Presented at the FIG e-Working Week 2021,
21-25 June 2021 in Virtually in the Netherlands

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT
CHALLENGES IN A NEW REALITY

FIG NL THE NETHERLANDS

e WORKING WEEK 2021
20-25 JUNE

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10863

Study for the Development of a Guidance and Information System Based on Wi-Fi for TU Wien

23 June, 15:00 – 16:30 CEST

Introduction / Motivation

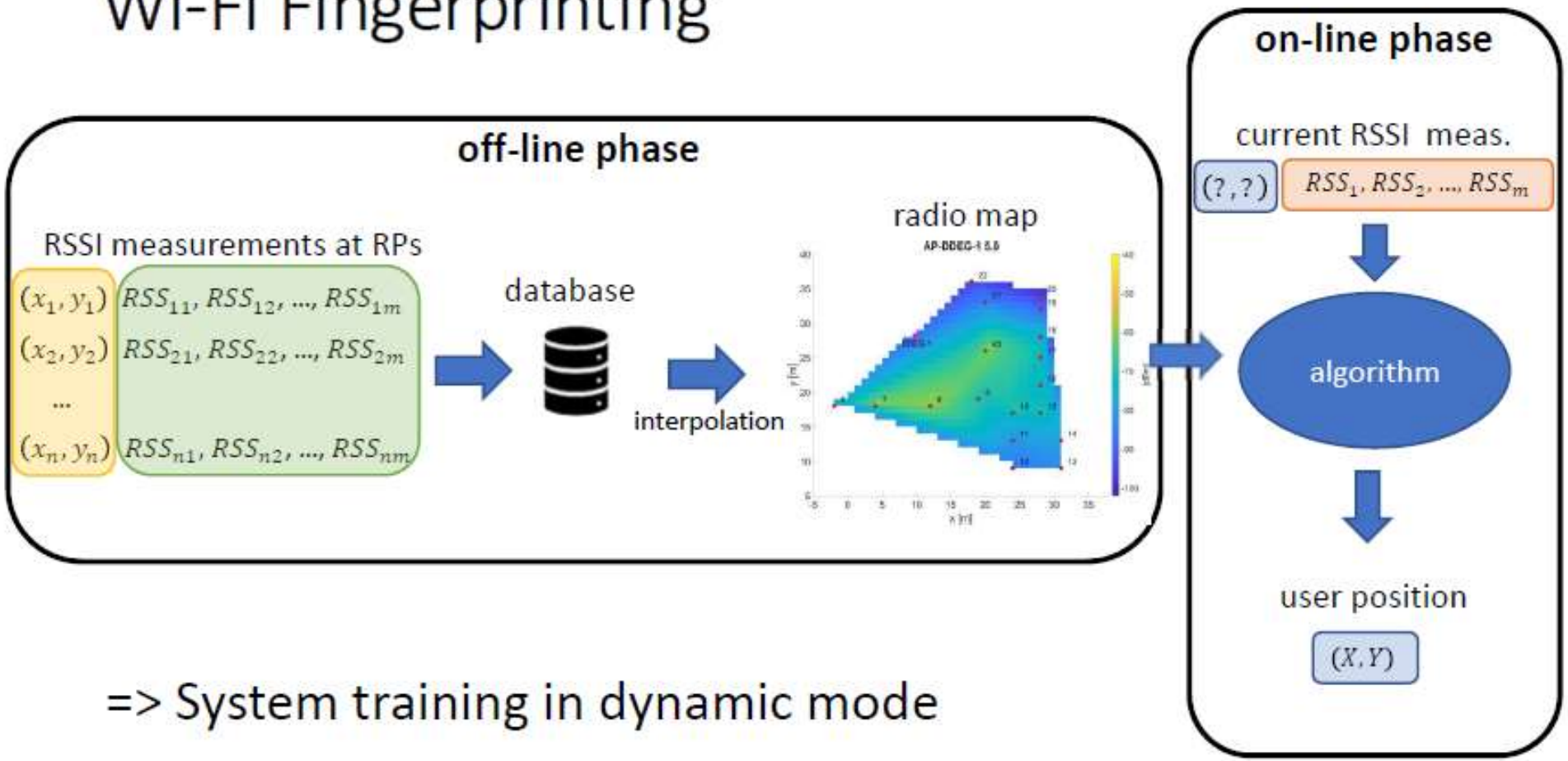
- TU Wien has over 12,000 rooms in 30 buildings
- Library has 1,160 m² on six levels
- Development of a campus-wide navigation and information service
- Navigation to a certain bookshelf with low-cost system

IPS Selection Criteria

- No additional hardware deployment
- Use of signals-of-opportunity
- For common mobile devices, such as smartphones and tablets
- High reliability and coverage on campus
- User-friendliness
- Data protection guaranteed

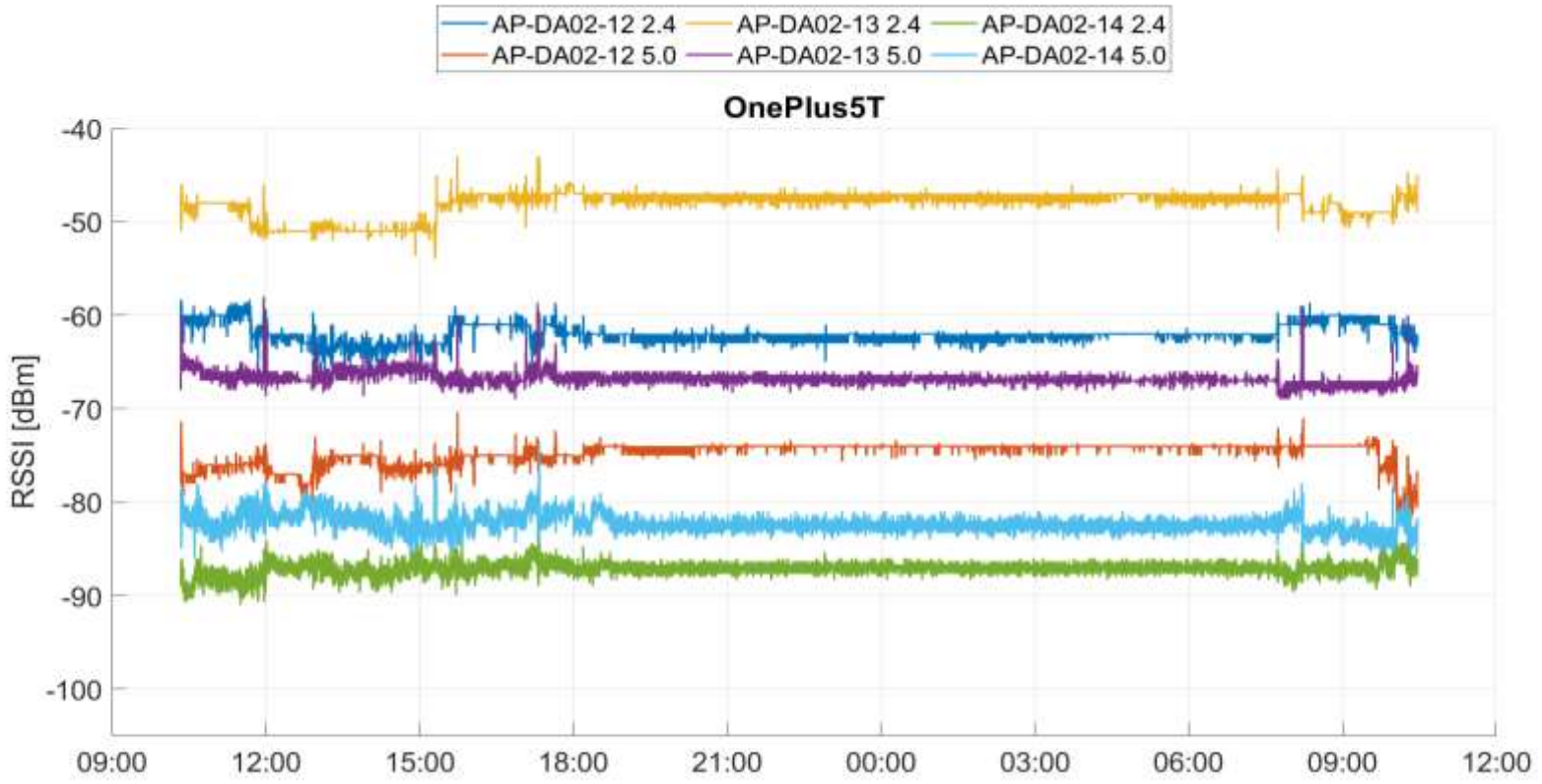
=> Wi-Fi RSSI-based positioning system

Wi-Fi Fingerprinting



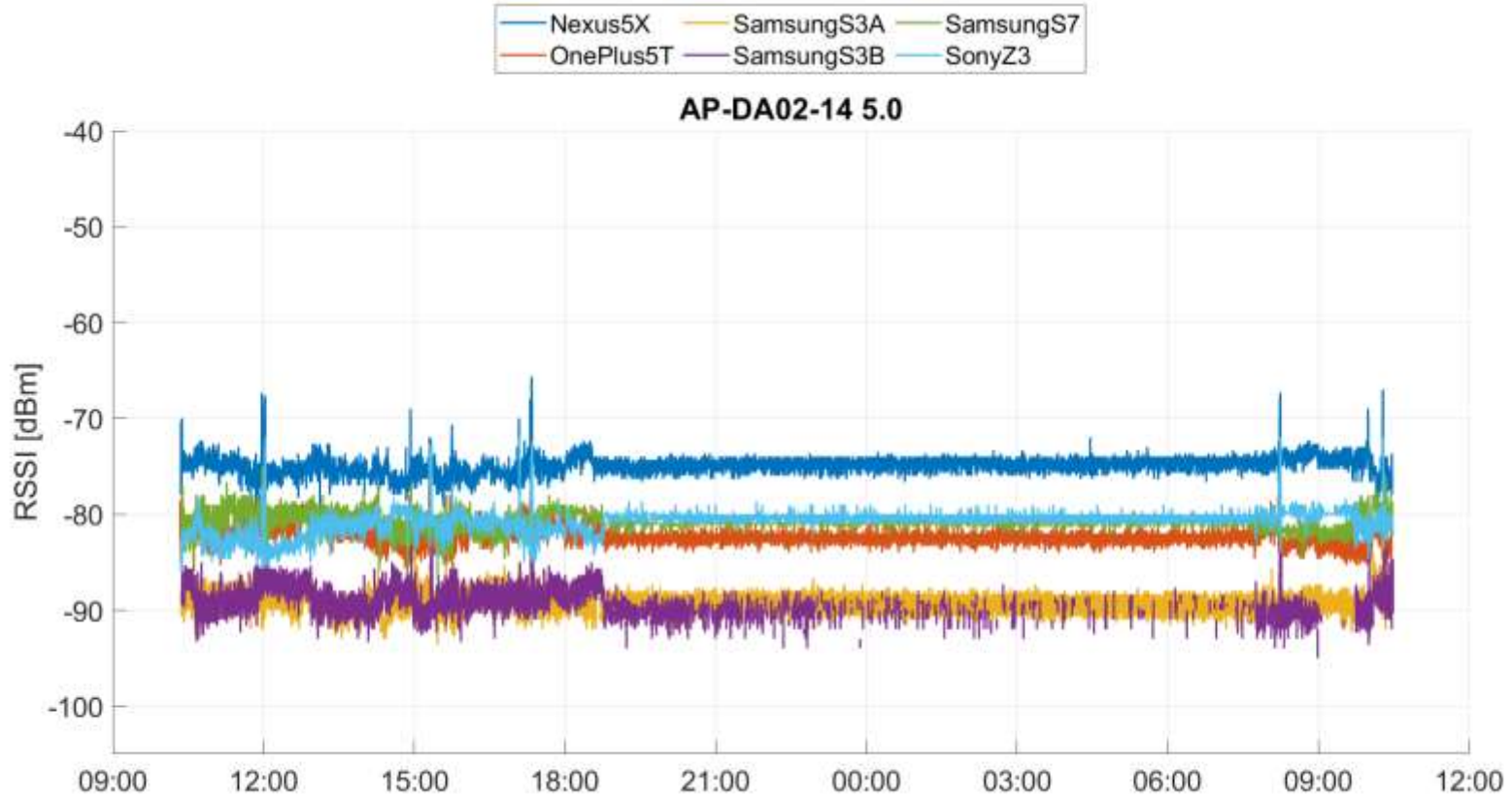
=> System training in dynamic mode

Long-term Signal Observation



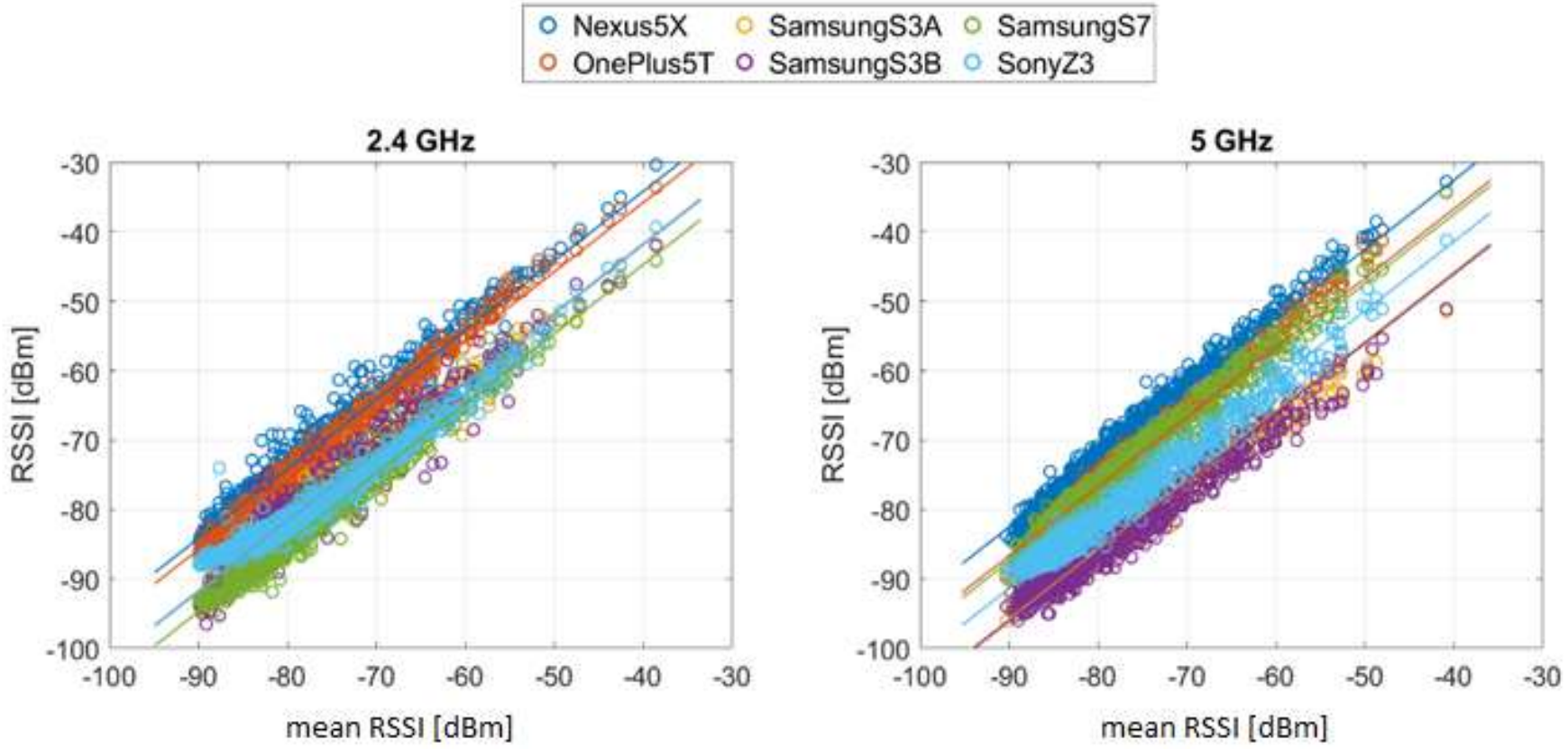
significant difference between day and night

Smartphone Dependence



significant offset

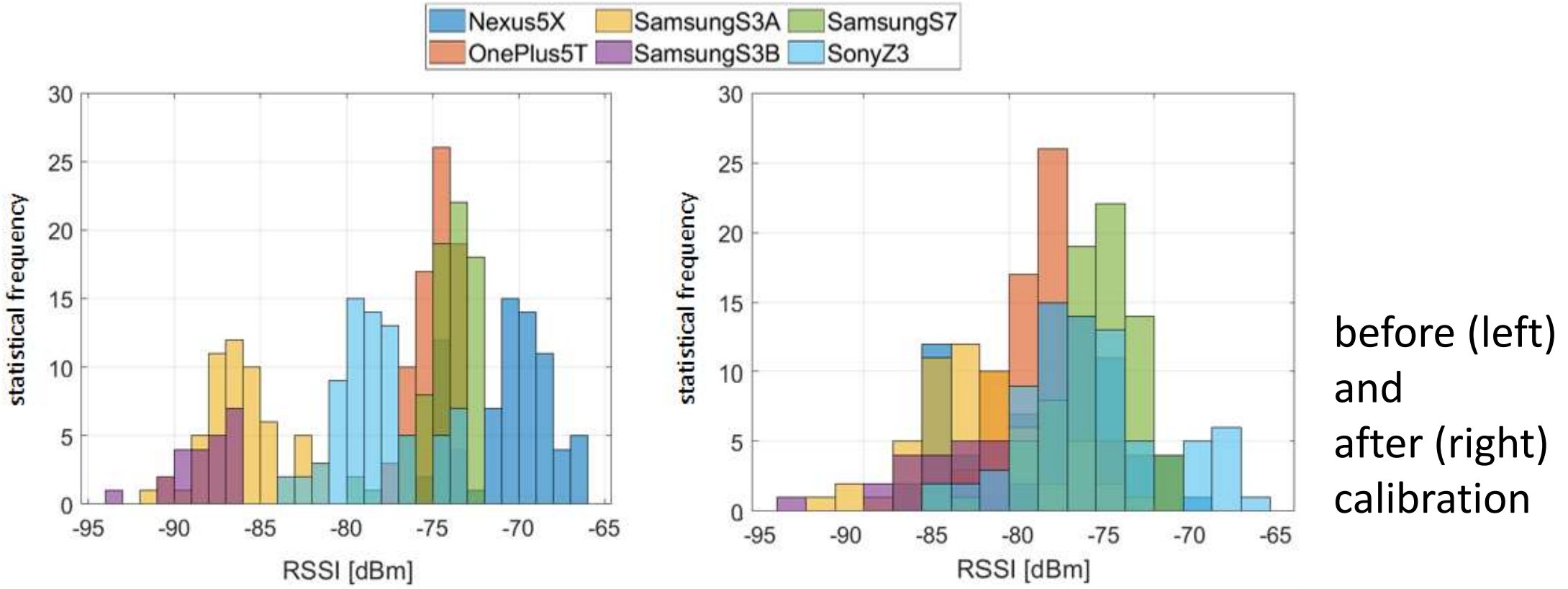
Smartphone Calibration



multivariate linear regression for offset determination

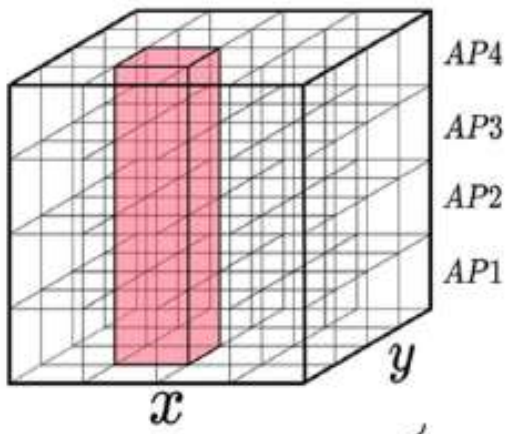
$$\boldsymbol{y}_{RSSI} = a_S \cdot \boldsymbol{x}_S + b_S$$

RSSI Distribution



before (left)
and
after (right)
calibration

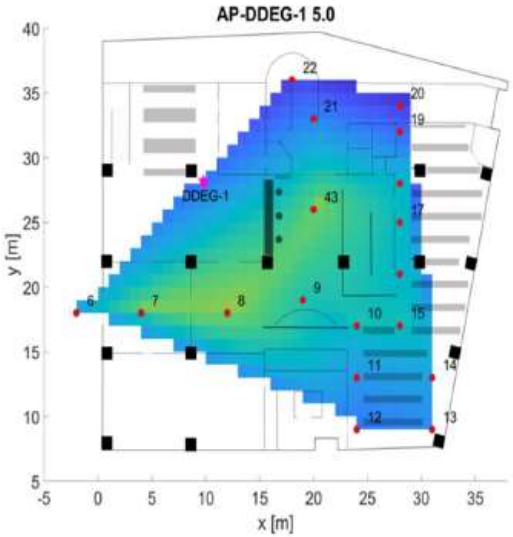
Radio Map Stack Datacube

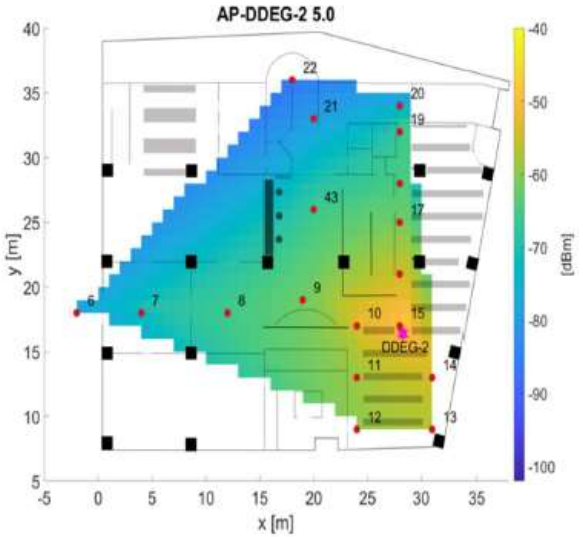


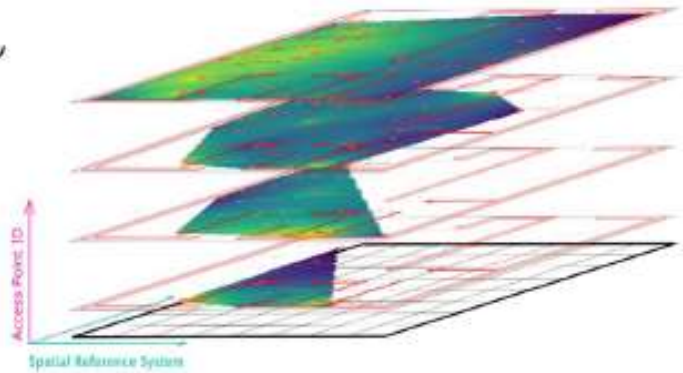
$$\boldsymbol{p}_{x,y} = \boldsymbol{s}_{RP_i,x,y} = \begin{bmatrix} rss_{AP_1} \\ rss_{AP_2} \\ rss_{AP_3} \\ rss_{AP_4} \end{bmatrix}$$

$$\boldsymbol{s}_{meas.} = \begin{bmatrix} rss_{AP_1,meas.} \\ rss_{AP_2,meas.} \\ rss_{AP_3,meas.} \\ rss_{AP_4,meas.} \end{bmatrix}$$

$$\boldsymbol{p}_{x,y} - \boldsymbol{s}_{meas.} \rightarrow min. \rightarrow \boldsymbol{s}_{meas.} = \boldsymbol{s}_{x,y}$$







User Position Estimation

- Probabilistic matching of fingerprints between off- and on-line measurements using the radio map datacubes
- Mahalanobis distance

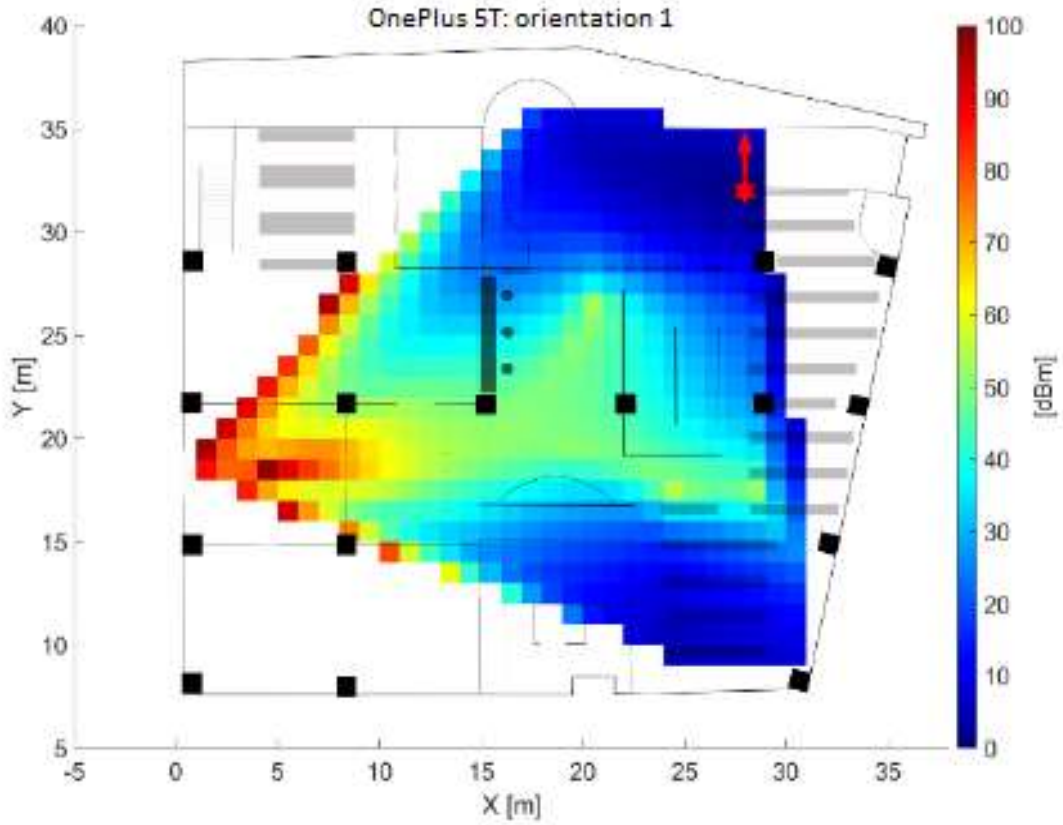
$$d^M(\boldsymbol{f}^i_{map}, \boldsymbol{f}_{obs}) = (\boldsymbol{f}_{obs} - \boldsymbol{f}^i_{map})^T \boldsymbol{C}^{-1}_{ff_{map,i}} (\boldsymbol{f}_{obs} - \boldsymbol{f}^i_{map})$$

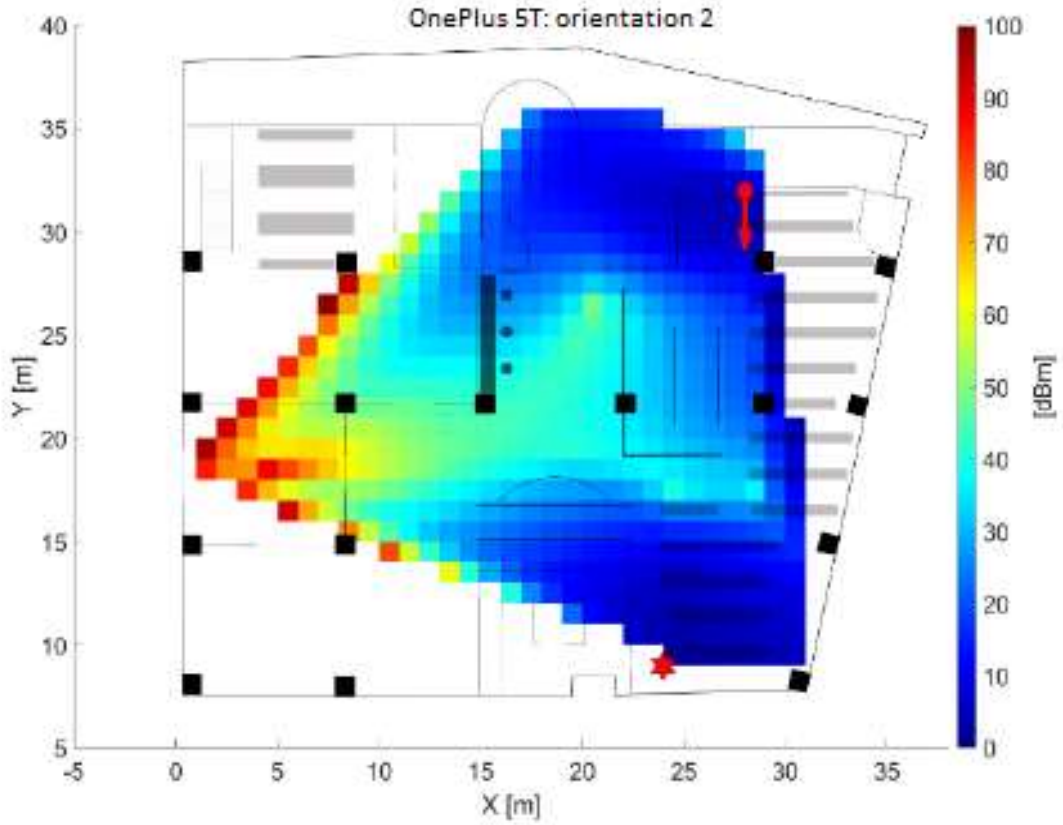
  - Calculation of a weighted square sum of the RSSI differences between off- and on-line phase
  - The weighting is inversely proportional to the variance of the off-line fingerprint

Mahalanobis Distance

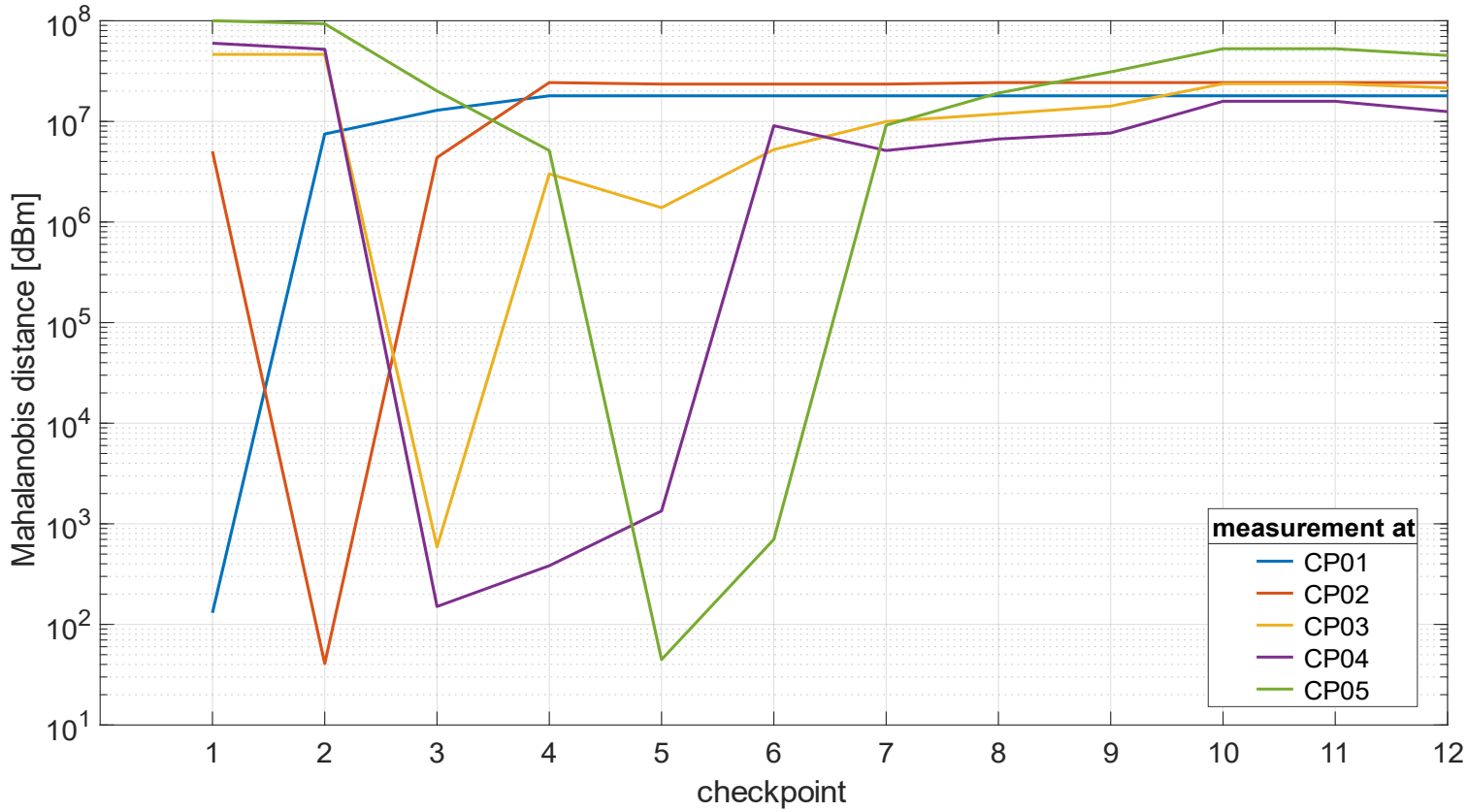
true location and user orientation

estimated position





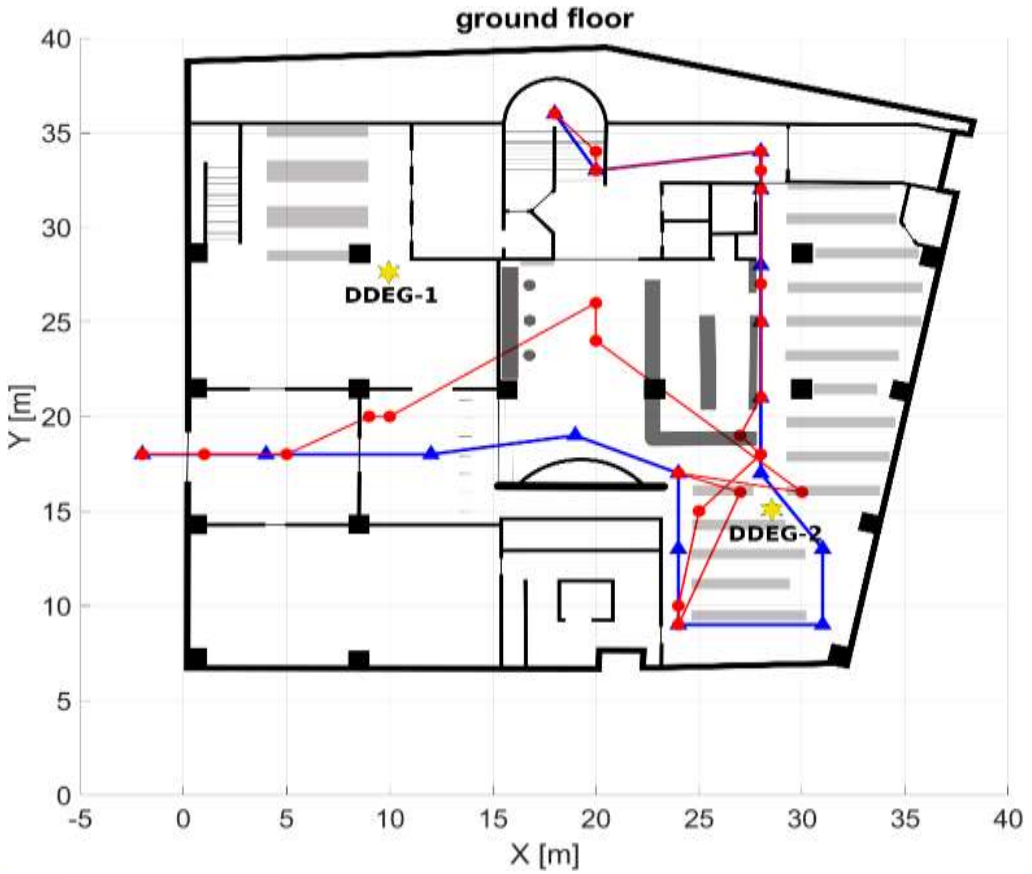
Positioning Using the Mahalanobis Distance

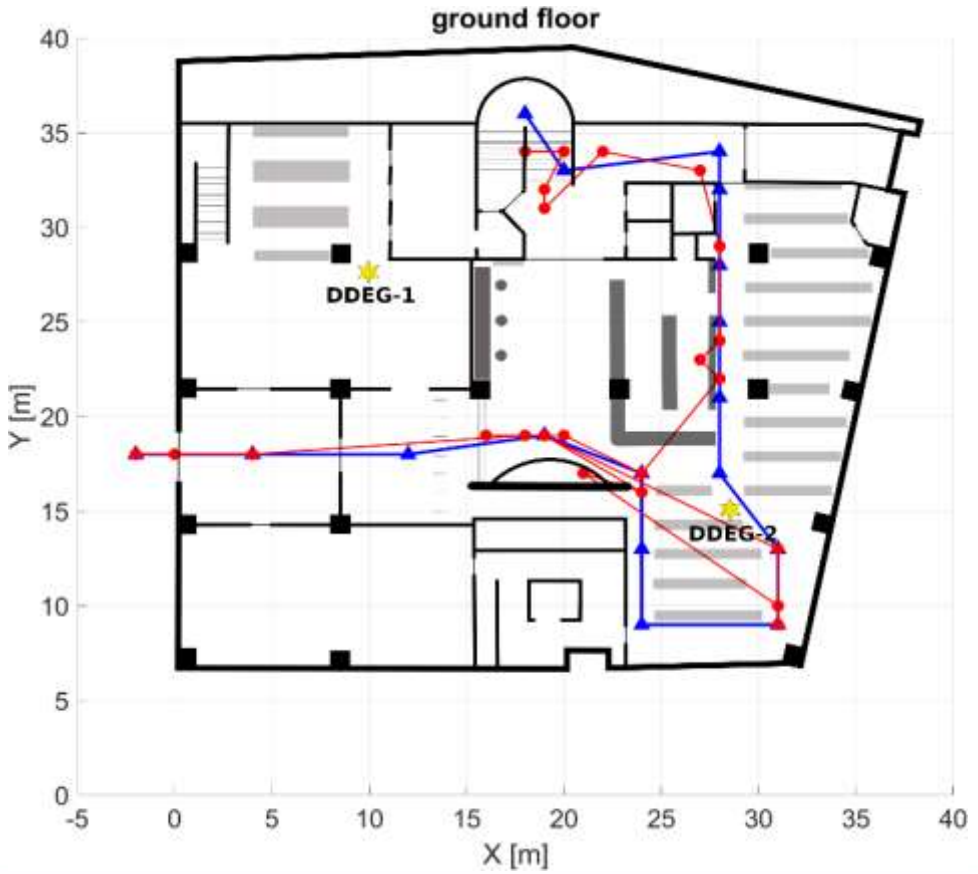


CP01, CP02, CP03 and CP05 have been correctly determined

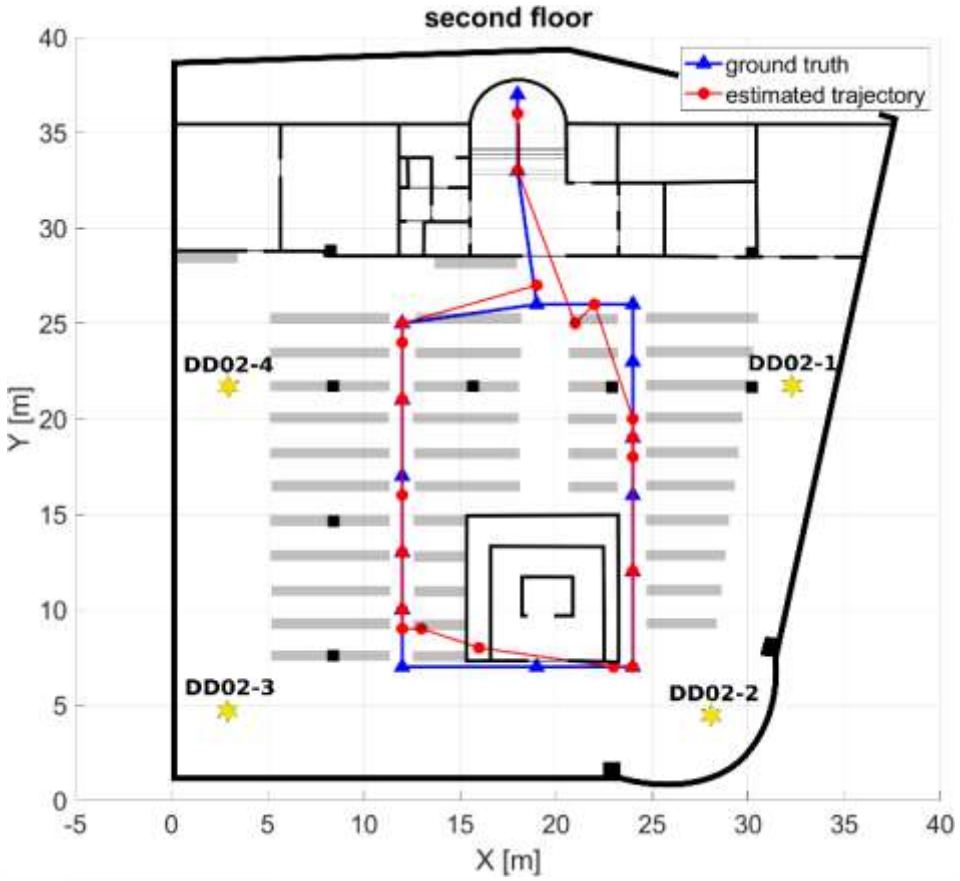
The on-line measurement at CP04, however, has its minimum Mahalanobis distance at CP03

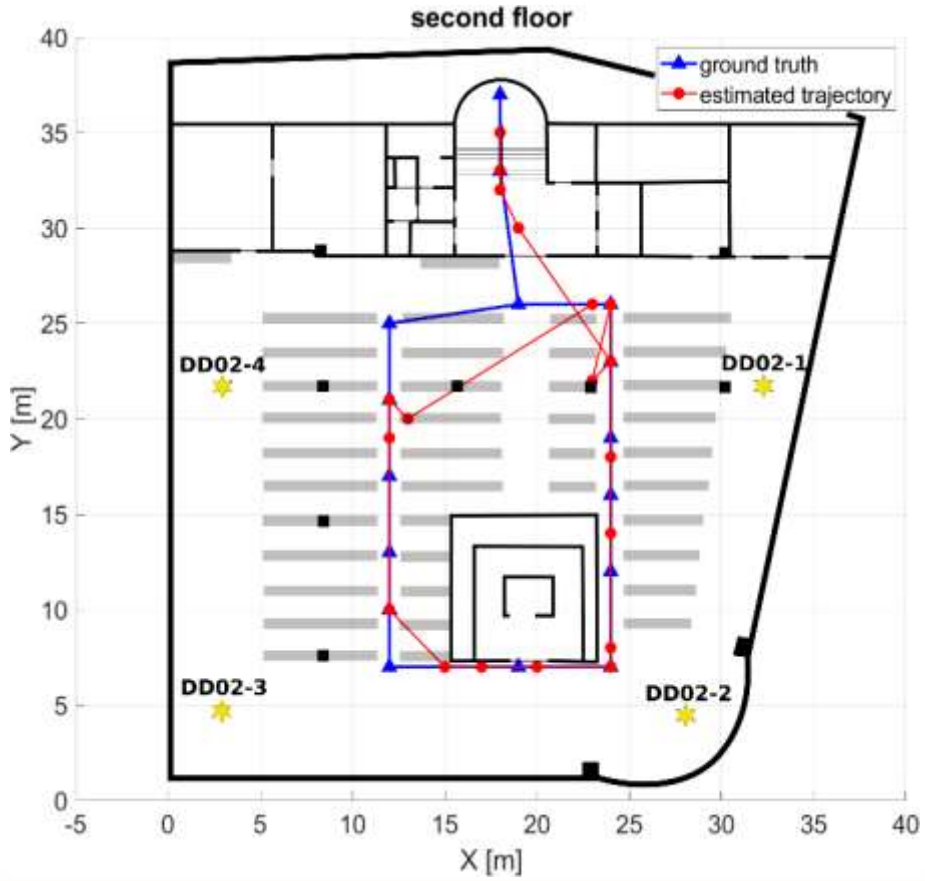
Results of 2 kinematic measurement runs



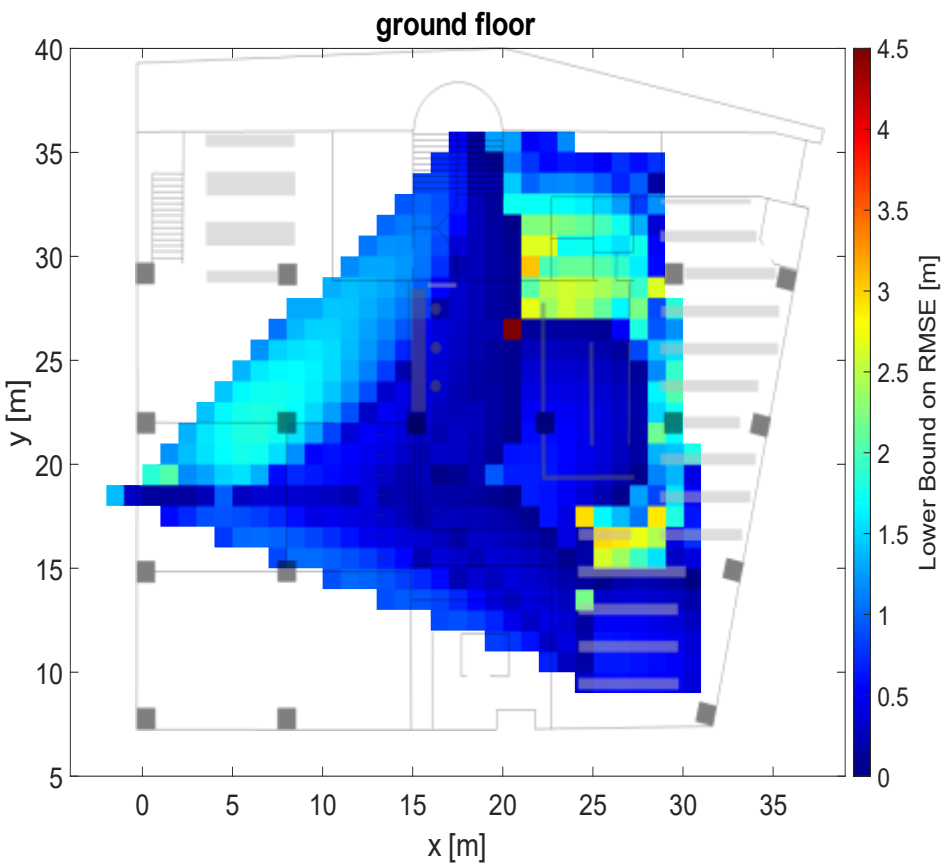


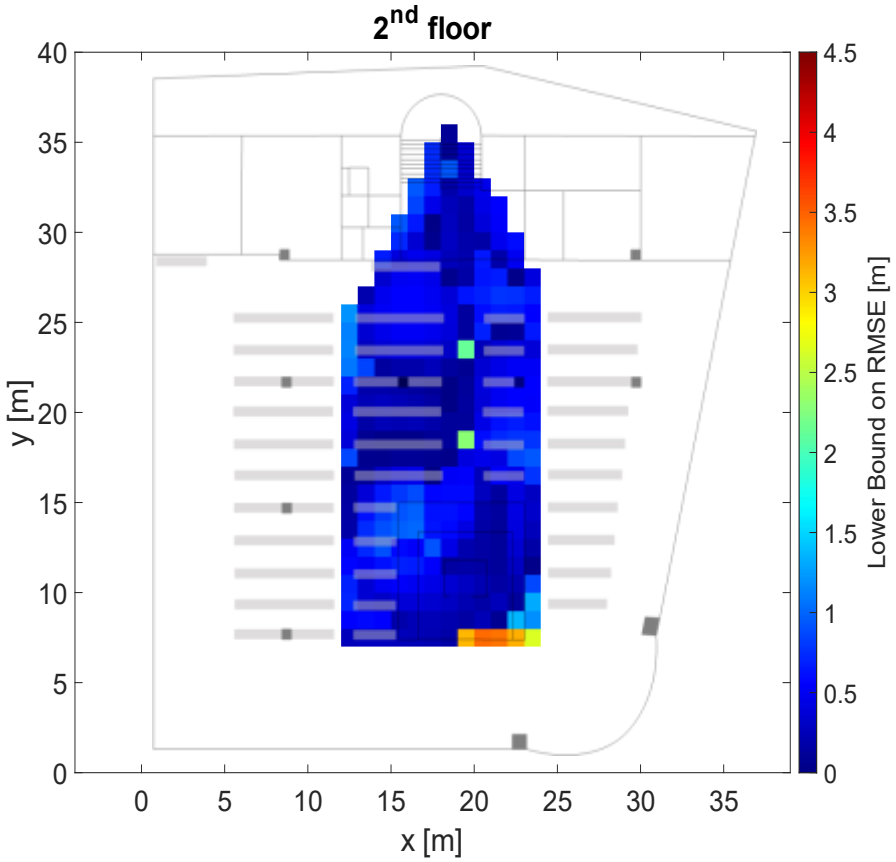
Results of 2 kinematic measurement runs





Cramér-Rao Lower Bound (CRLB) on RMSE





Low CRLB values (dark blue) indicate higher positioning accuracies during the on-line phase, while higher values (red) mean lower accuracy

Concluding Remarks and Outlook

- Sufficient stable Wi-Fi signals can be sensed with RSSI fluctuations of ±5 dBm during the day
- Deviations from ground truth on the meter range
- Smartphone calibration is essential
- Densification and rearrangement of Access Point network beneficial
- Continuous RSSI recordings
- New hardware for Wi-Fi RTT FTM capability
- Combination with other technologies