported as Total Station data,
Manufacturer: “MOVE3 csv”
{Observation, Known_CellTower,
~~height_Observation~~, height_CellTower,
~~hor_angle~~, ~~ver_angle~~, distance}

CSV file with known coordinates of the Cell Towers

Imported as Coordinate file,
Add as “Known Station”,
{CellTower_Name, X East, Y North,
Height}

COMPUTE

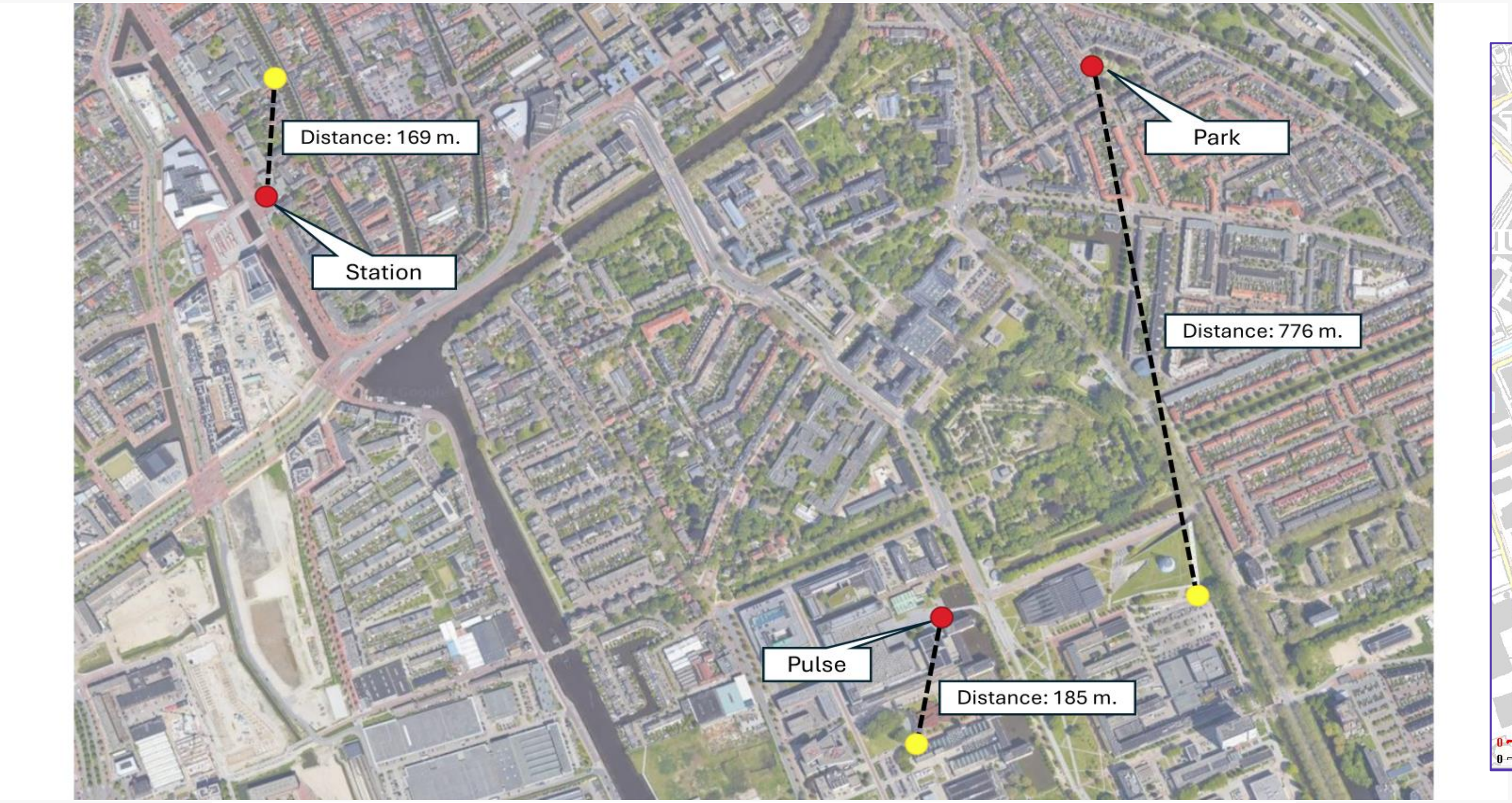
Approximate Coordinates

Pseudo Least Squares Adjustment

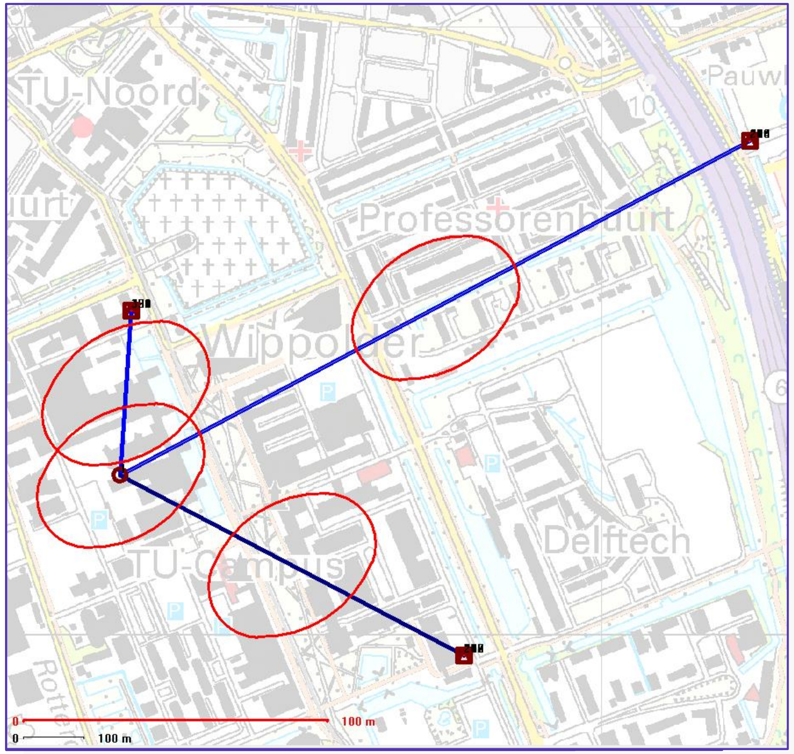
RESULTS

Deselect observations – possible outliers (W-test) - adjust the standard deviations so as F-test is accepted

Position Estimation through Trilateration using MOVE3 Software

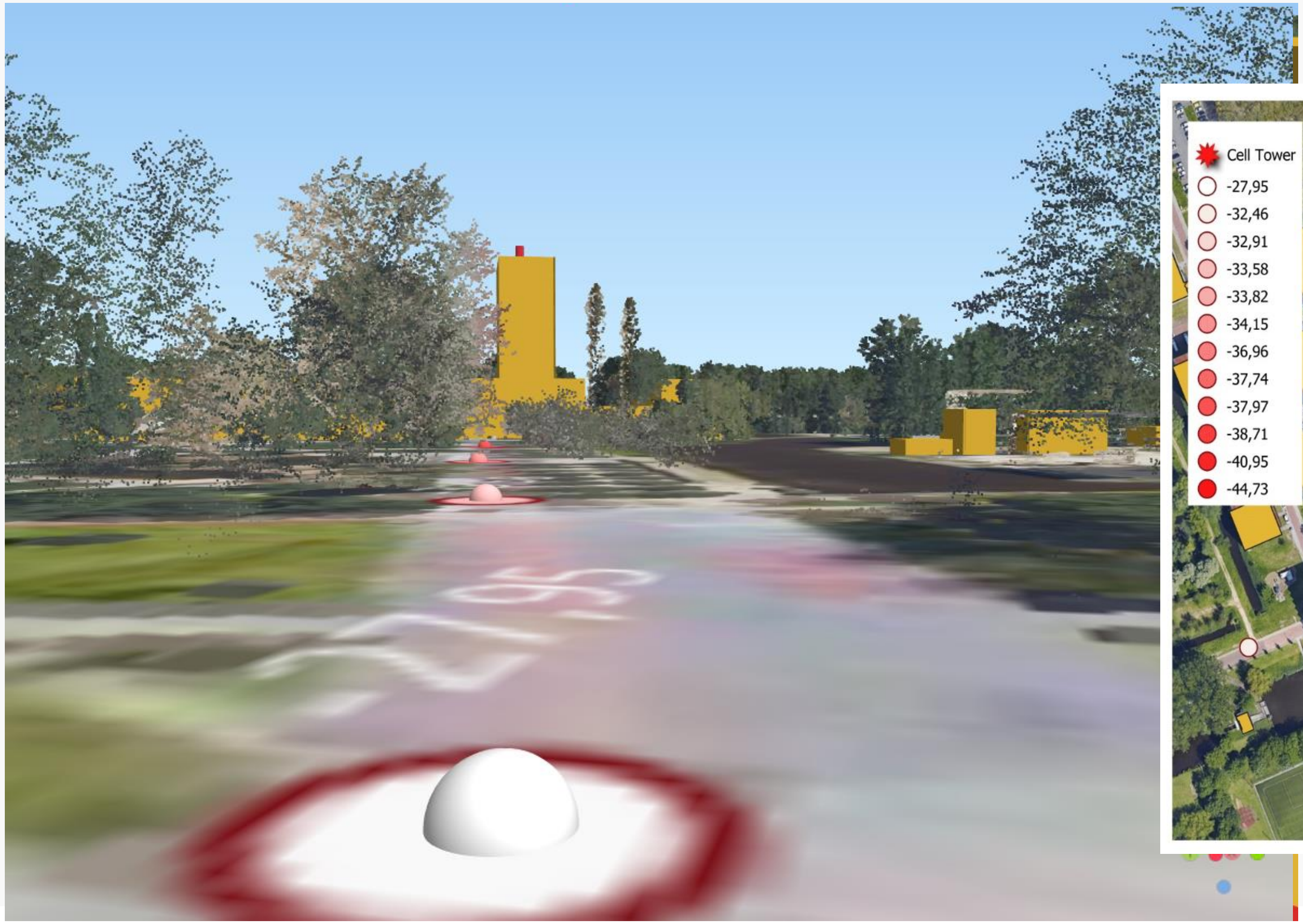


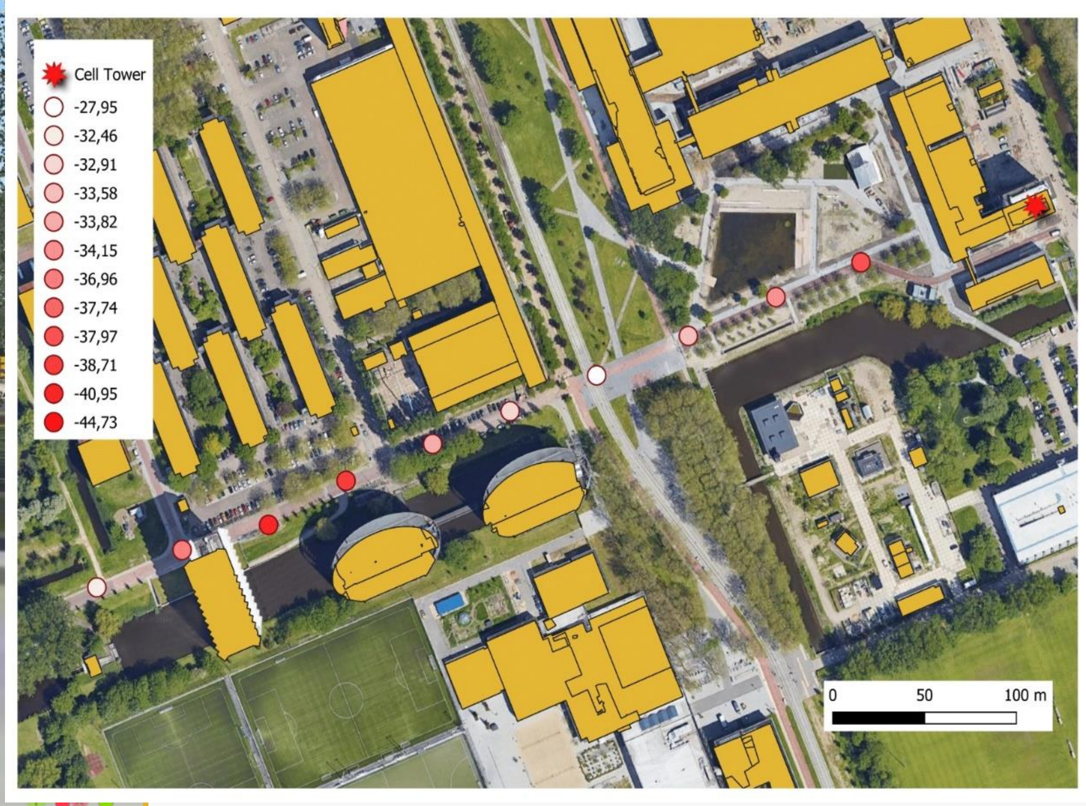
Park
Pulse
Station



RSSI variation and Gaussian fit at 50-meter intervals (PCI 364).

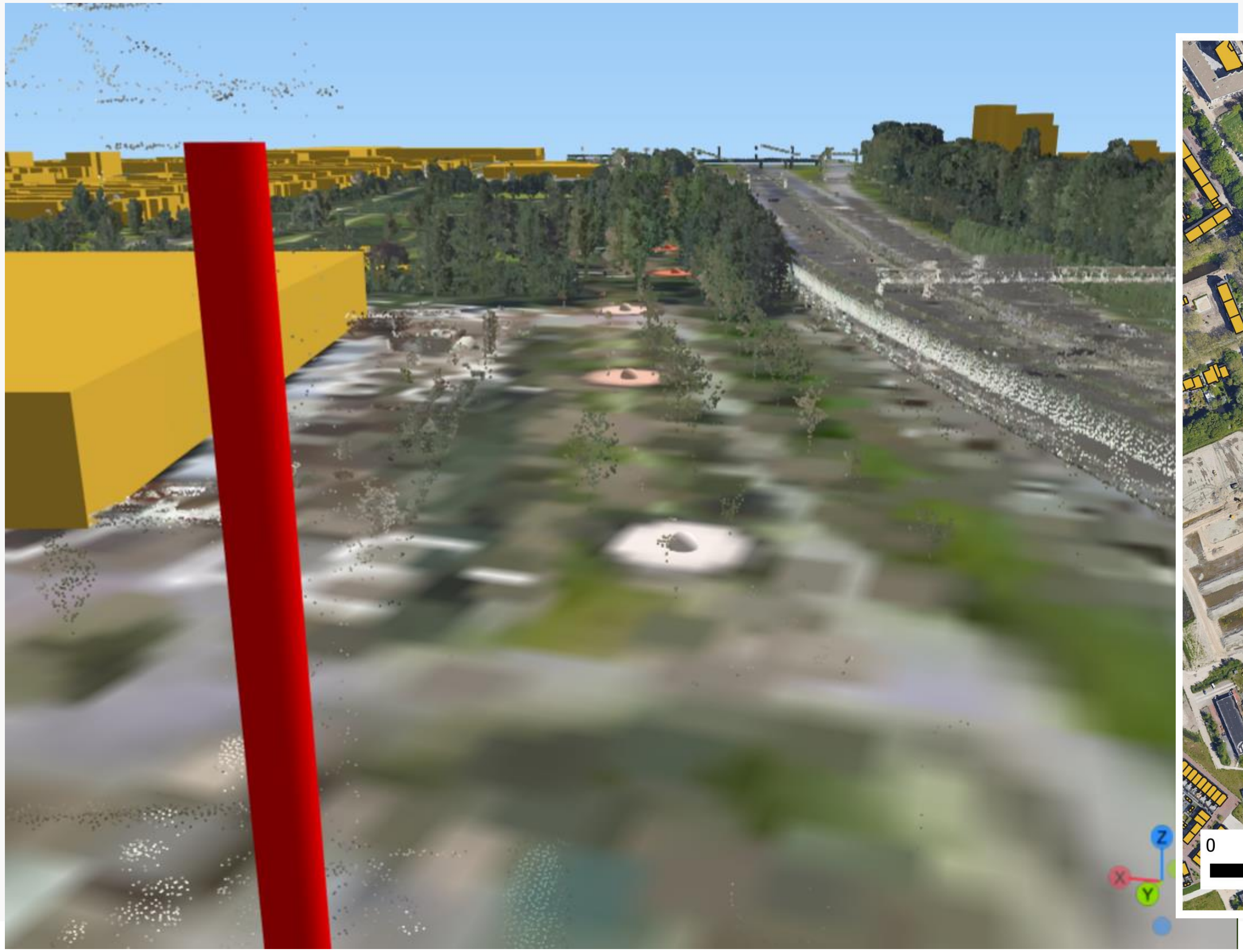
Impact of Topographic Factors on 5G Positioning Accuracy

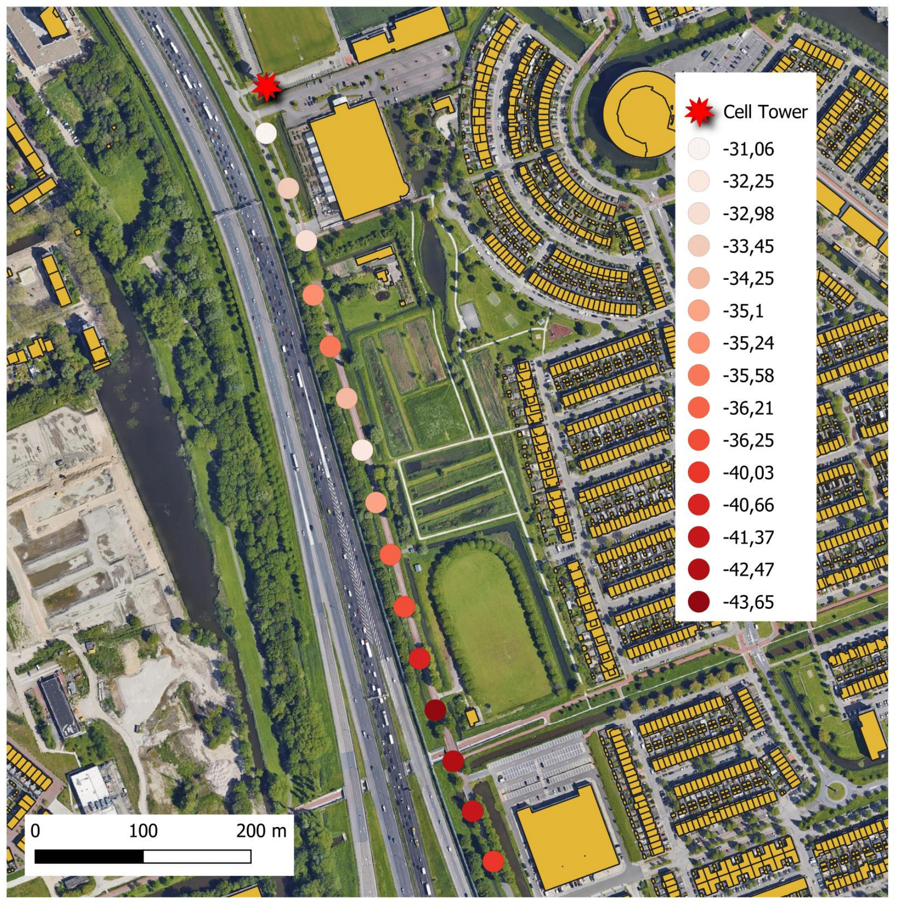




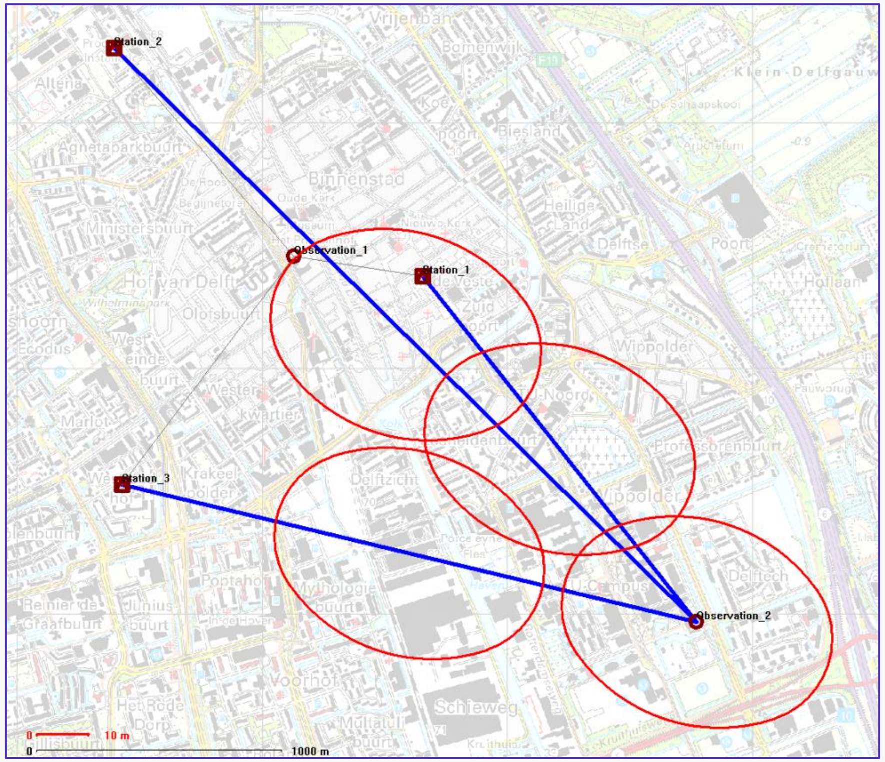
RSSI measurements showing signal strength variations due to tree & building obstructions.

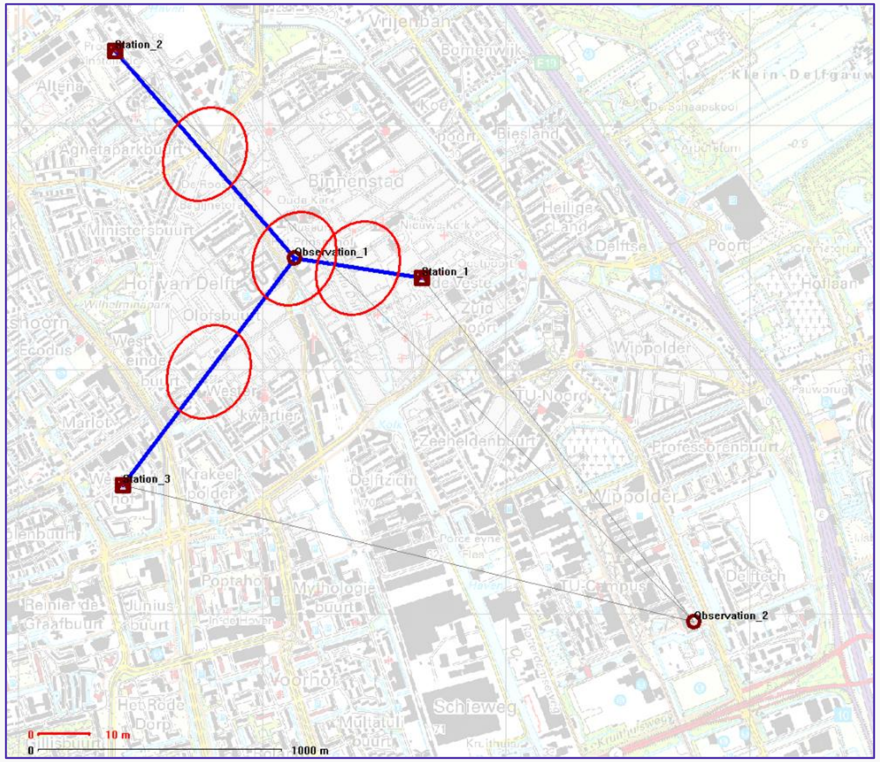
Impact of Topographic Factors on 5G Positioning Accuracy





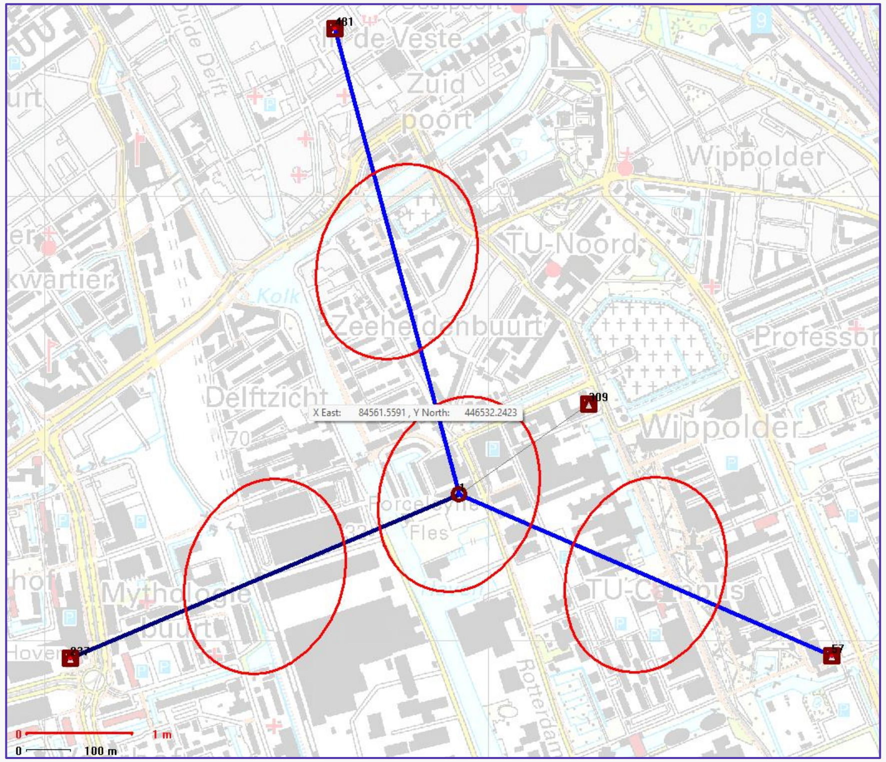
Effect of 5G Network Distribution on PDOP Accuracy

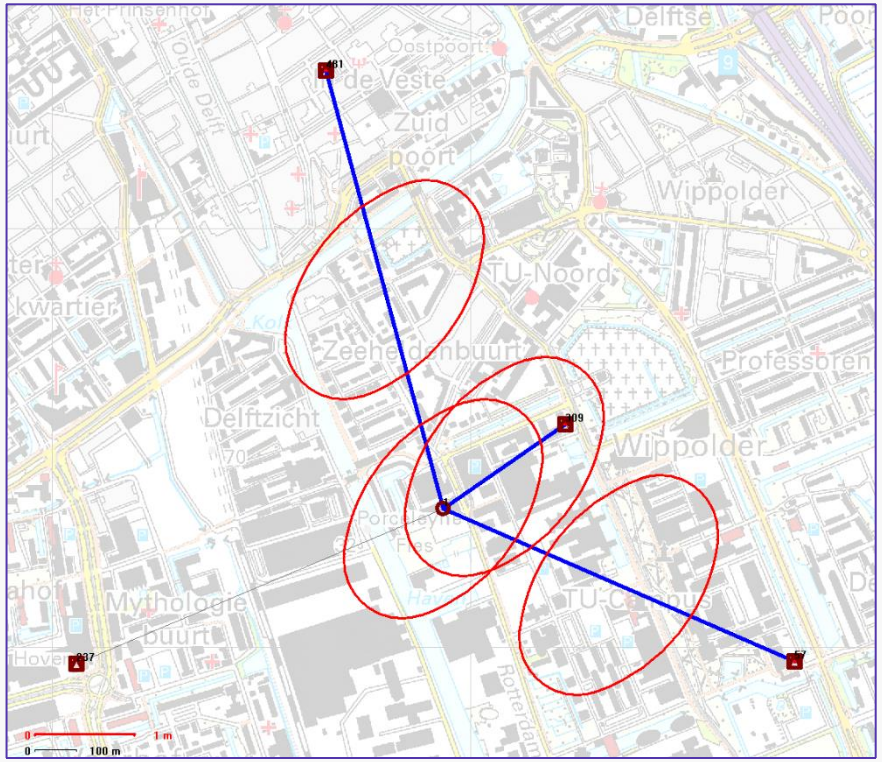




PDOP distribution when the observation point is outside the triangle that the antennas form (left image) and when it is outside (right image).

Effect of 5G Network Distribution on PDOP Accuracy





PDOP distribution when the connected cell towers form a triangle and the observation point lies in that (left image) in comparison to when they are collinear (right image).

Conclusions & Recommendations

Conclusions

- **FSPL Modeling Challenges**: Substantial fluctuations in RSSI, not aligning with expected FSPL
- **Distance Estimation**: Irregular RSSI behavior complicates accurate distance calculation
- **Trilateration**: RSSI-based trilateration results in large position errors and spatial uncertainty
- **Urban Obstructions**: Tree and building obstructions degrading positioning accuracy based on RSSI.
- **Cell Towers' Geometric Configuration**: Great impact on positioning accuracy, poor tower distribution increases PDOP and positioning uncertainty.

Future Work

Alternative 5G Positioning Techniques

AOA, AOD, TDoA: Investigate positioning methods with potential for higher accuracy than RSSI.

Optimizing RSSI-based Positioning

- 5G Features: Leverage dense small-cell deployments, beamforming, and mmWave frequencies.
- Mitigation Strategies: Explore calibration, filtering, and machine learning to reduce RSSI issues (e.g., multipath, attenuation).

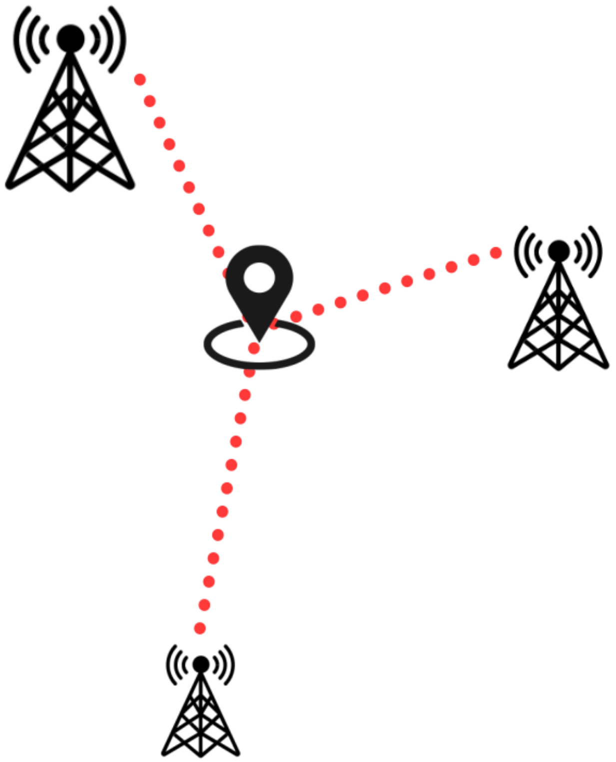
Developing a DOP Map of Delft

Map DOP values for the city to visualize potential positioning accuracy based on cell tower distribution.

Indoor Positioning Potential

- Controlled Environment: Utilize floor plans and reference points for precise indoor localization.
- Signal Boosters: Position smaller antennas to reduce interference and improve reliability.

EXPLORING THE POTENTIAL OF 5G POSITIONING VIA RSSI, COMPARING ITS EFFICACY WITH GNSS-RTK POSITIONING



Akis G.K. Nestoras

Thesis Presentation - MSc Geomatics