Wi-Fi Fingerprinting with Reduced Signal Strength Observations from Long-time Measurements

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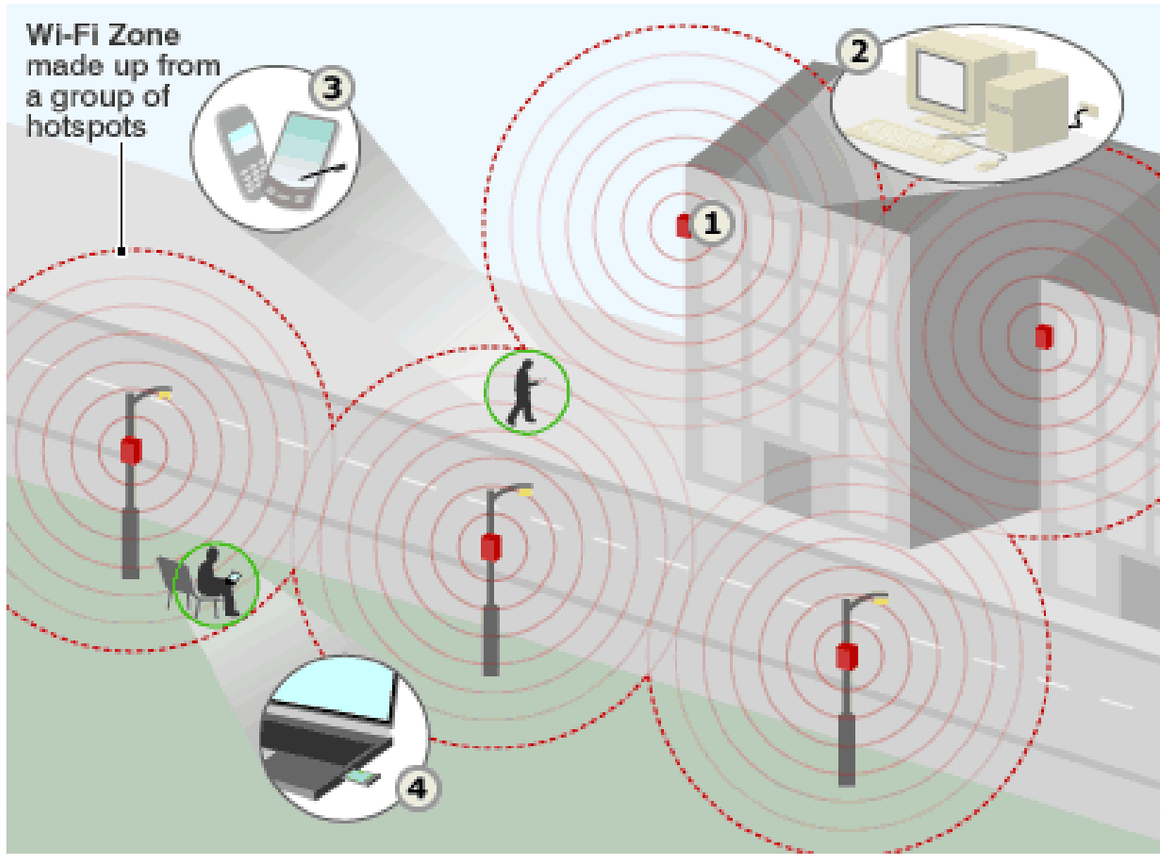
Wi-Fi Positioning

- Signal-of-Opportunity
- Use of already available infrastructure
- IEEE-802.11 standard in 2,4 GHz band
- Compatible devices
- Received Signal Strength RSS
- Location fingerprinting
- Trilateration



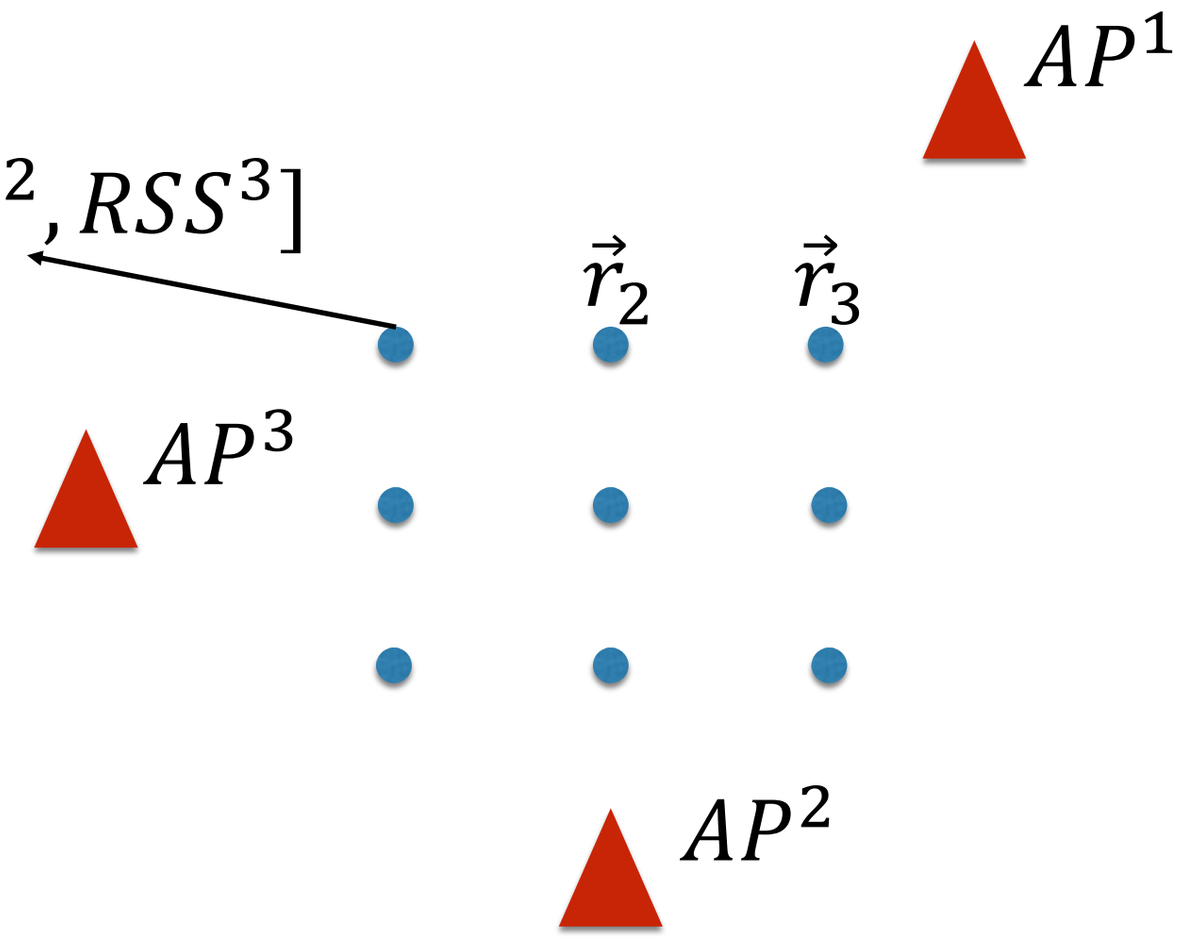
Challenges

- Low positioning accuracies of several meters caused by RSS fluctuations
  - Multipath propagation
  - Signal absorption and shielding
  - Radio interference
  - Device and number of user dependance

-> Spatial and temporal signal variations

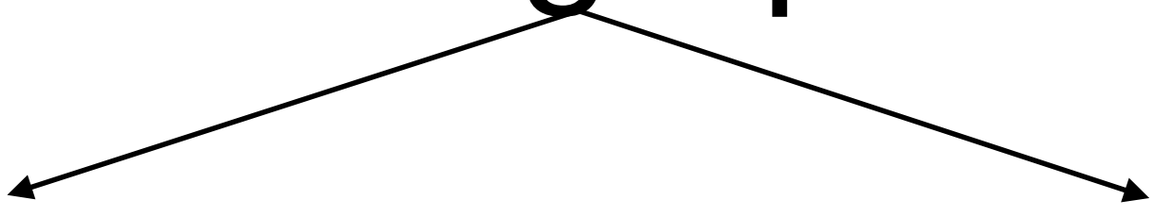
Fingerprinting

$$\vec{r}_1 = [RSS^1, RSS^2, RSS^3]$$



- Reference points
- Fingerprints
  (spatial dependance)
- Radio map $R = \{(\vec{p}_i, \vec{r}_i)\}$

Wi-Fi Fingerprinting



Training phase

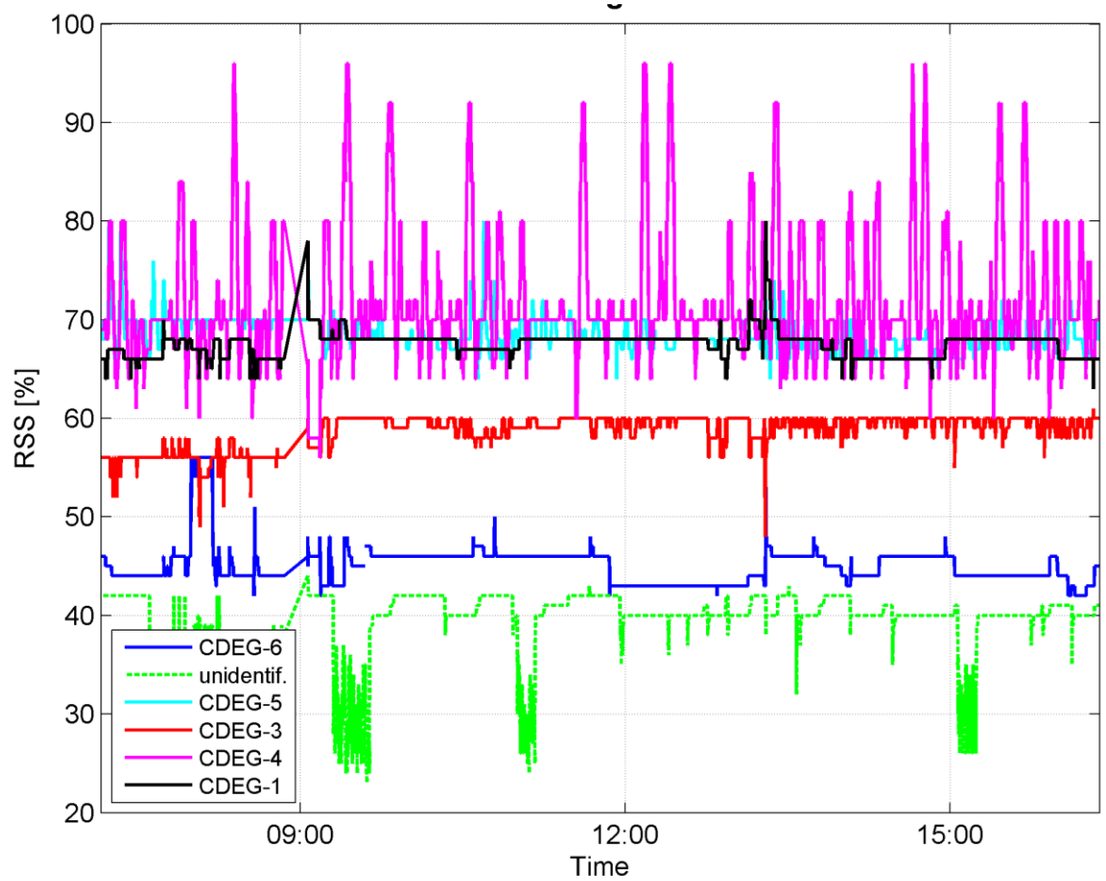
- System components
- RSS measurements for radio map generation

Positioning phase

- RSS fingerprint at unknown location
- Matching approach
- Estimated location

Wi-Fi Fingerprinting with Reduced RSS Values

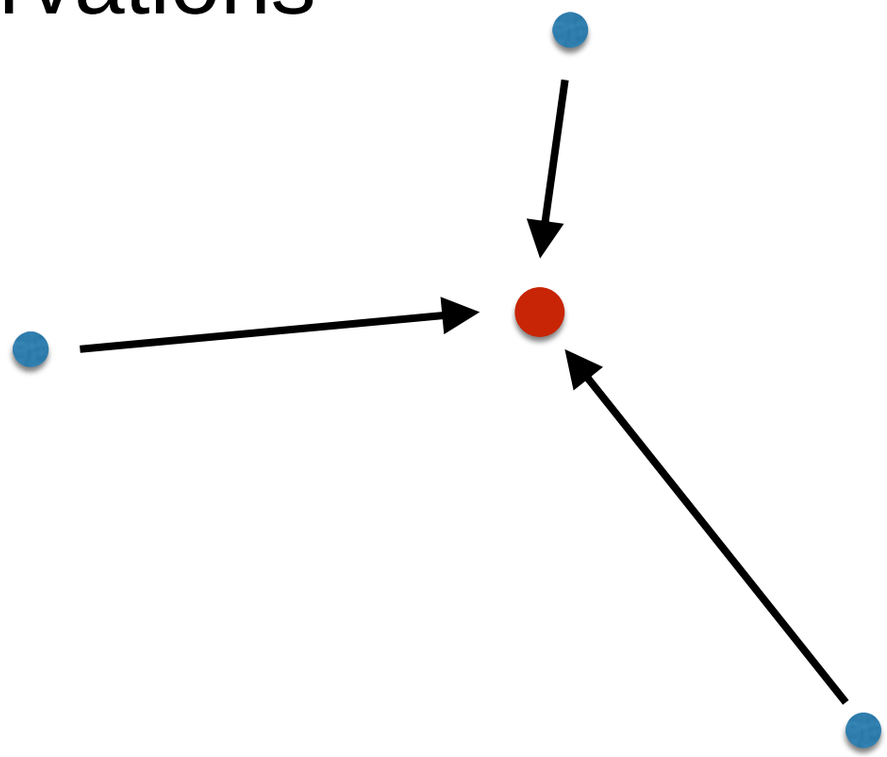
- Long-time observations
- RSS variation reduction
- 2 investigated methods:
  - Interpolation method
  - Daily average improvement method (DAI)



Interpolation method

- Interpolation of long-time observations
  - 2 variants:
    - Known position
    - Approximated position
- Assumption:

$$RSS_{theo}(\vec{p}, t) \approx RSS_{int}(\vec{p}, t)$$



2 components of measured RSS value

$$\widetilde{RSS}_{mes}(\vec{p},t) = RSS_{theo}(\vec{p},t) + \Delta_{RSS}(\vec{p},t)$$

Theoretical RSS $RSS_{theo}(\vec{p},t)$

- Transmitted RSS
- No other influences

Deviation caused by environment $\Delta_{RSS}(\vec{p},t)$

Interpolation of long-time measurements

$$RSS_{theo}(\vec{p},t) \approx RSS_{int}(\vec{p},t)$$

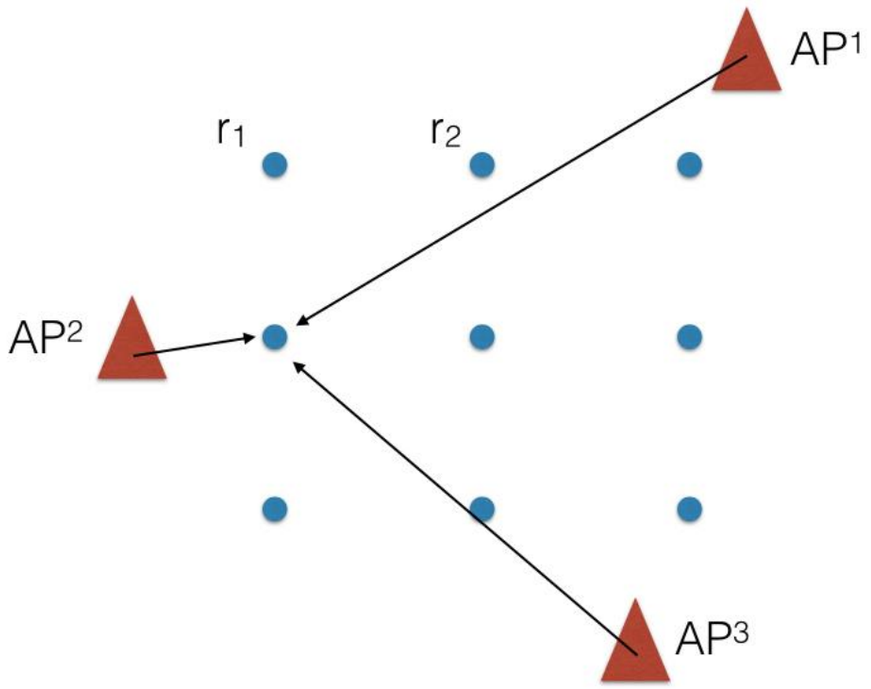
Known position

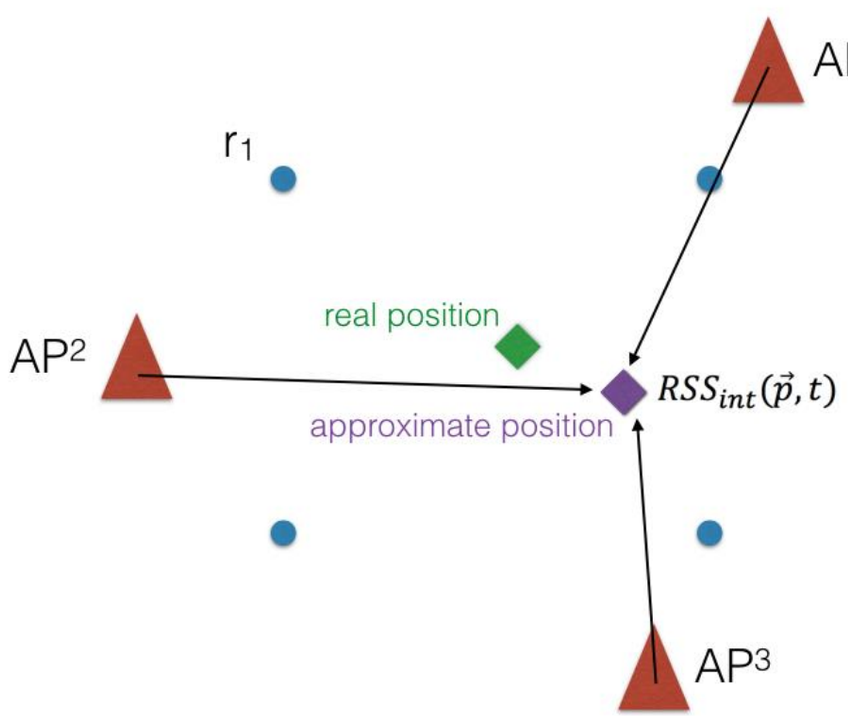
Approximated position

Reduced RSS

$$\Delta_{RSS}(\vec{p},t) \approx \widetilde{RSS}_{mes}(\vec{p},t) - RSS_{int}(\vec{p},t)$$

Training and Positioning Phase





Reduced RSS

$$\Delta_{RSS}(\vec{p},t) \approx \widetilde{RSS}_{mes}(\vec{p},t) - RSS_{int}(\vec{p},t)$$

- High spatial dependance
- Theoreticaly free from RSS variations

DAI Method (1)

- Average of long-time measurements of a whole day:

$$\hat{\vec{r}} = [\widehat{RSS}^{AP_1}, \widehat{RSS}^{AP_2}, \dots, \widehat{\mathrm{RSS}}^{AP_k}]$$

- Determination of corrections $\vec{r}_{corr}(t)$ for a certain time epoch:

$$\vec{r}_{corr}(t) = \vec{r}_{\overline{lt}}(t) - \hat{\vec{r}}$$

$\vec{r}_{\overline{lt}}(t)$ is the average of long-time measurements for a certain time epoch t

DAI Method (2)

$$\vec{r}_{imp}(t) = \vec{r}(t) + \vec{r}_{corr}(t)$$

improved fingerprint

to be improved fingerprint

- Reduction of signal variations
- No approximated position necessary

Average of long-time measurements of one day

$$\hat{\vec{r}} = [\widehat{RSS}^{AP_1}, \widehat{RSS}^{AP_2}, \ldots, \widehat{\mathrm{RSS}}^{AP_k}]$$

Calculation of mean RSS $\vec{r}_{\overline{lt}}(t)$ for a certain epoch t

Calculation of RSS corrections for a certain epoch t

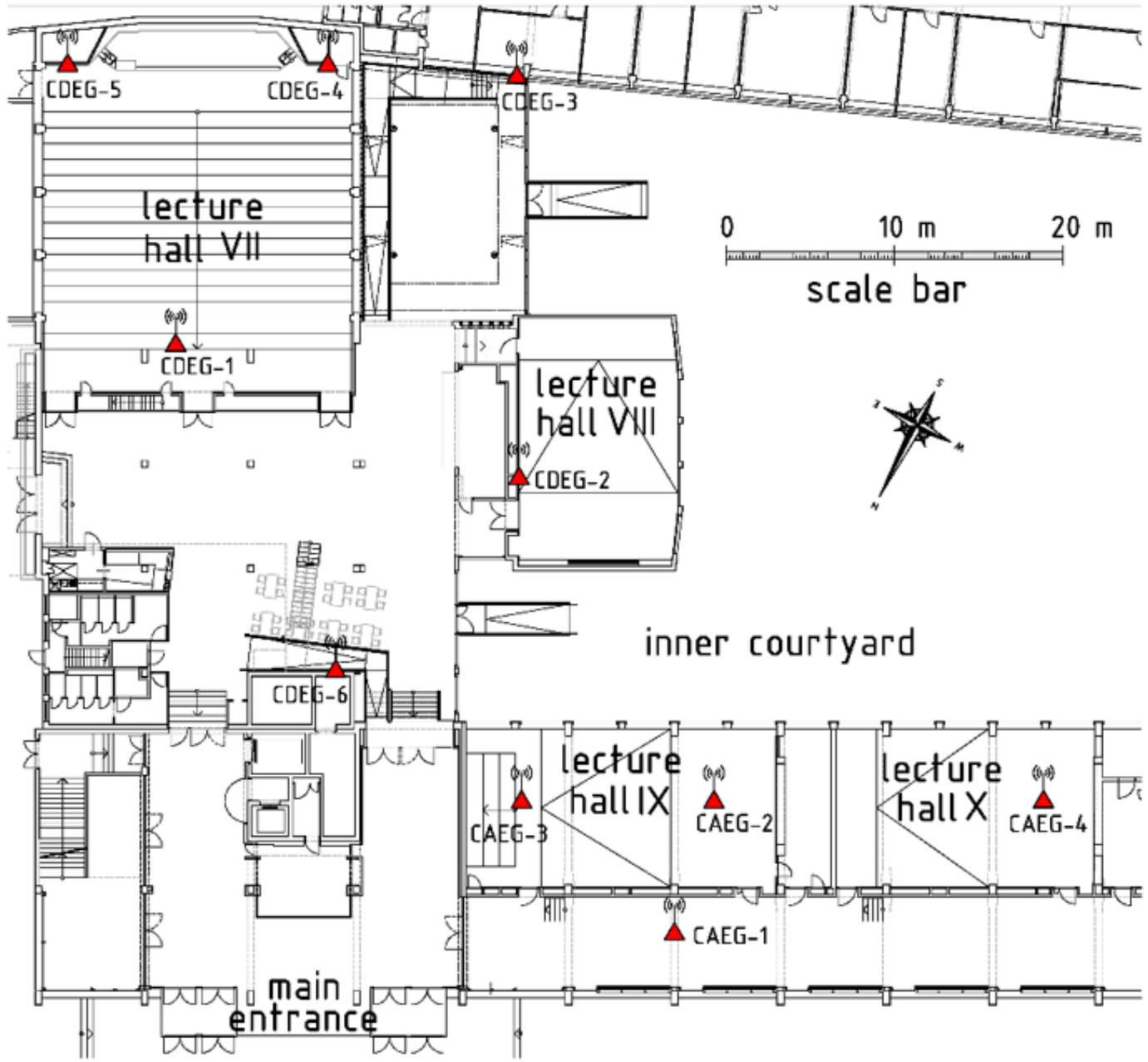
$$\vec{r}_{corr}(t) = \vec{r}_{\overline{lt}}(t) - \hat{\vec{r}}$$

Improved RSS fingerprint

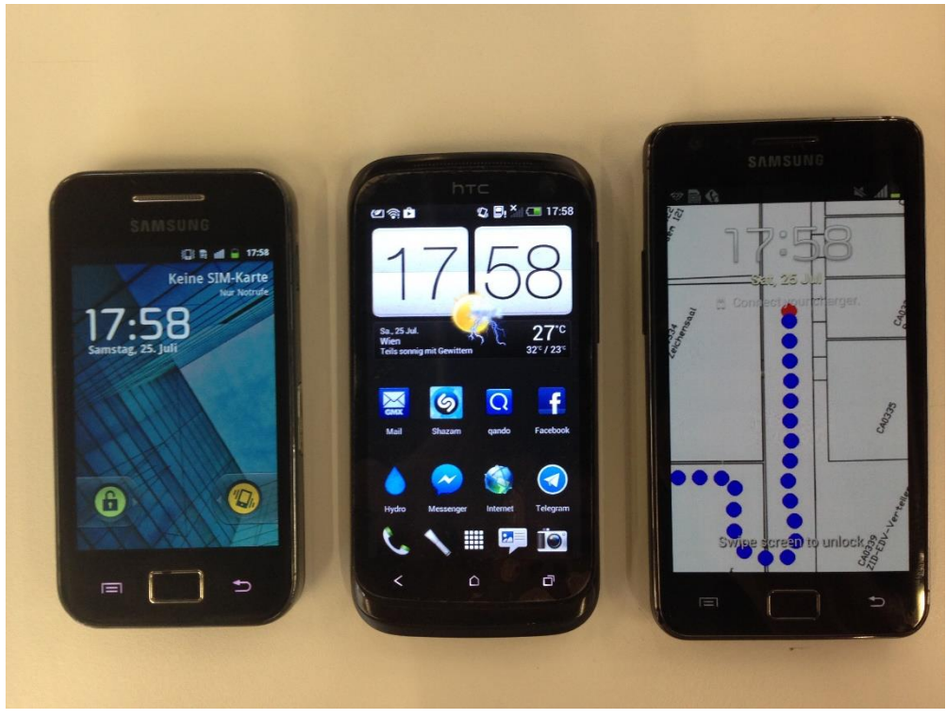
$$\vec{r}_{imp}(t) = \vec{r}(t) + \vec{r}_{corr}(t)$$

Experiments

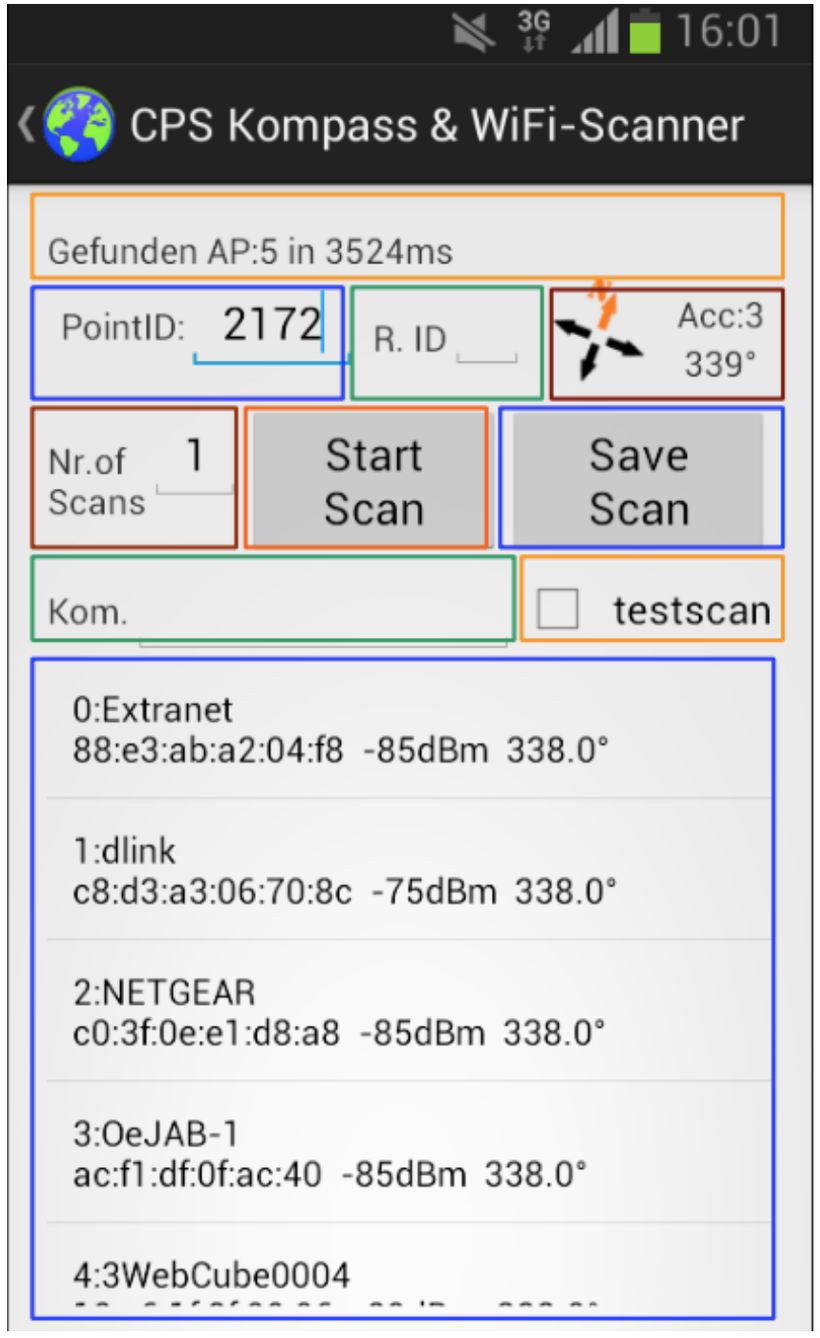
- 93 grid reference points
- 4 orientations

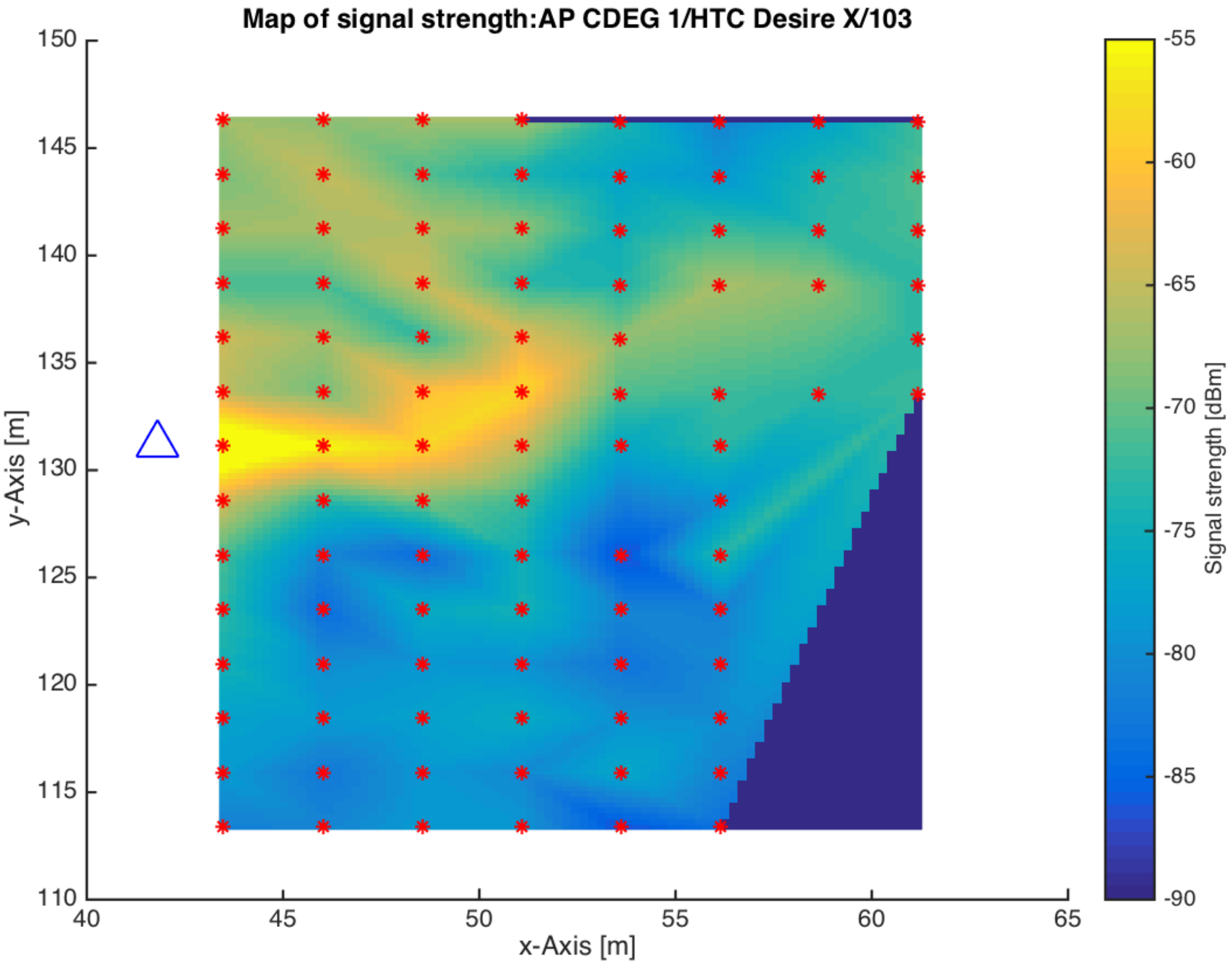


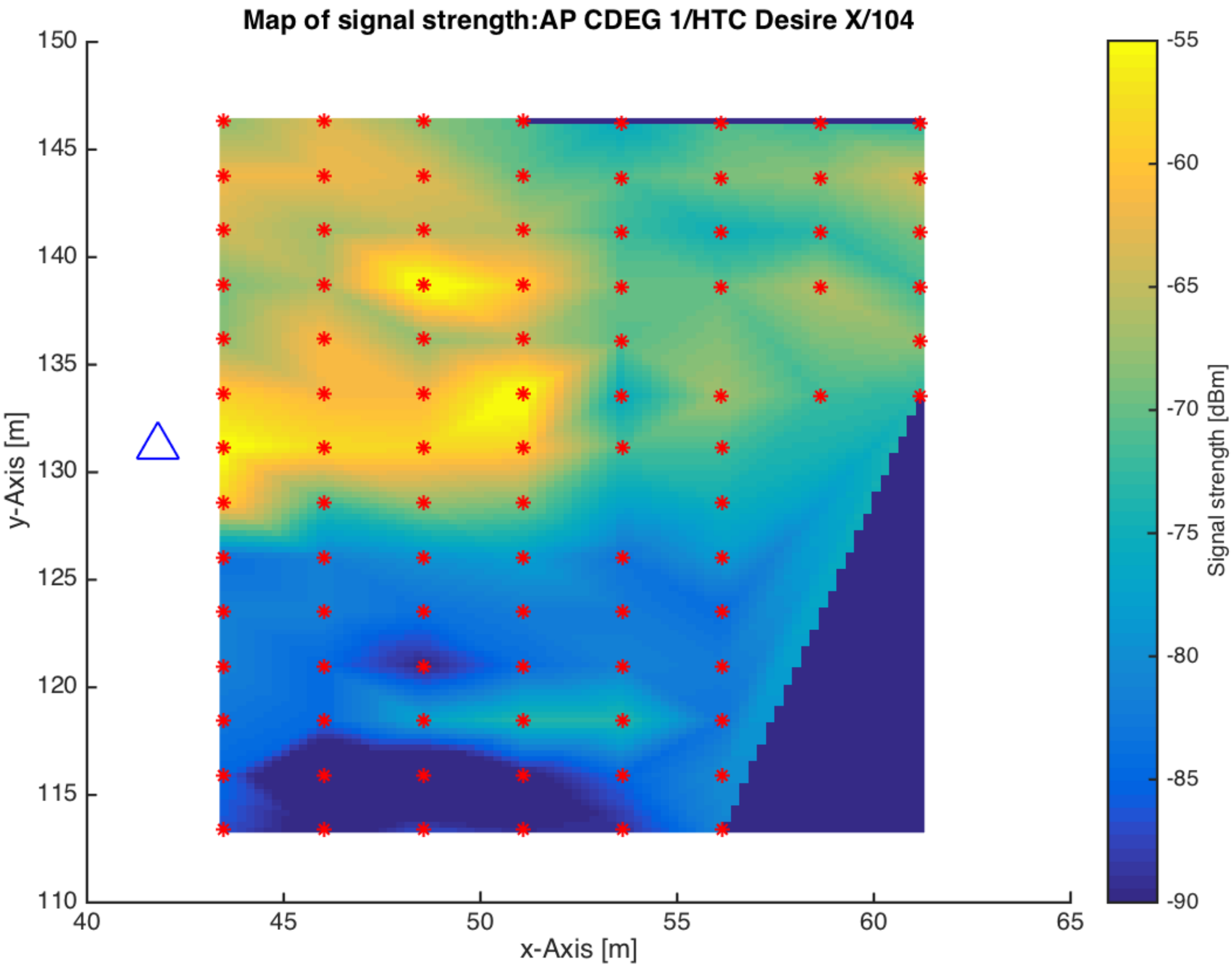
Equipment


SAMSUNG
Keine SIM-Karte
17:58
Samstag, 25. Juli
htc
17:58
17 58
Mail
Shazam
qando
Facebook
Hydro
Messenger
Internet
Telegram
SAMSUNG
17:58
Swipe screen to unlock


HDMI
EDAC


16:01
CPS Kompass & WiFi-Scanner
Gefunden AP:5 in 3524ms
PointID: 2172
R. ID
Acc:3
339°
Nr.of Scans 1
Start Scan
Save Scan
Kom.
testscan
0:Extranet
88:e3:ab:a2:04:f8 -85dBm 338.0°
1:dlink
c8:d3:a3:06:70:8c -75dBm 338.0°
2:NETGEAR
c0:3f:0e:e1:d8:a8 -85dBm 338.0°
3:OeJAB-1
ac:f1:df:0f:ac:40 -85dBm 338.0°
4:3WebCube0004


Map of signal strength:AP CDEG 1/HTC Desire X/103
150
145
140
135
130
125
120
115
110
y-Axis [m]
40
45
50
55
60
65
x-Axis [m]
-55
-60
-65
-70
-75
-80
-85
-90
Signal strength [dBm]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150
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110
y-Axis [m]
40
45
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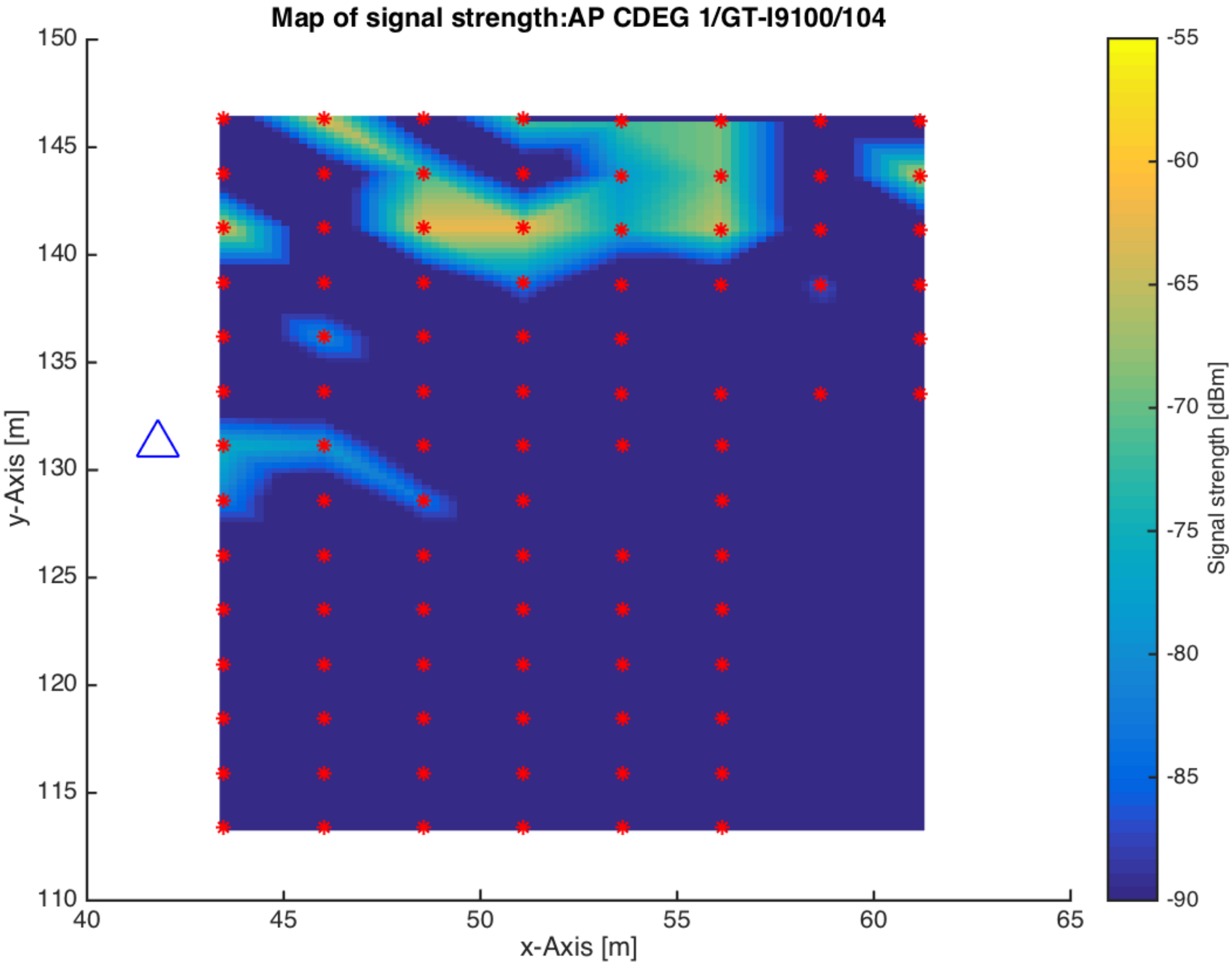
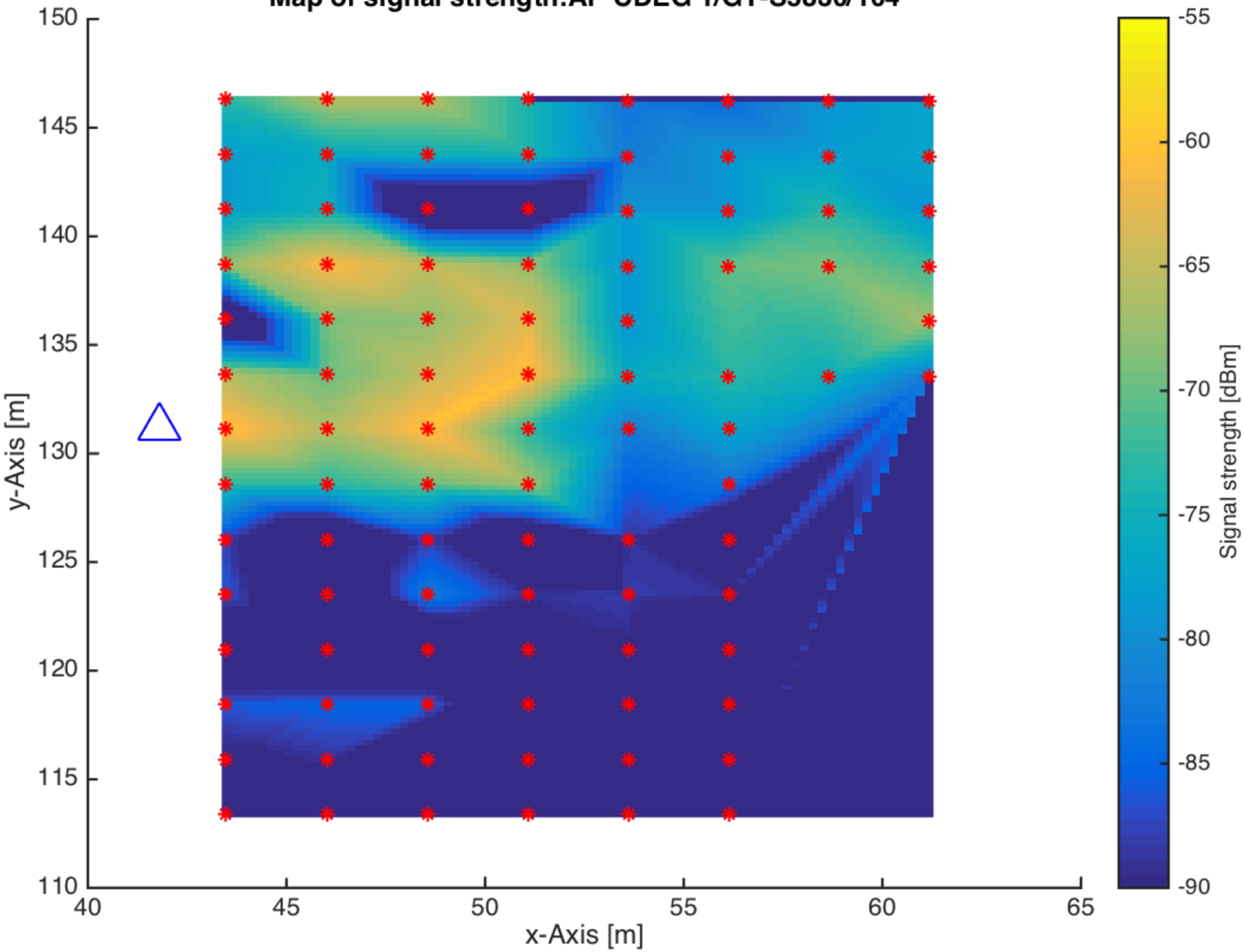
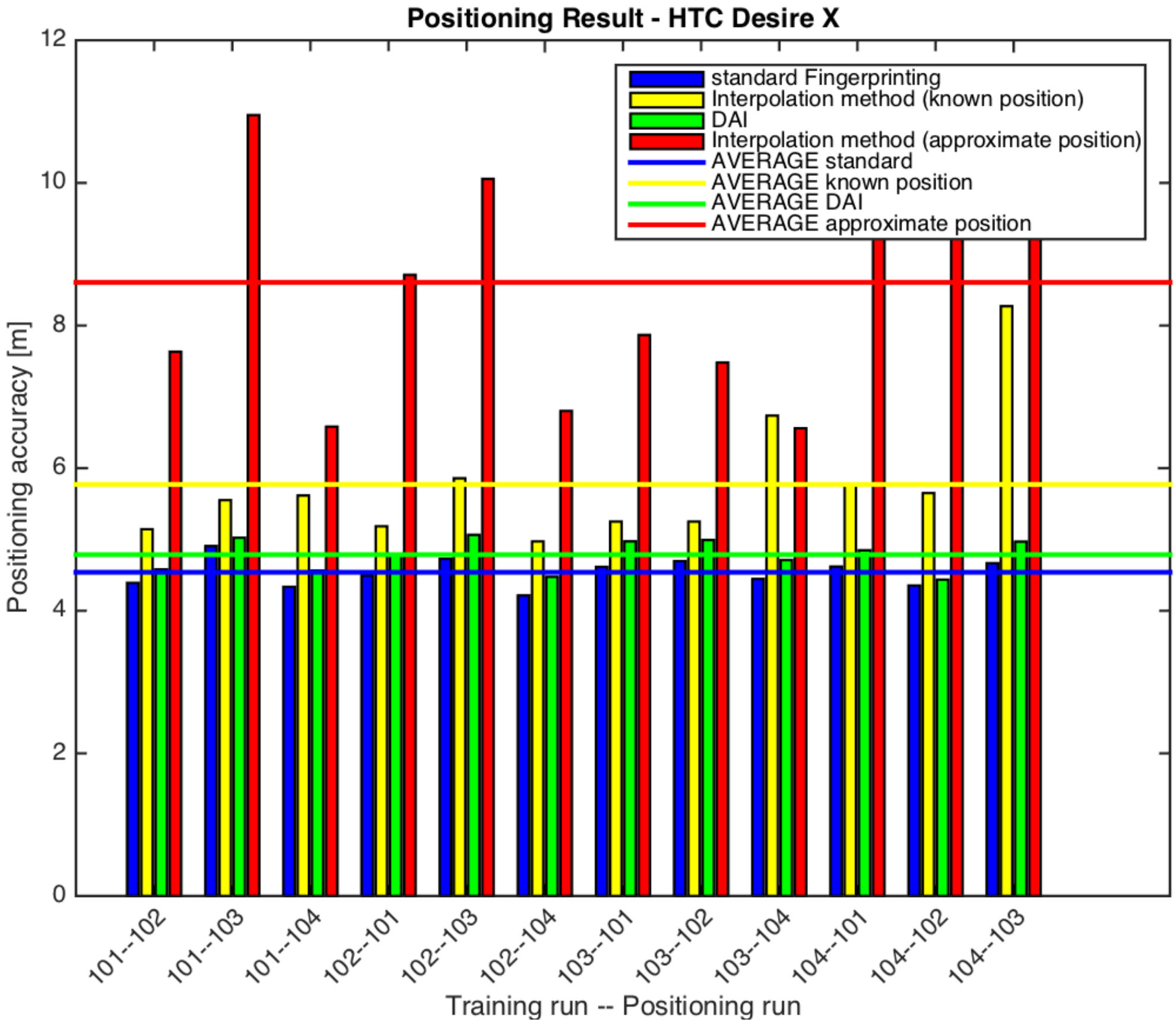
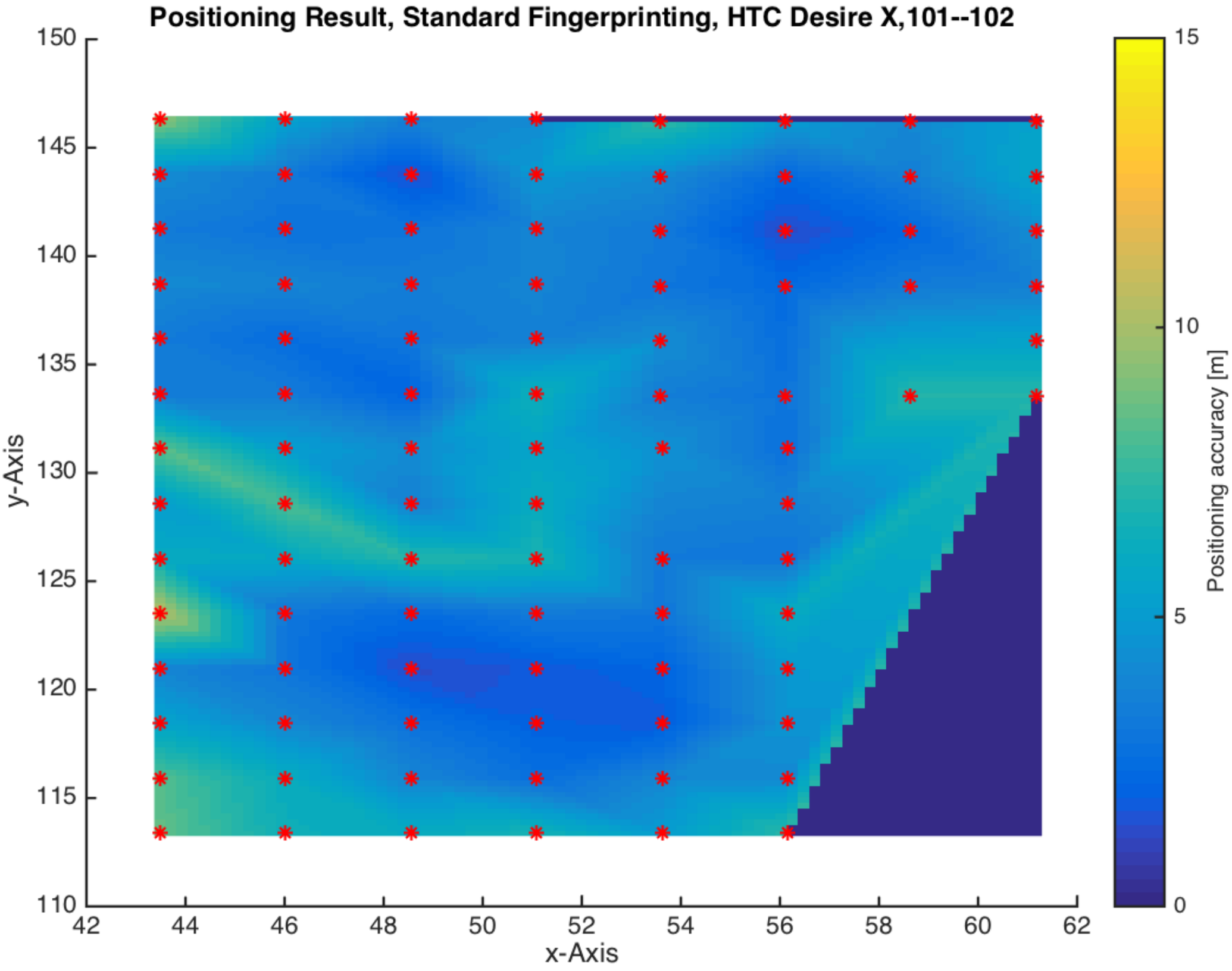
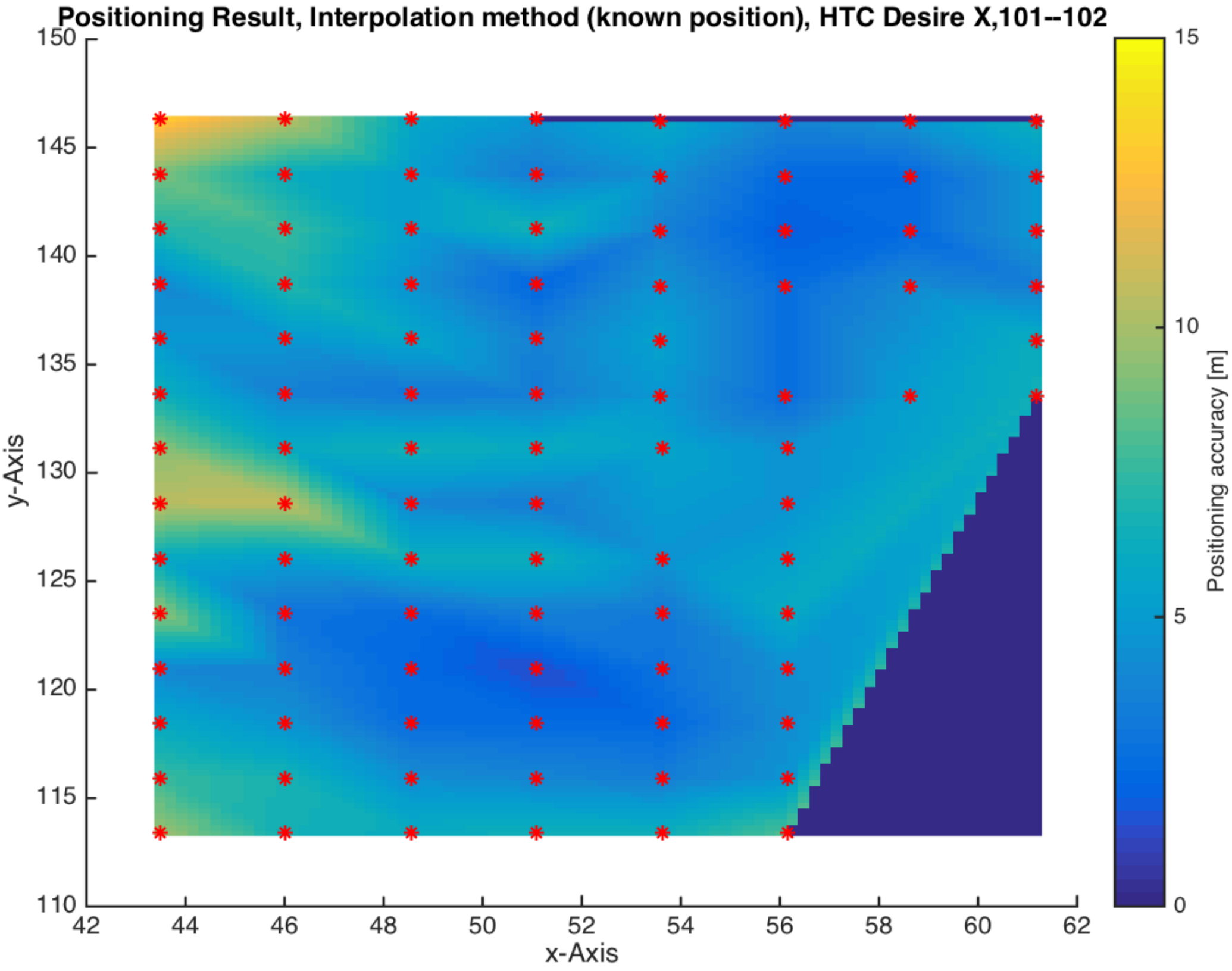
55
60
65
x-Axis [m]
-55
-60
-65
-70
-75
-80
-85
-90
Signal strength [dBm]

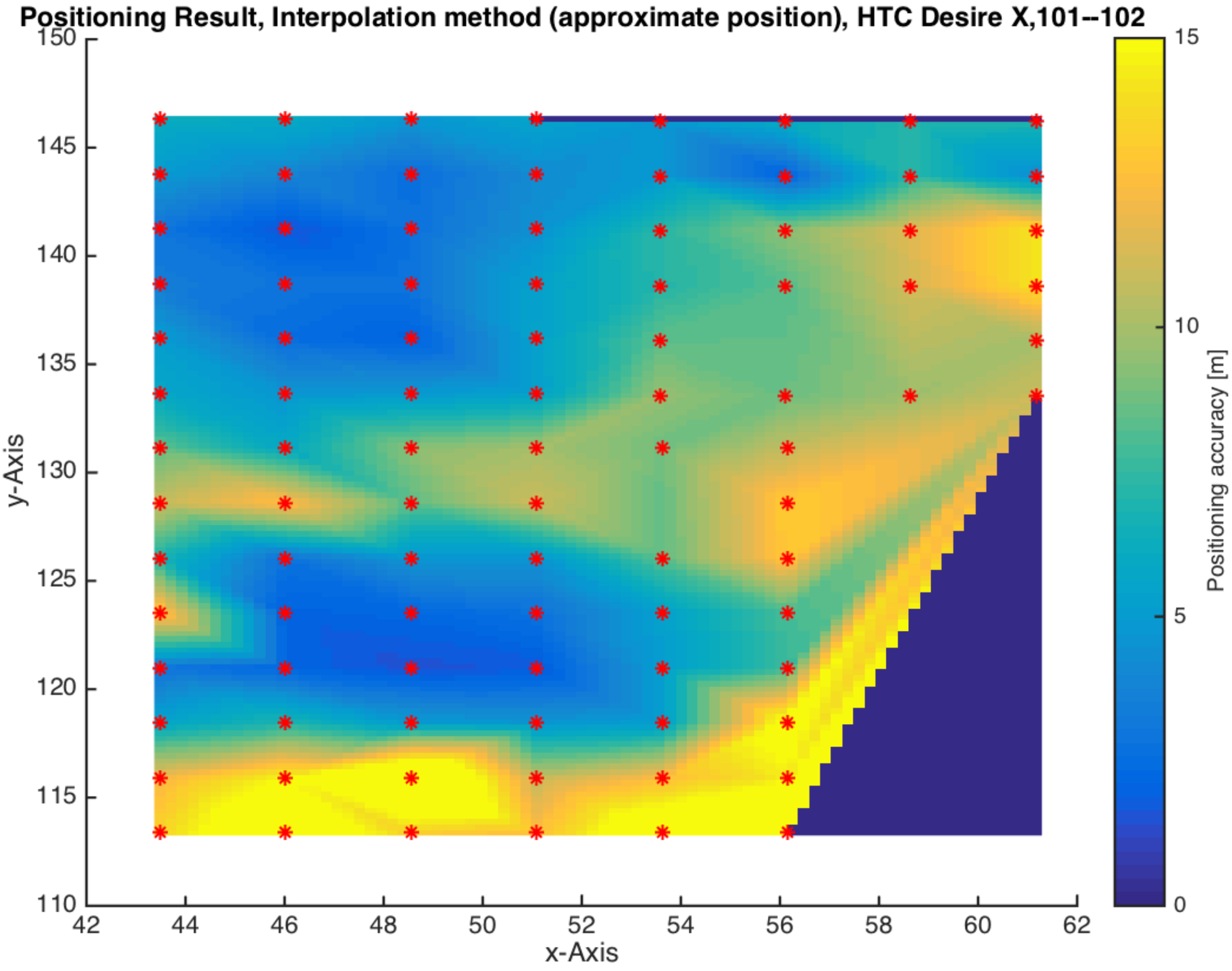

Map of signal strength:AP CDEG 1/GT-I9100/104
150
145
140
135
130
125
120
115
110
y-Axis [m]
40
45
50
55
60
65
x-Axis [m]
-55
-60
-65
-70
-75
-80
-85
-90
Signal strength [dBm]

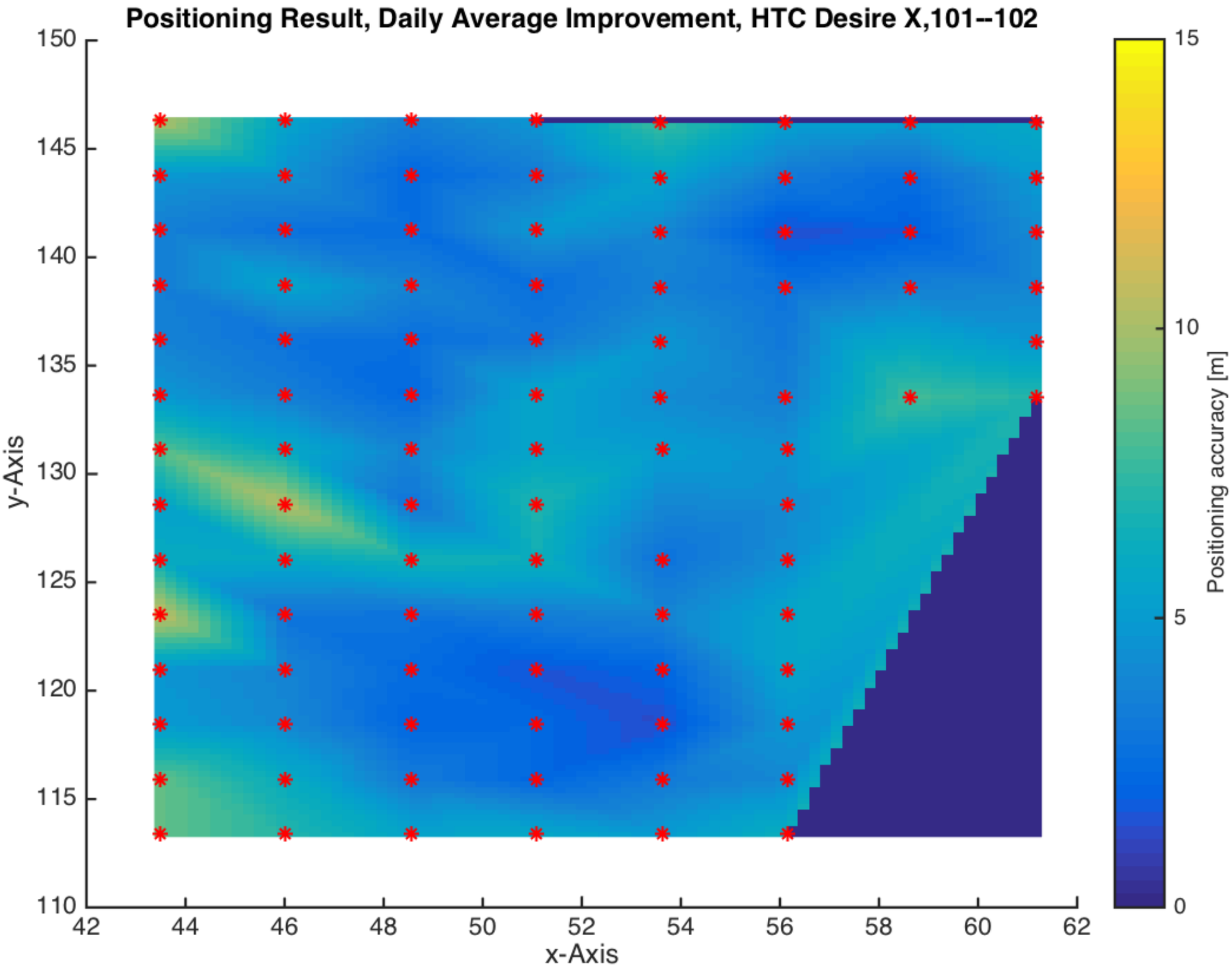

Map of signal strength:AP CDEG 1/GT-S5830/104
150
145
140
135
130
125
120
115
110
y-Axis [m]
40
45
50
55
60
65
x-Axis [m]
-55
-60
-65
-70
-75
-80
-85
-90
Signal strength [dBm]


Positioning Result - HTC Desire X
standard Fingerprinting
Interpolation method (known position)
DAI
Interpolation method (approximate position)
AVERAGE standard
AVERAGE known position
AVERAGE DAI
AVERAGE approximate position
Positioning accuracy [m]
0
2
4
6
8
10
12
101--102
101--103
101--104
102--101
102--103
102--104
103--101
103--102
103--104
104--101
104--102
104--103
Training run -- Positioning run


Positioning Result, Standard Fingerprinting, HTC Desire X,101--102
150
145
140
135
130
125
120
115
110
y-Axis
42
44
46
48
50
52
54
56
58
60
62
x-Axis
15
10
5
0
Positioning accuracy [m]


Positioning Result, Interpolation method (known position), HTC Desire X,101--102
150
145
140
135
130
125
120
115
110
y-Axis
42
44
46
48
50
52
54
56
58
60
62
x-Axis
15
10
5
0
Positioning accuracy [m]

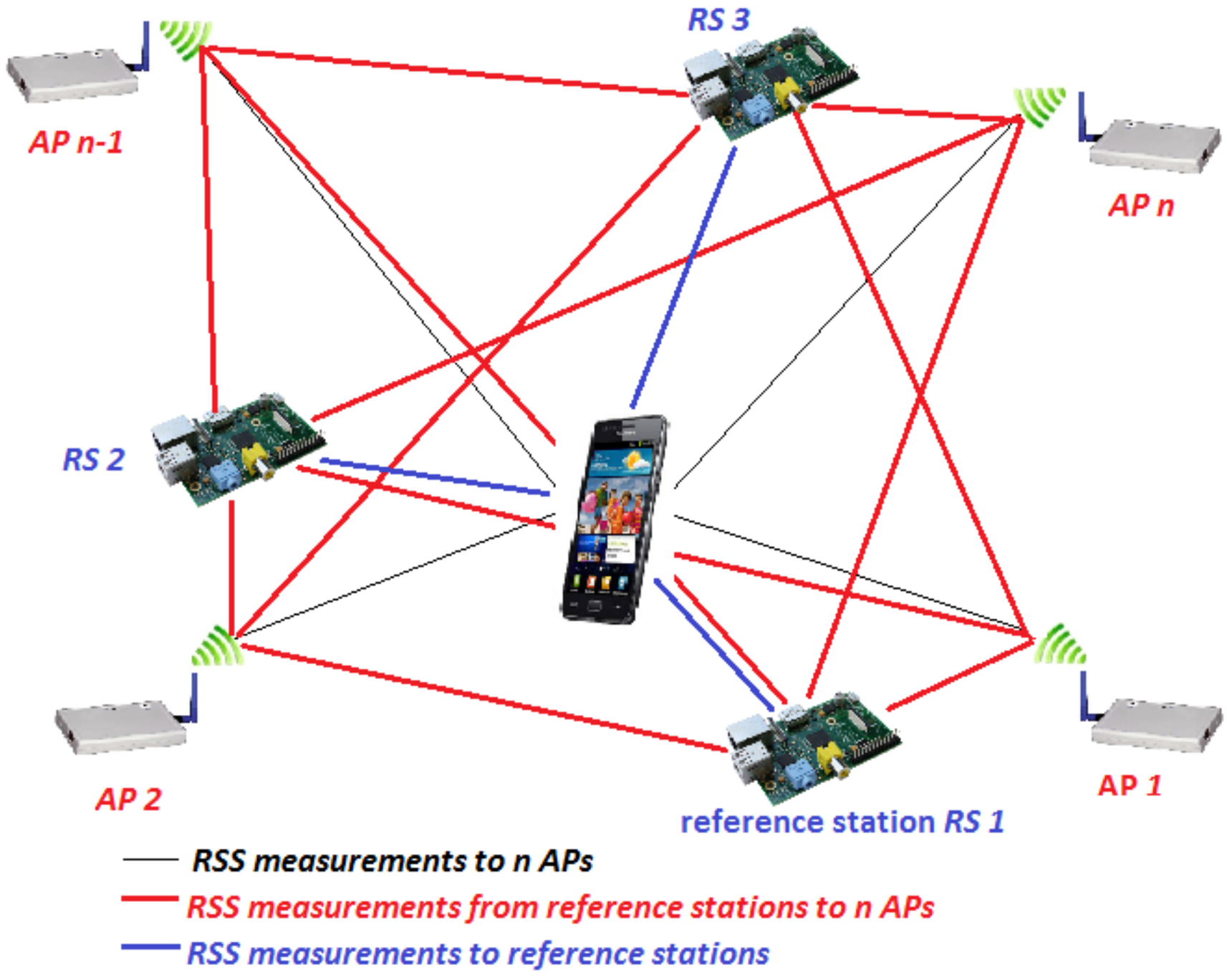

Positioning Result, Interpolation method (approximate position), HTC Desire X,101--102
y-Axis
x-Axis
Positioning accuracy [m]
150
145
140
135
130
125
120
115
110
42
44
46
48
50
52
54
56
58
60
62
15
10
5
0


Positioning Result, Daily Average Improvement, HTC Desire X,101--102
150
145
140
135
130
125
120
115
110
y-Axis
42
44
46
48
50
52
54
56
58
60
62
x-Axis
15
10
5
0
Positioning accuracy [m]

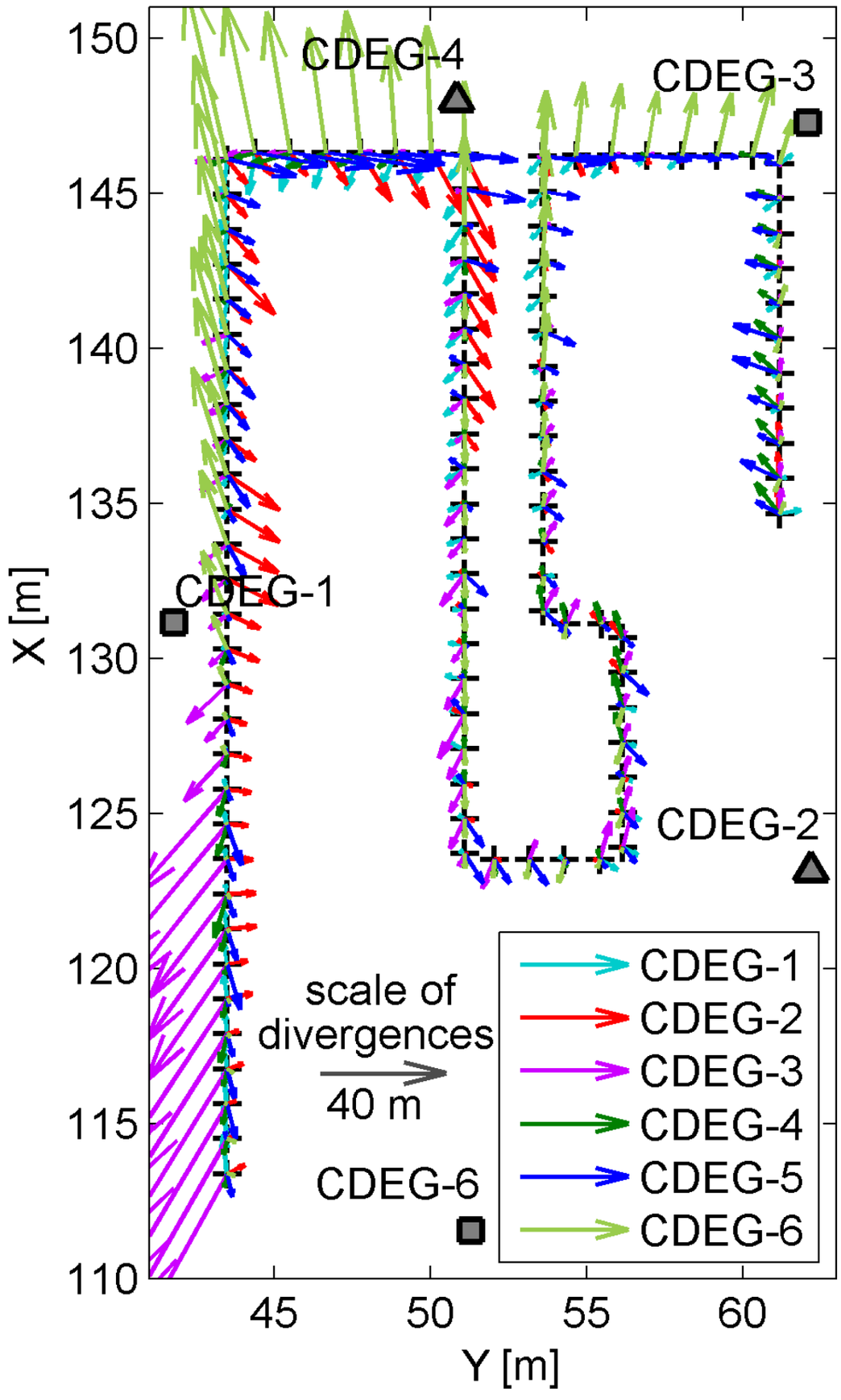
Result Interpretation

- No significant differences on average
- DAI method shows best performance
- Approximated position requirement for interpolation reduces positioning accuracies
- Largest deviations outside the triangle of reference stations and at peripheral areas
- Smartphone dependance

Differential Wi-Fi



DWi-Fi Kinematic Positioning Result



Future Work

- Improved approximate position determination using dead reckoning with inertial smartphone sensors
- Better location and adding of more Raspberry Pi‘s covering the whole area of interest
- Improvement of time synchronistation
- Change of time interval for averaging in DAI method depending on the environmental conditions and occuring RSS fluctuations of certain APs
- Radio maps for each smartphone and their combination
- Investigation if reference station observations lead to an improvement if time interval between training and positioning phase is longer

Concluding Remarks

- Current set-up showed only slightly performance improvement in a few situations
- Suggestions for improvement in future research have been derived
- Differential Wi-Fi positioning is promising technology and approach
- Real-time derivation of dynamical radio maps
- Combination of fingerprinting and trilateration