



IWATE UNIVERSITY
JAPAN

Indoor-Positioning Using RSSI: DOD-Based Technique Versus RSSI-Ranging Technique



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Contents

- Background
 - Indoor positioning techniques relying on RSSI
- Simulation: comparison study
 - RSSI-ranging versus DOD-triangulation
- Experiment: performance evaluation
 - Positioning accuracy of DOD-triangulation
 - Hybrid technique: DOD + PDR
- Conclusion



Background

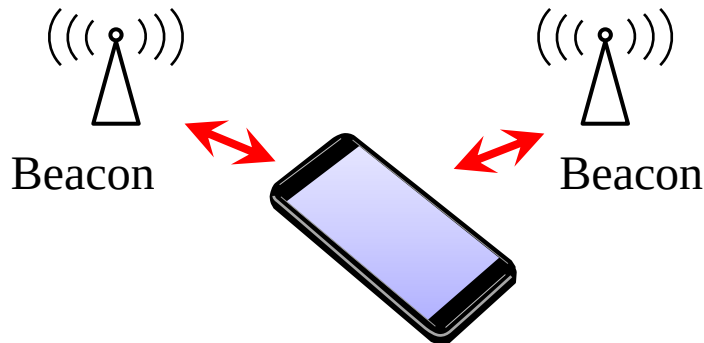
■ Why Indoor Positioning?

□ GNSS

Satellite signal is not available in an indoor environment

□ Indoor positioning system using beacons

COTS (Commercial-Off-The-Shelf) devices → Accurate?

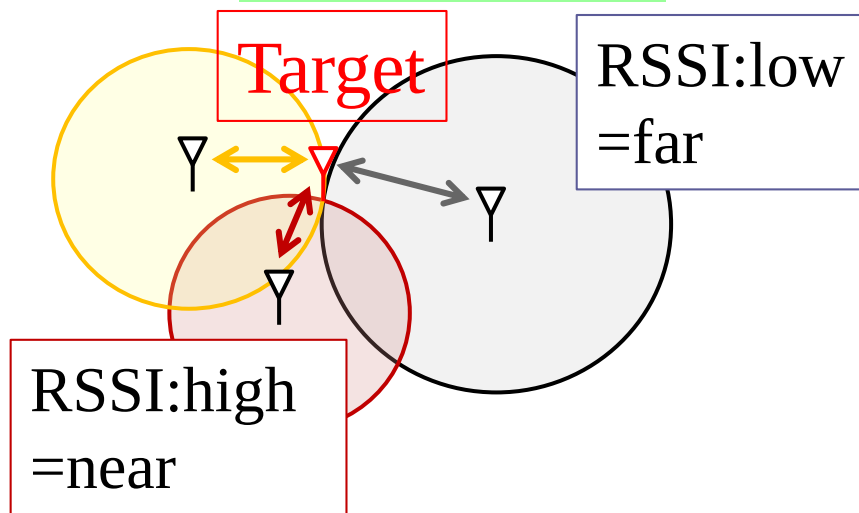


Accurate positioning is a key challenge now

Well-known Positioning Techniques

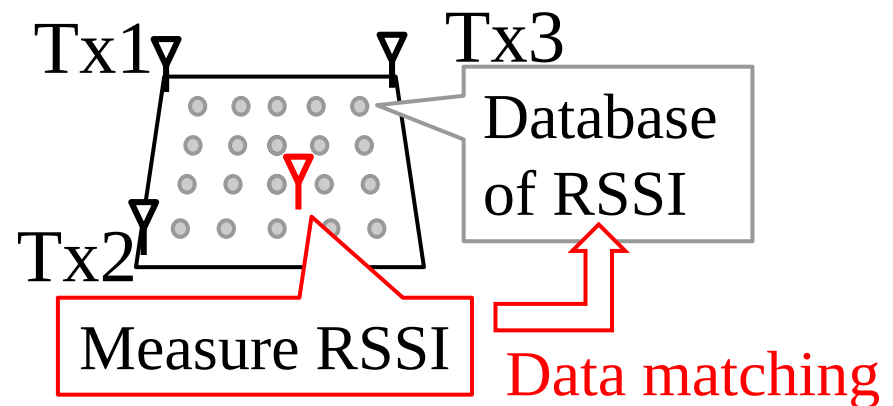


RSSI*-ranging



⊗ Poor accuracy for distant target due to multipath

Fingerprinting



- ⊗ In need of prior-measurement of RSSI distribution
- ⊗ Database susceptible to environmental change

Another approach ?

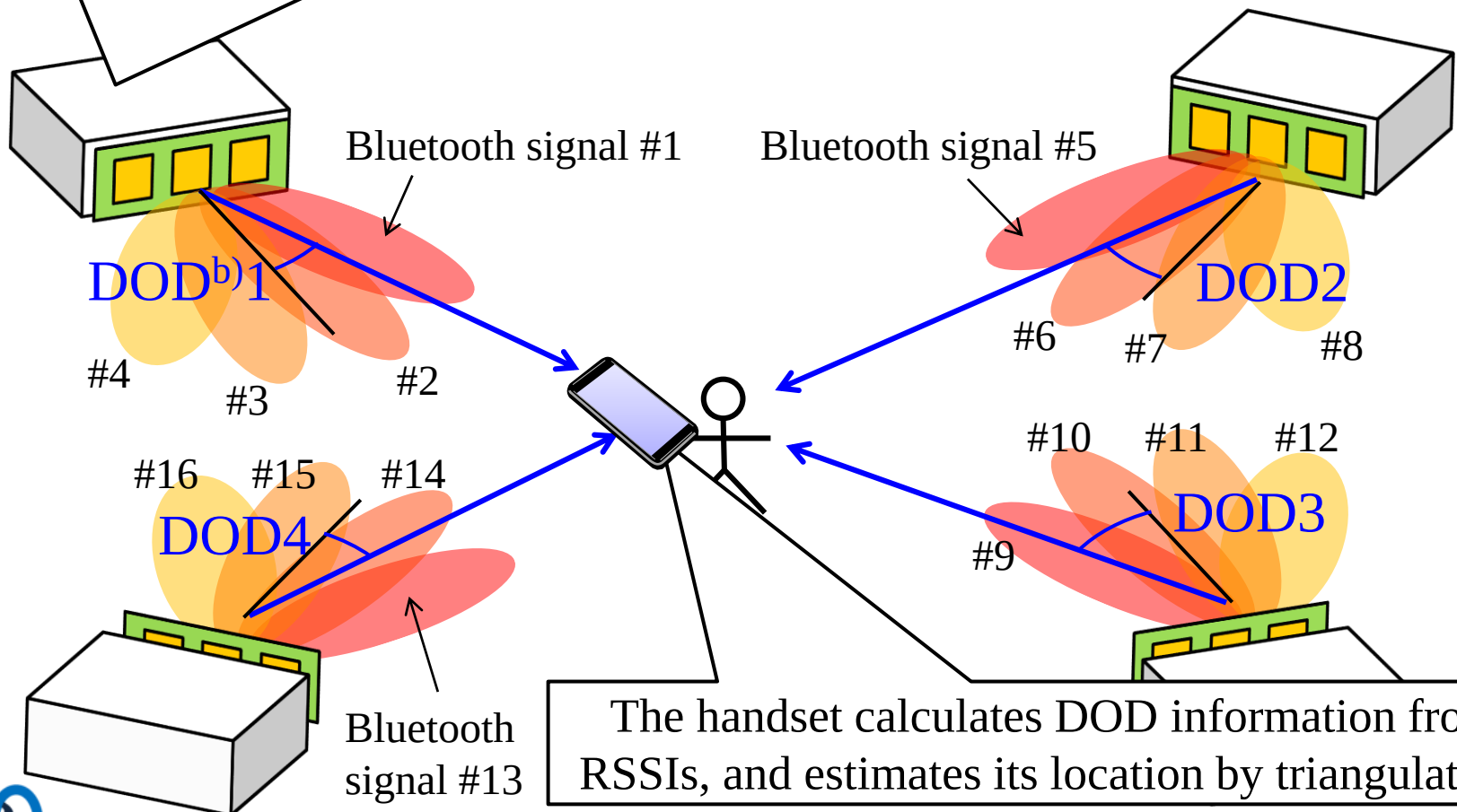
*RSSI: Received Signal Strength Indicator

BLEGONIO: DOD-Based Positioning



Each beacon transmits four BLE^{a)} signals using four different directivities.

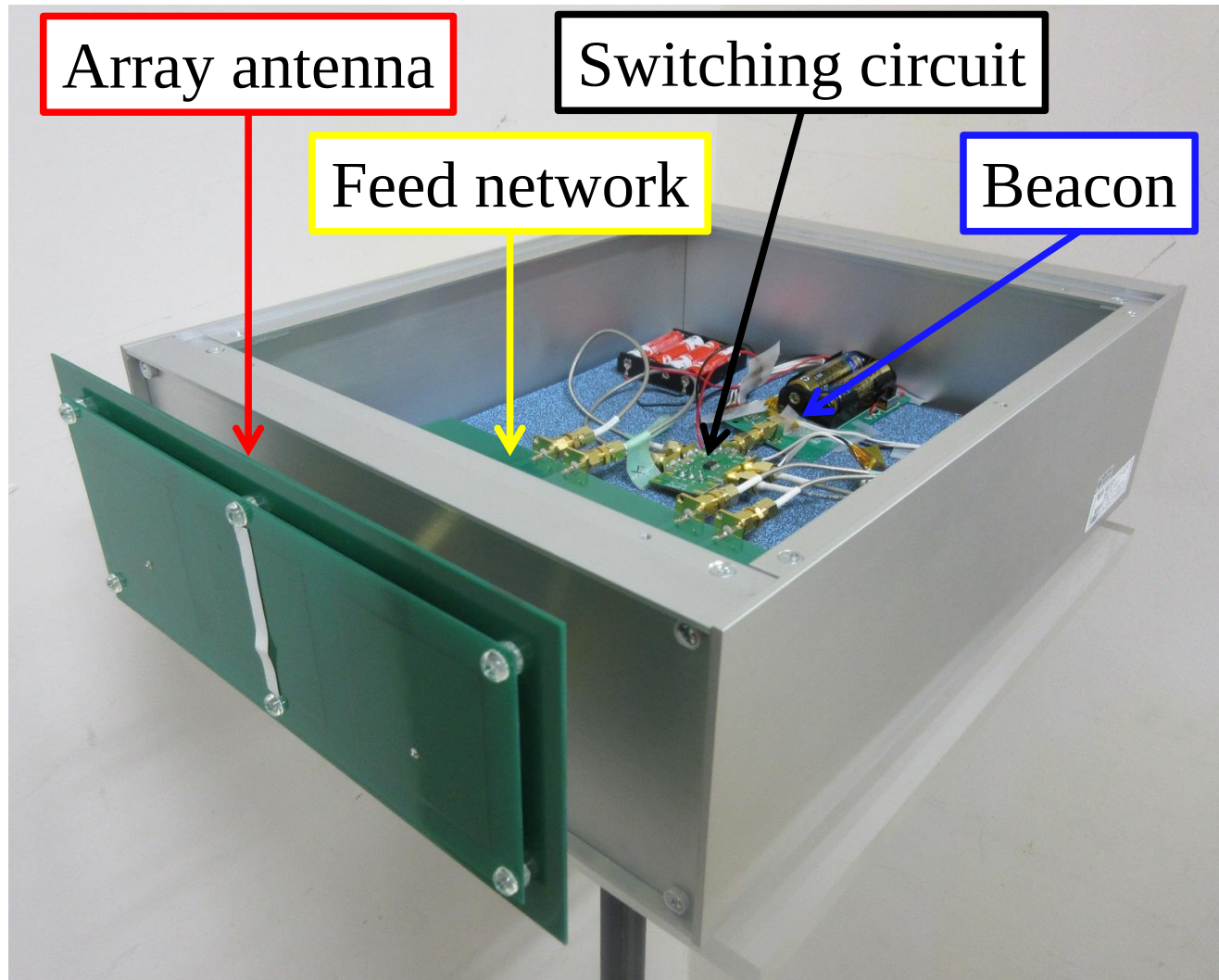
a) BLE: Bluetooth Low Energy
b) DOD: Direction of Departure



The handset calculates DOD information from RSSIs, and estimates its location by triangulation.



Developed Beacon Overview



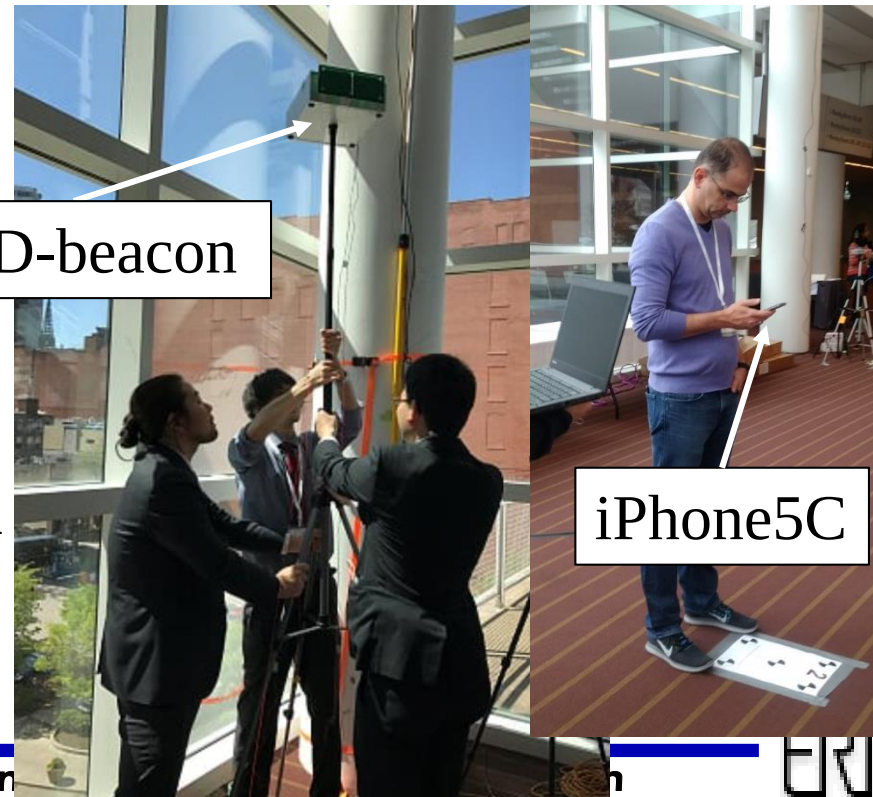
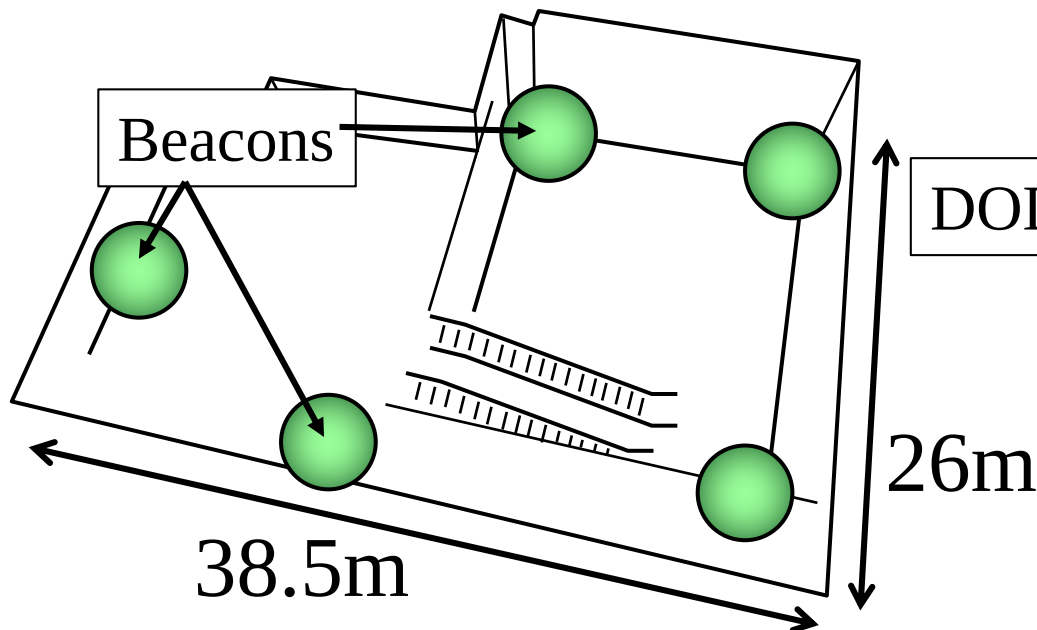


Microsoft Competition @ IPSN2017

IPSN 2017

The 16th ACM/IEEE International Conference on Information Processing in Sensor Networks
April 18-21, 2017
Pittsburgh, Pennsylvania, USA

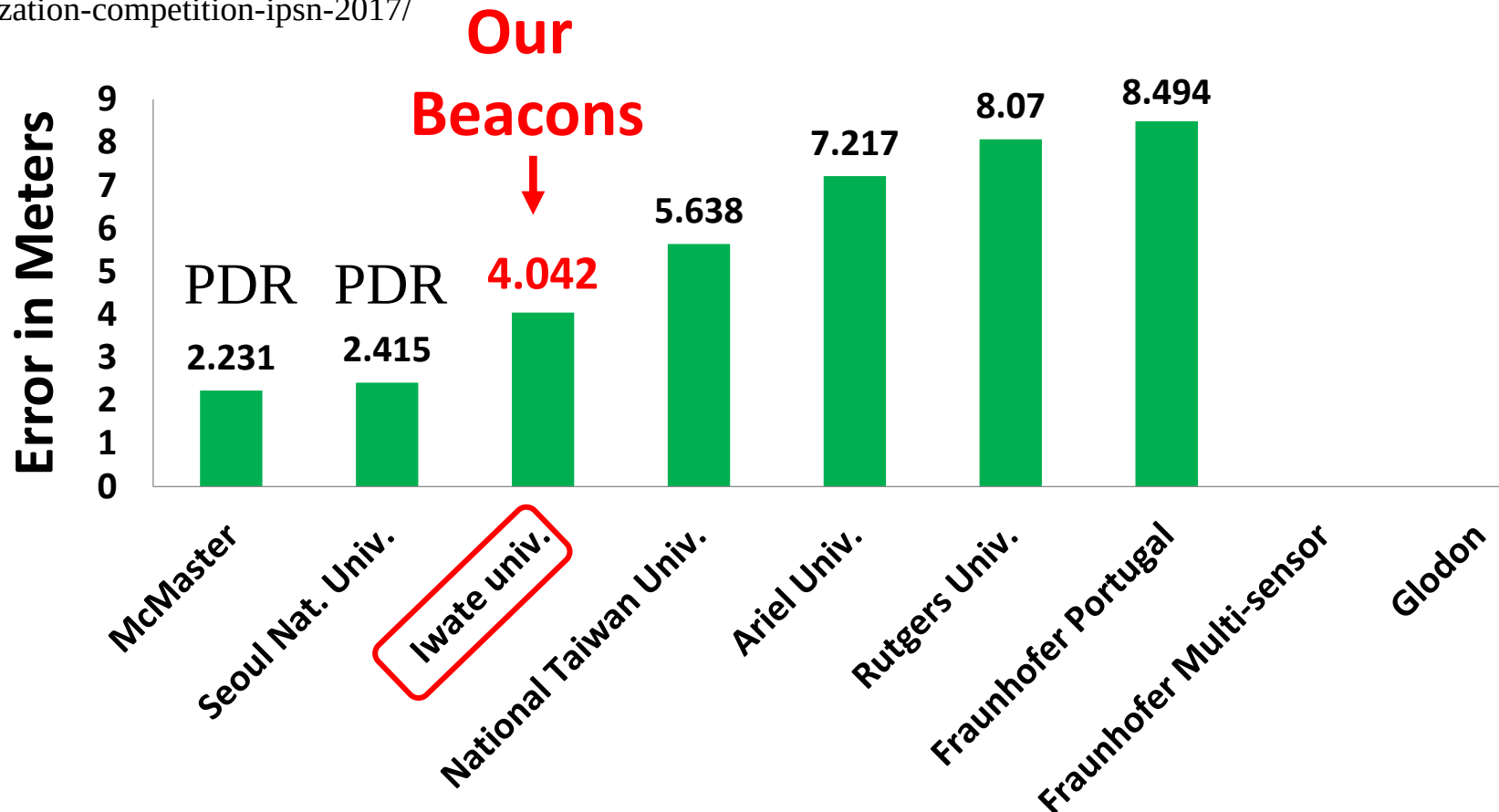
Two-floor site



Microsoft Competition @ IPSN2017

■ Results (2D-category)

<https://www.microsoft.com/en-us/research/event/microsoft-indoor-localization-competition-ipsn-2017/>



We got the best record in the radio-wave category



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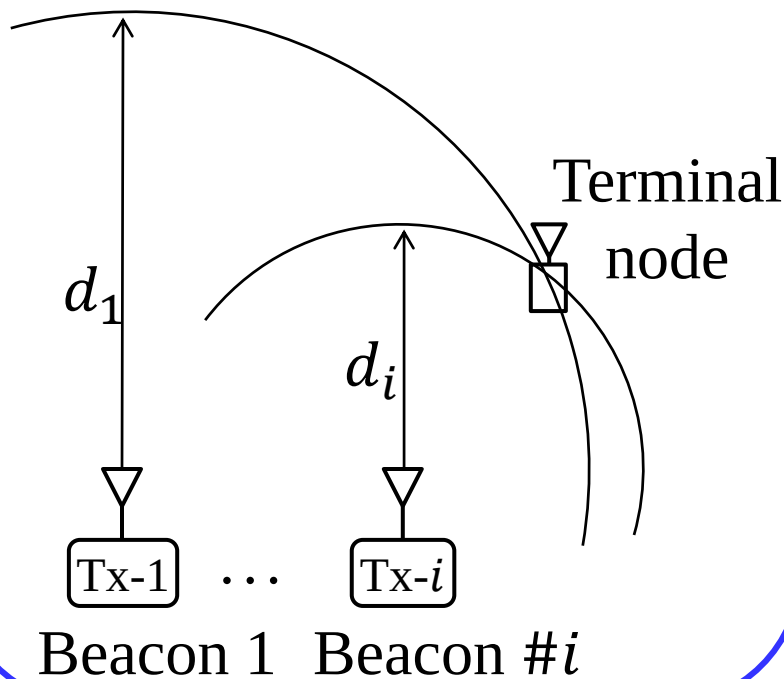
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- Hybrid technique: DOD + PDR

■ Conclusion

Question: which is better?

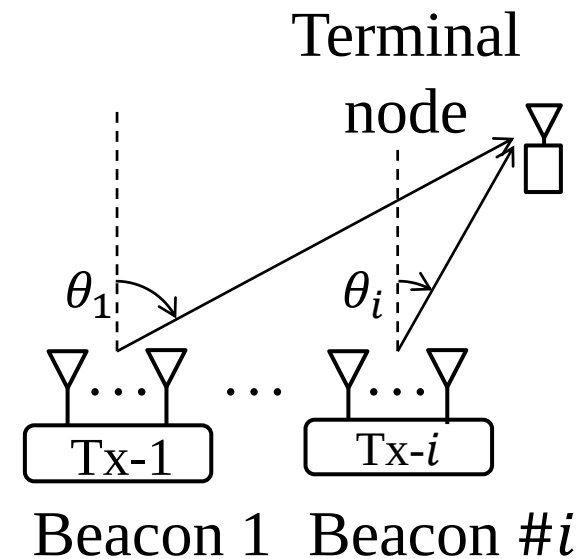


RSSI-Ranging



VS.

DOD Triangulation



☹ Multipath-fadings

☹ DOD-accuracy?

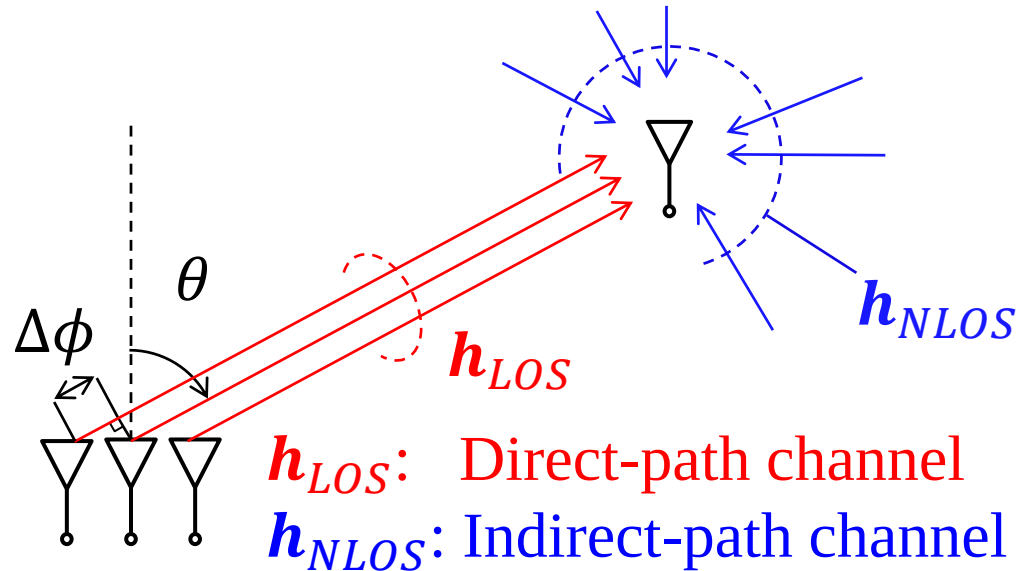
No one has compared them using fair conditions.



Simulation model

■ Rician-fading model

$$k\text{-factor} = \frac{\|\mathbf{h}_{LOS}\|_F^2}{\|\mathbf{h}_{NLOS}\|_F^2}$$



■ Generating channel

$$\text{Channel matrix: } \mathbf{h} = \underline{\mathbf{h}_{LOS}} + \underline{\mathbf{h}_{NLOS}}$$

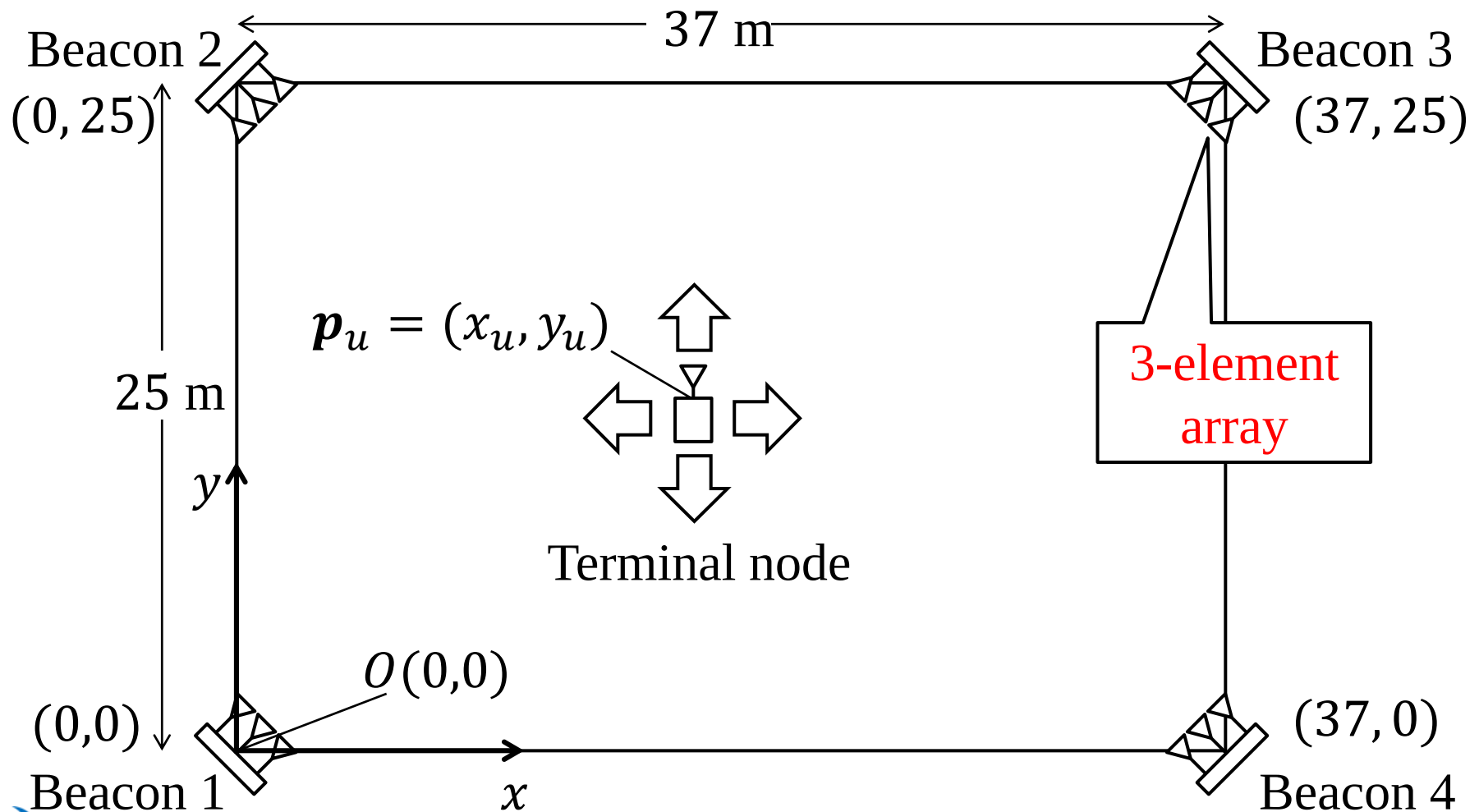
Geometric-optics
approach

Zero-mean gaussian
random matrix



Simulation model

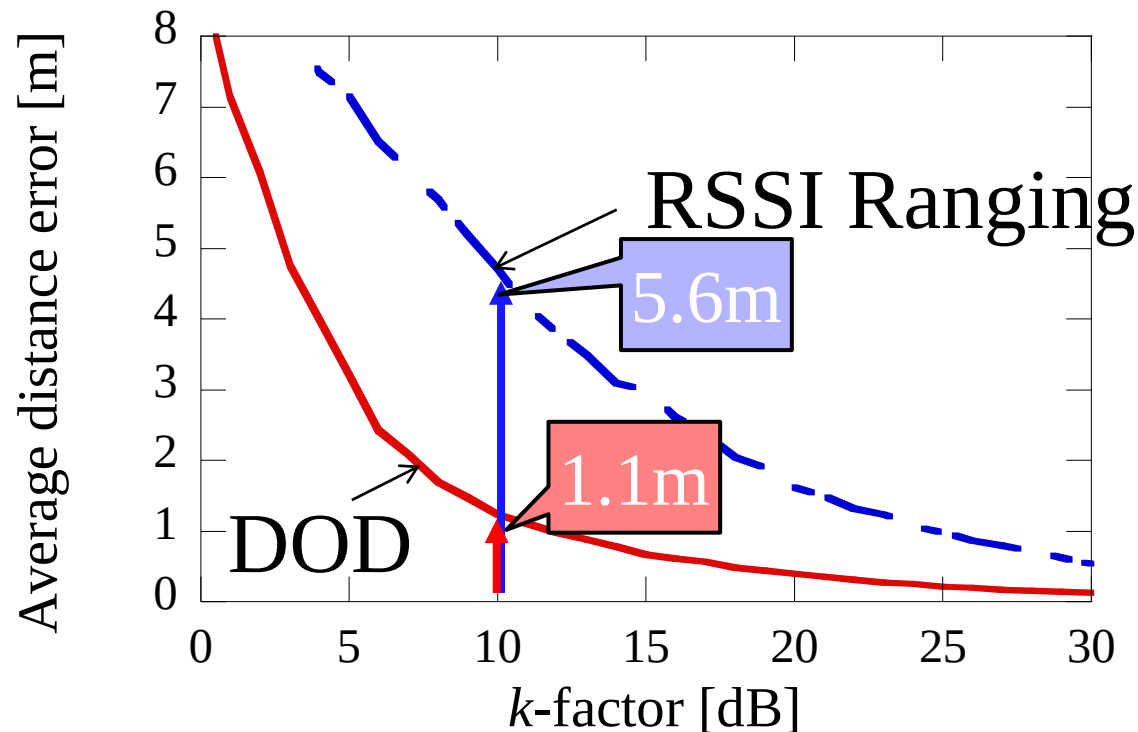
■ Environment





Results

■ RSSI-ranging versus DOD-triangulation



DOD-triangulation yields 5-times better accuracy



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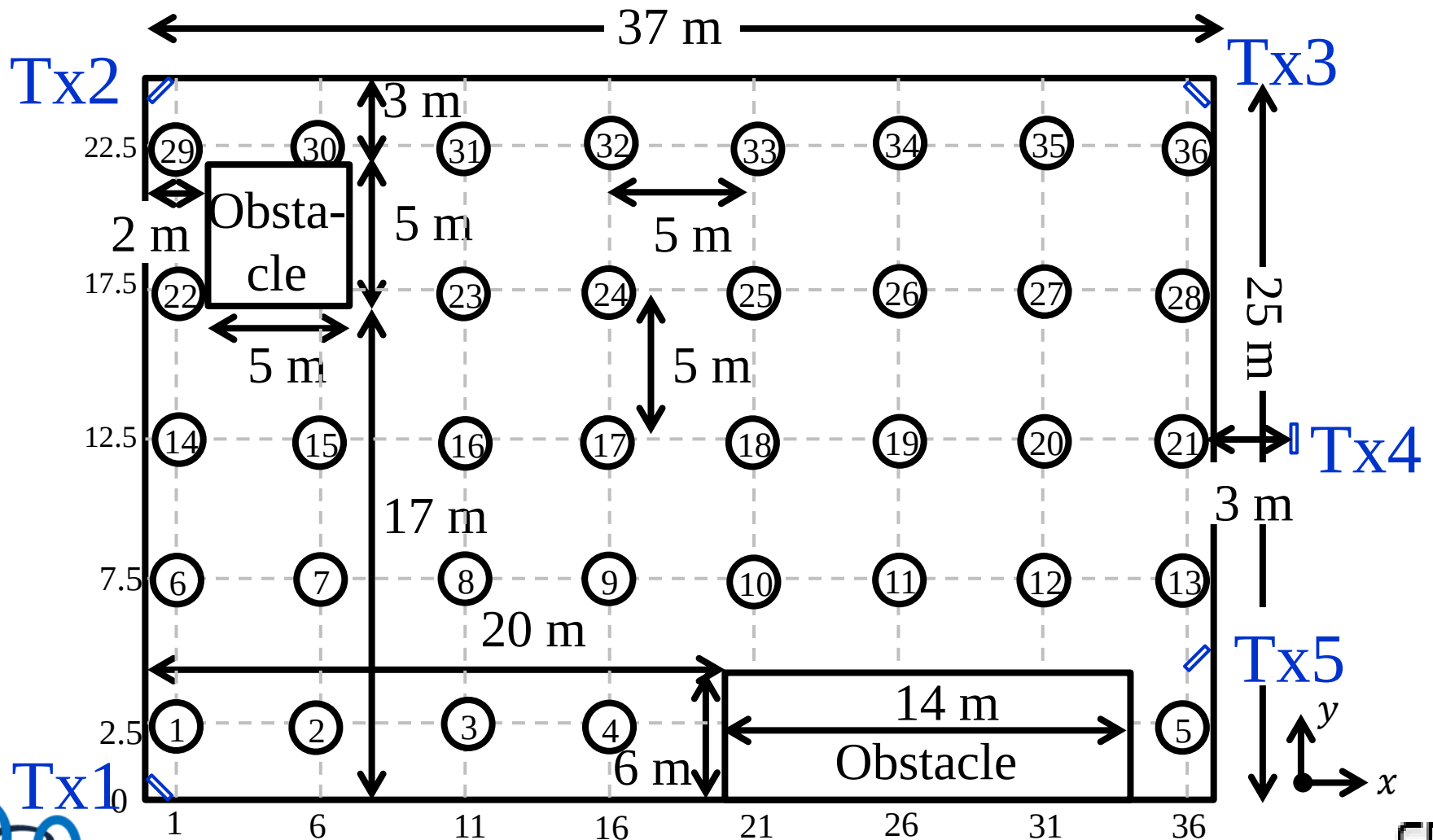
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■ Conclusion



Experiment

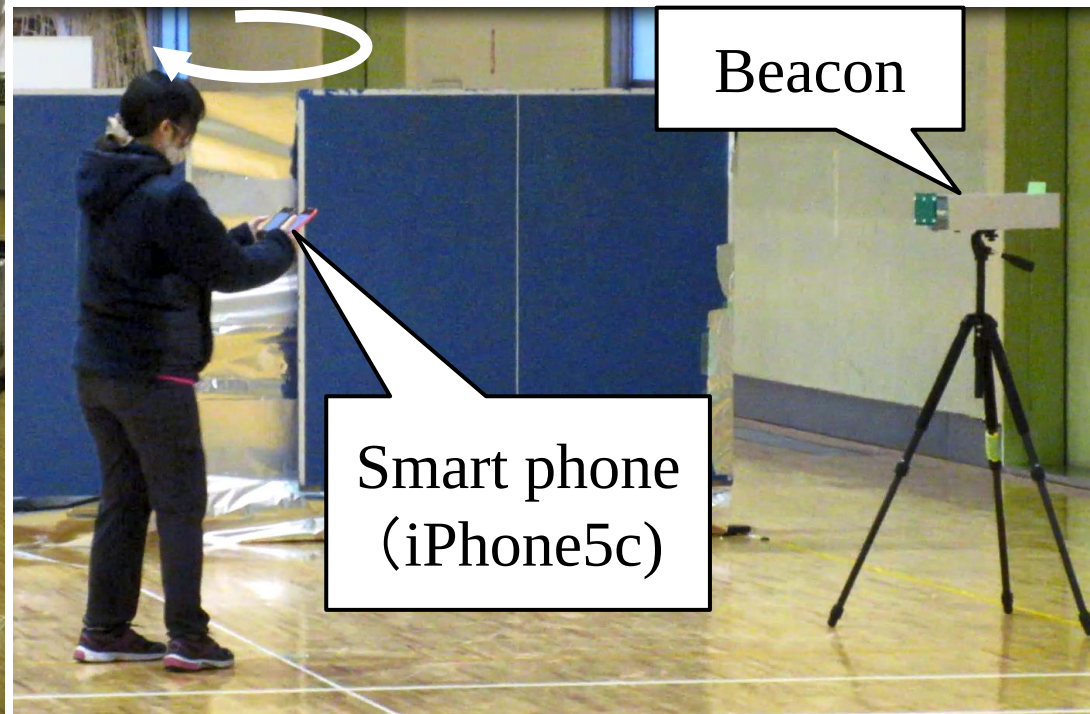
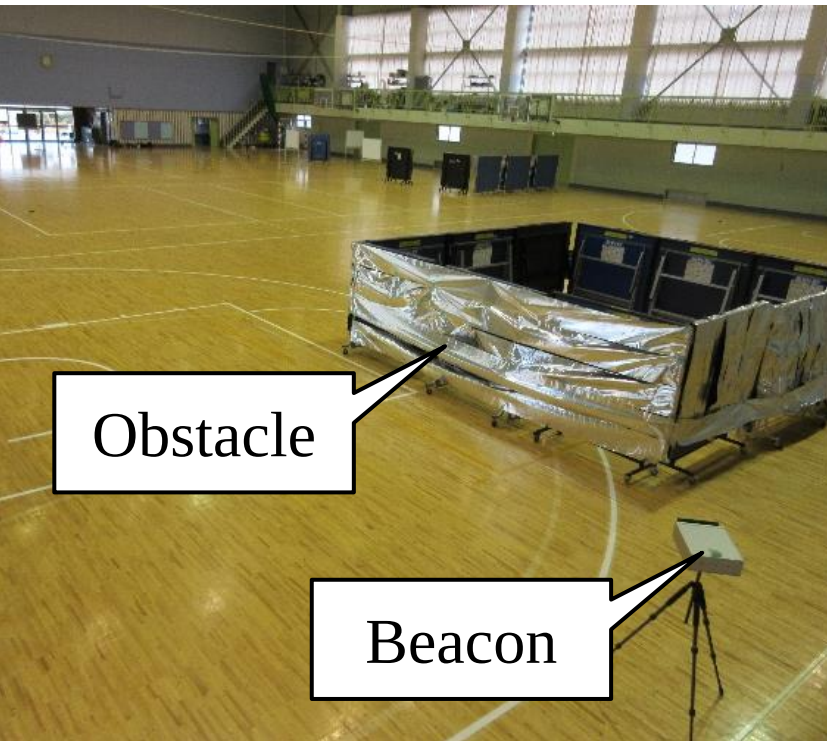
■ Environment





Experiment

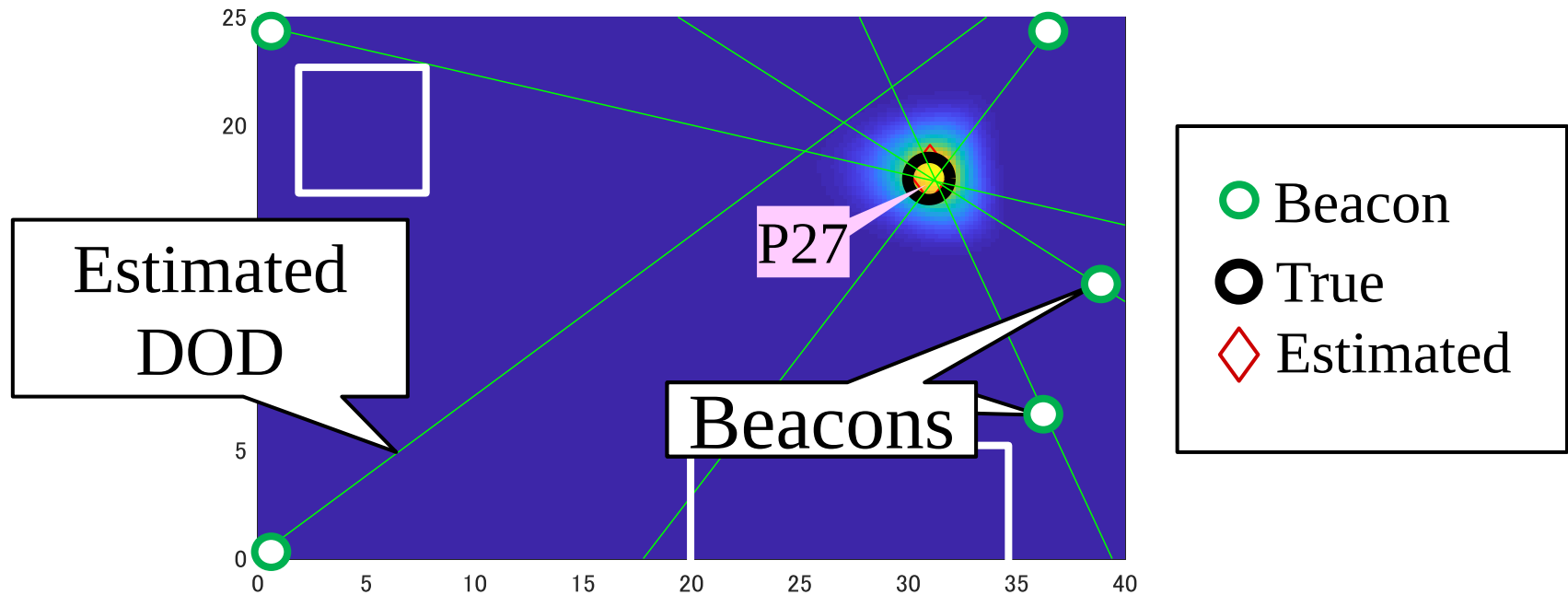
■ Photos





Experiment

■ Example result

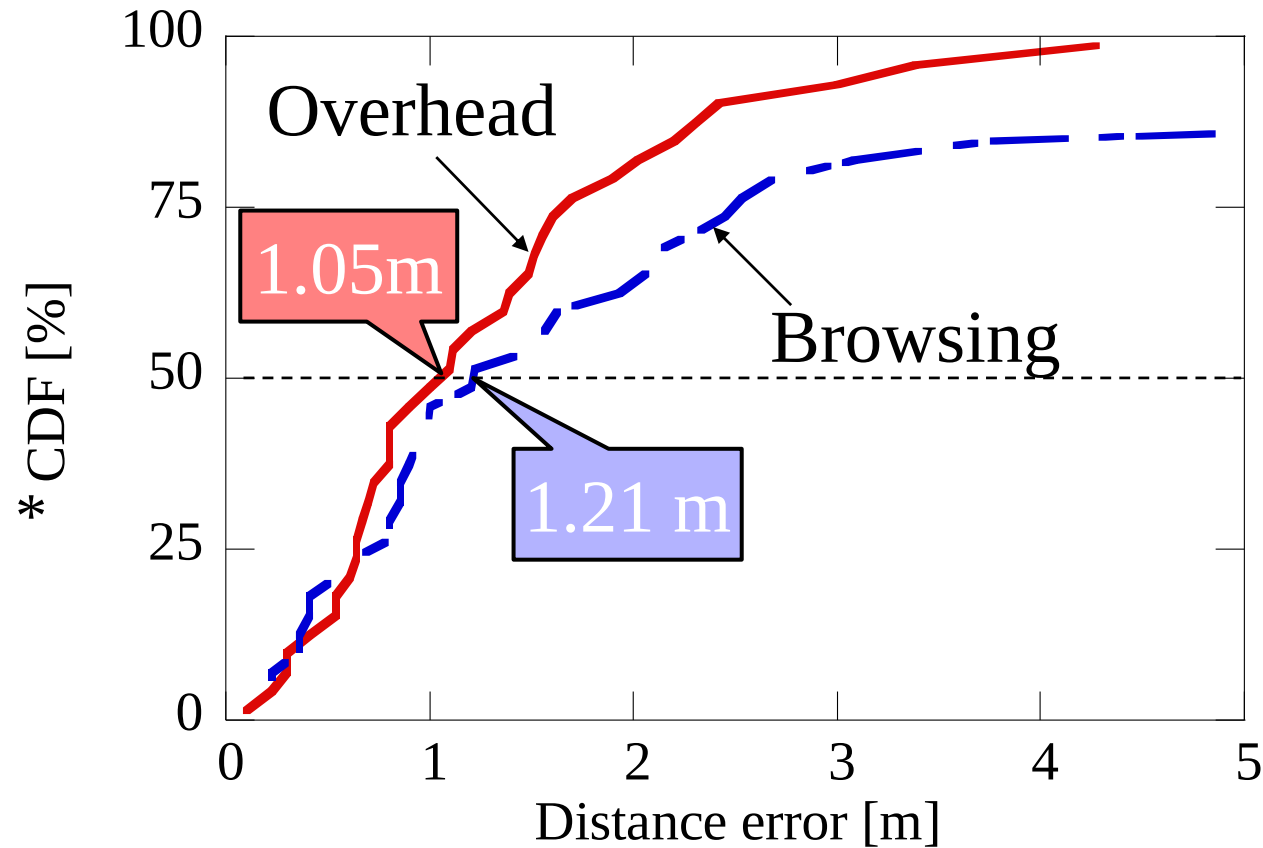


DODs can be well estimated at the mobile terminal



Experiment

*CDF: Cumulative Distribution Function



High accuracy is attained



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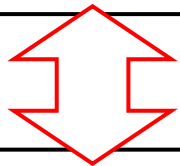
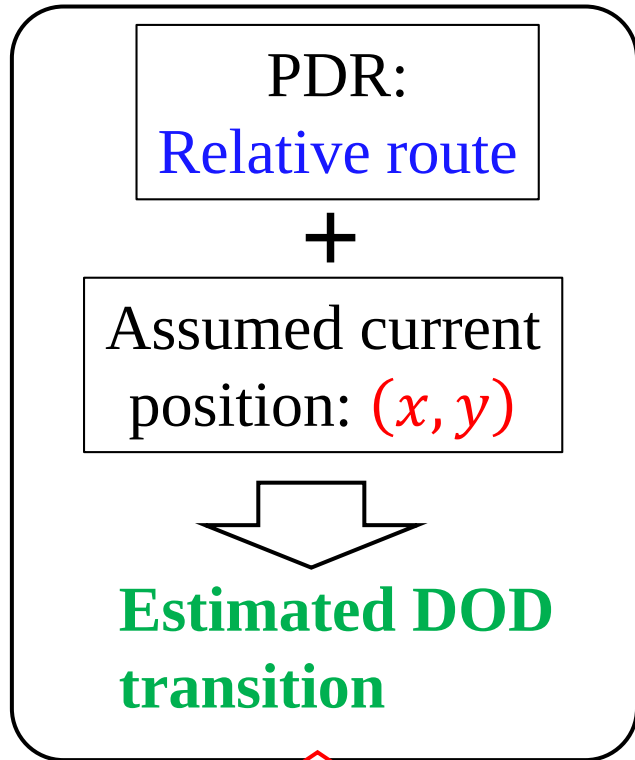
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■ Conclusion

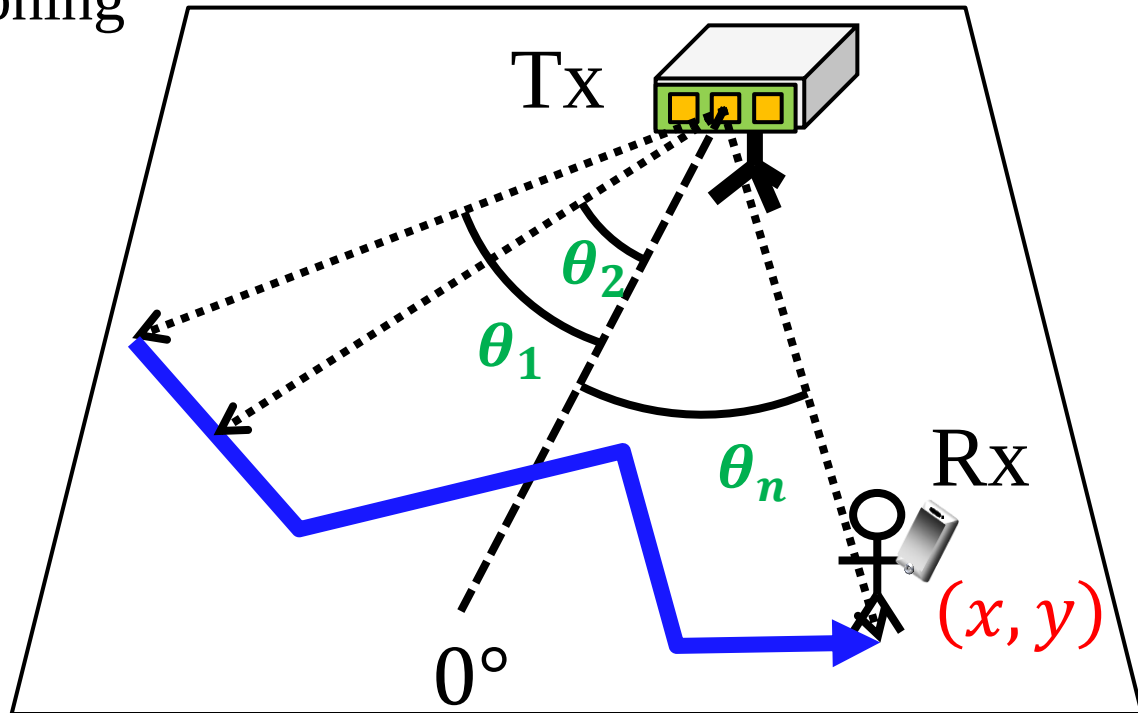


Hybrid method: DOD-beacon + PDR*

*PDR: Pedestrian dead reckoning

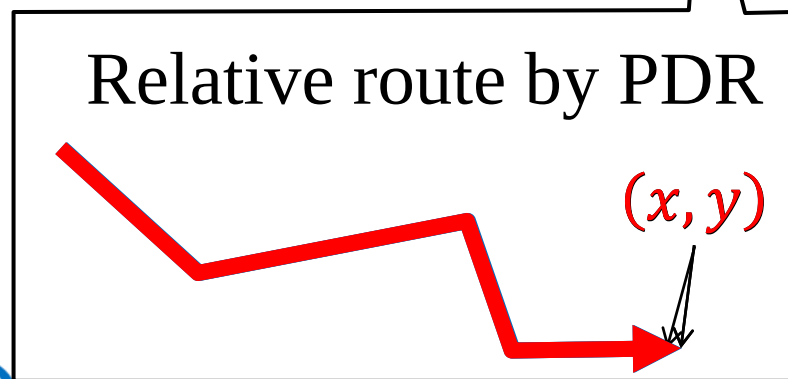
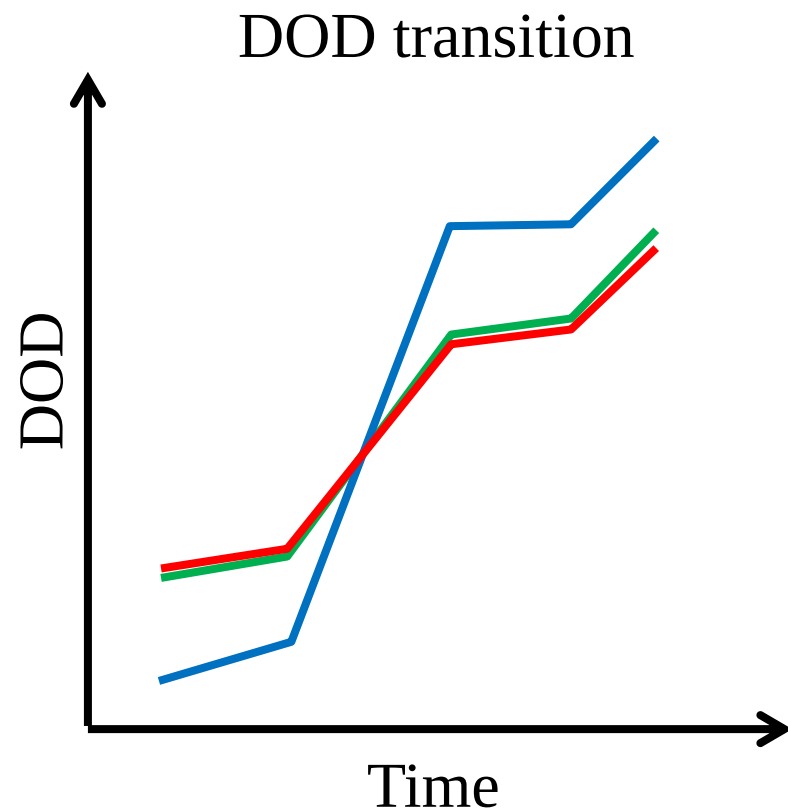
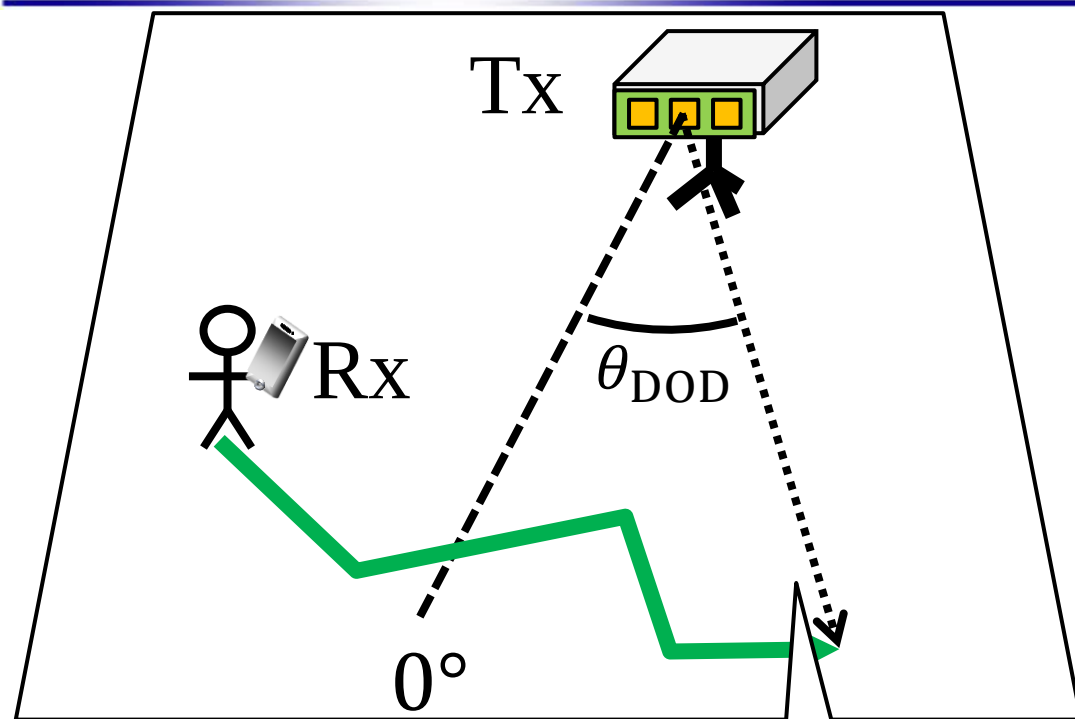


Comparison



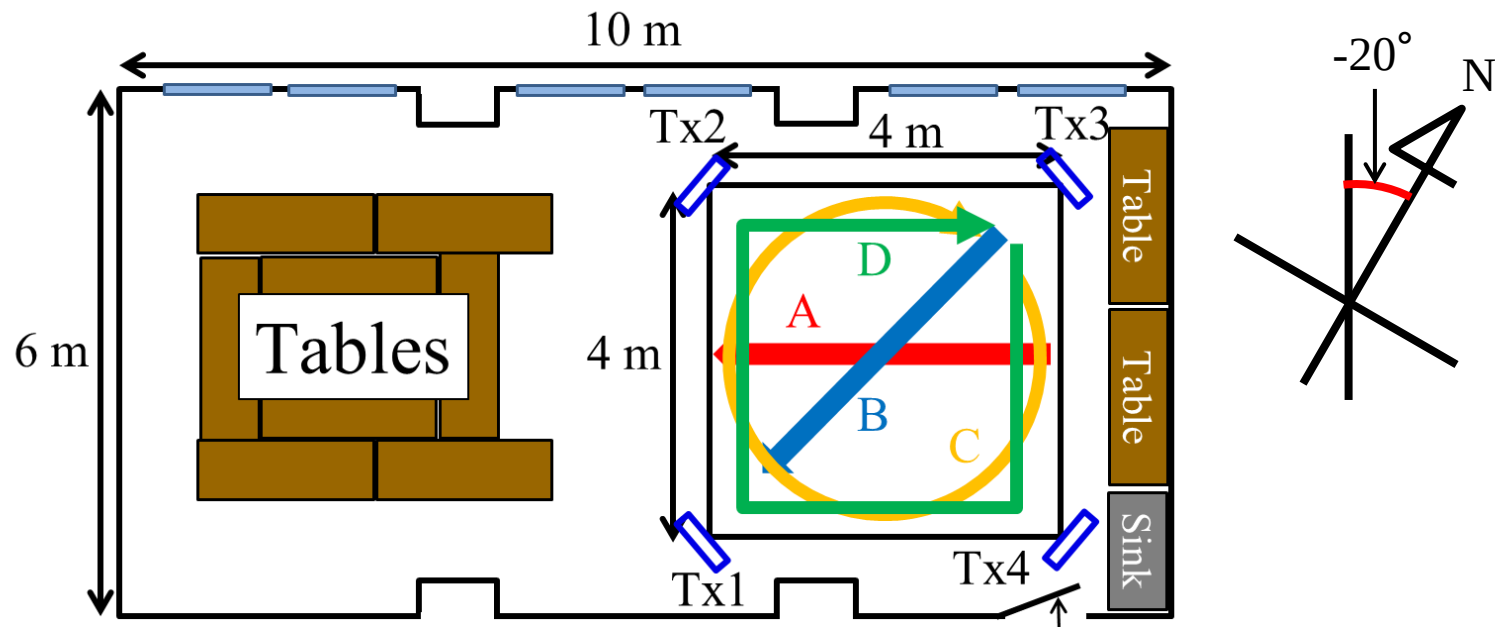
Find position (x, y) with most similar DOD transition

Hybrid method: DOD-beacon + PDR



Find position (x, y) with most similar DOD transition

Measurement setup

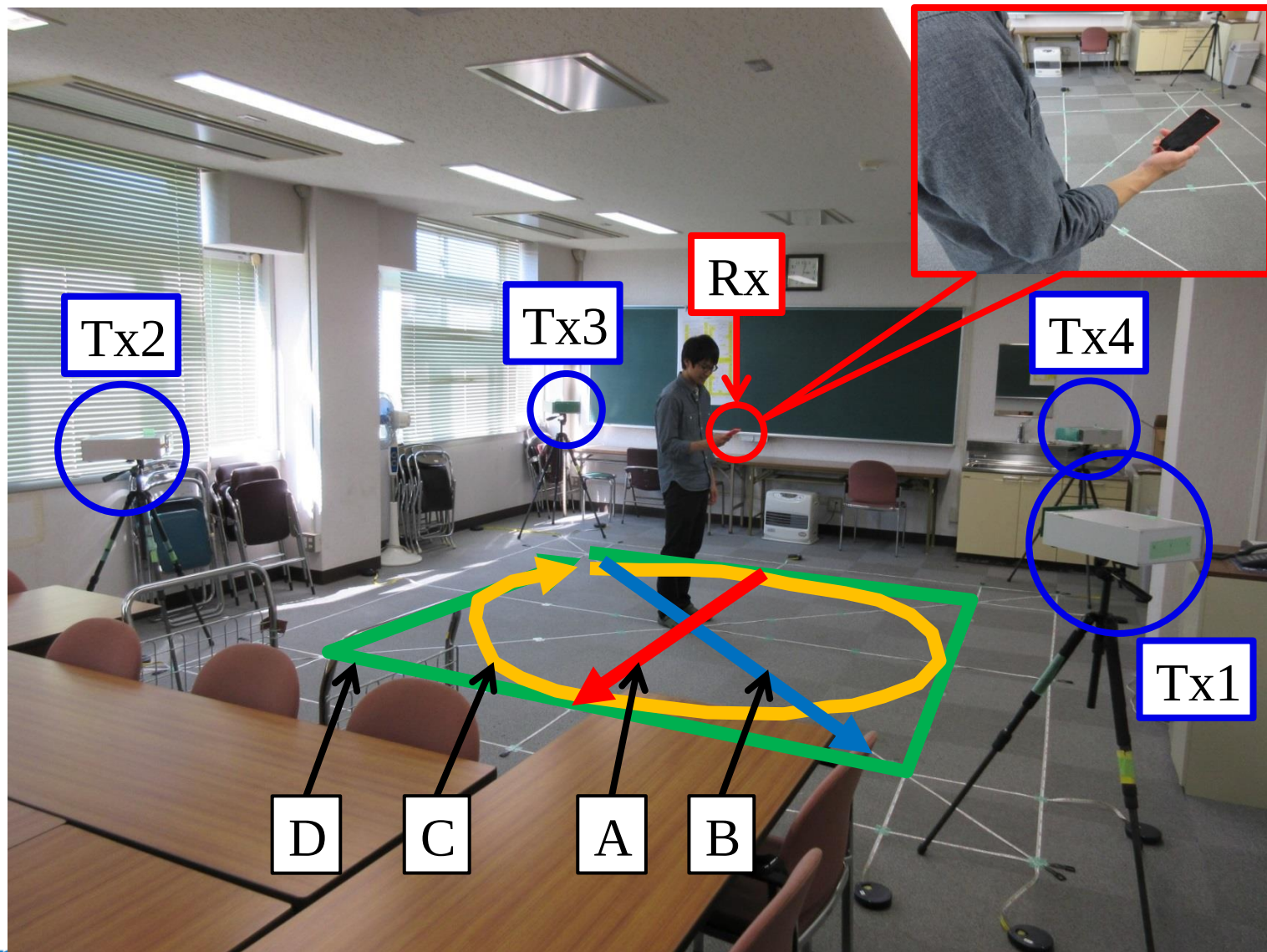


Measurement conditions

Route	Length	Meas. period
A	3.0m	15 s
B	4.0m	
C	9.2 m	30 s
D	12.0 m	

Handset	iPhone 5c
Num. of beacons	4
Height of ant.	1.15 m
Signal	Bluetooth (2.4GHz)
Num. of trials	30 times/ route

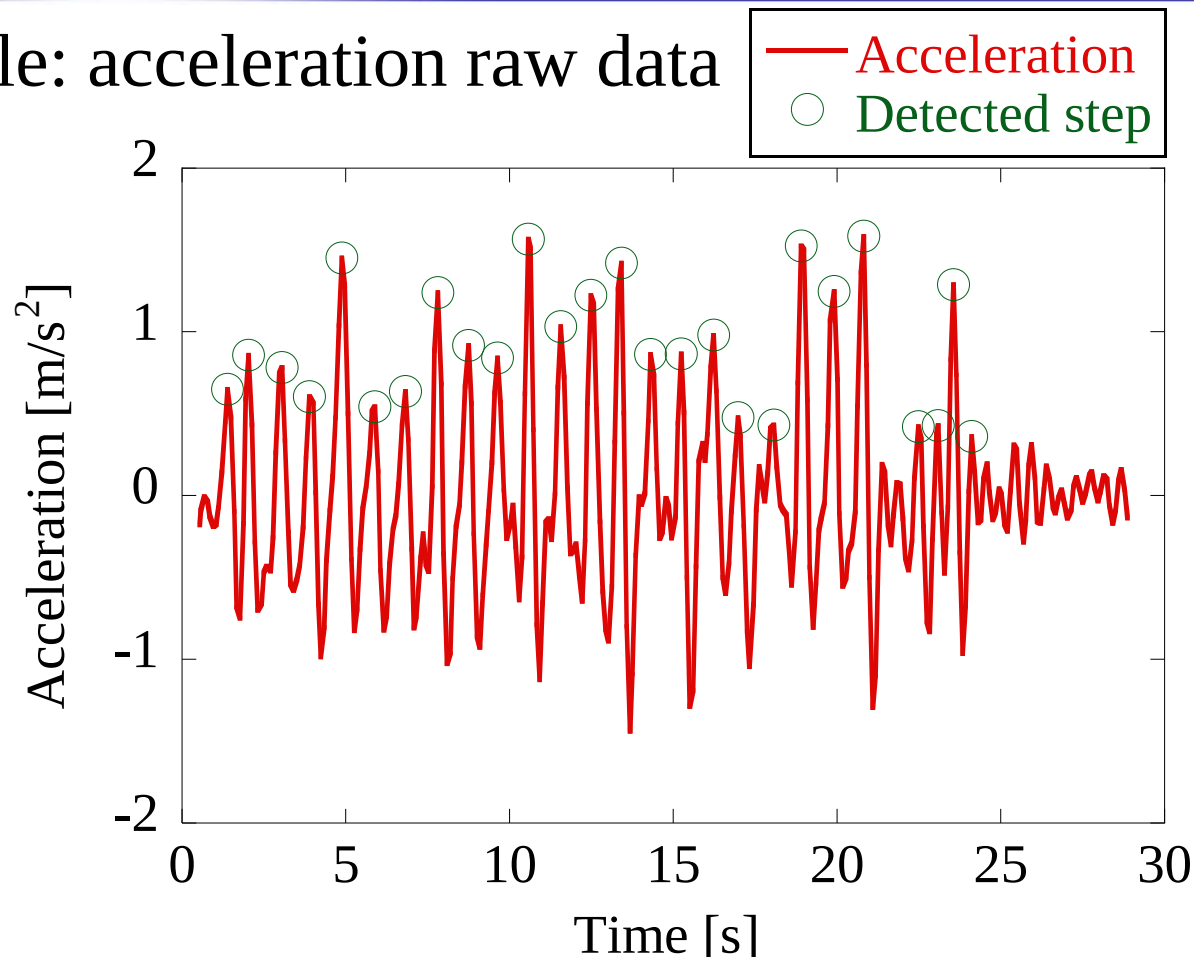
Environment



PDR by counting vertical acceleration variance



■ Example: acceleration raw data

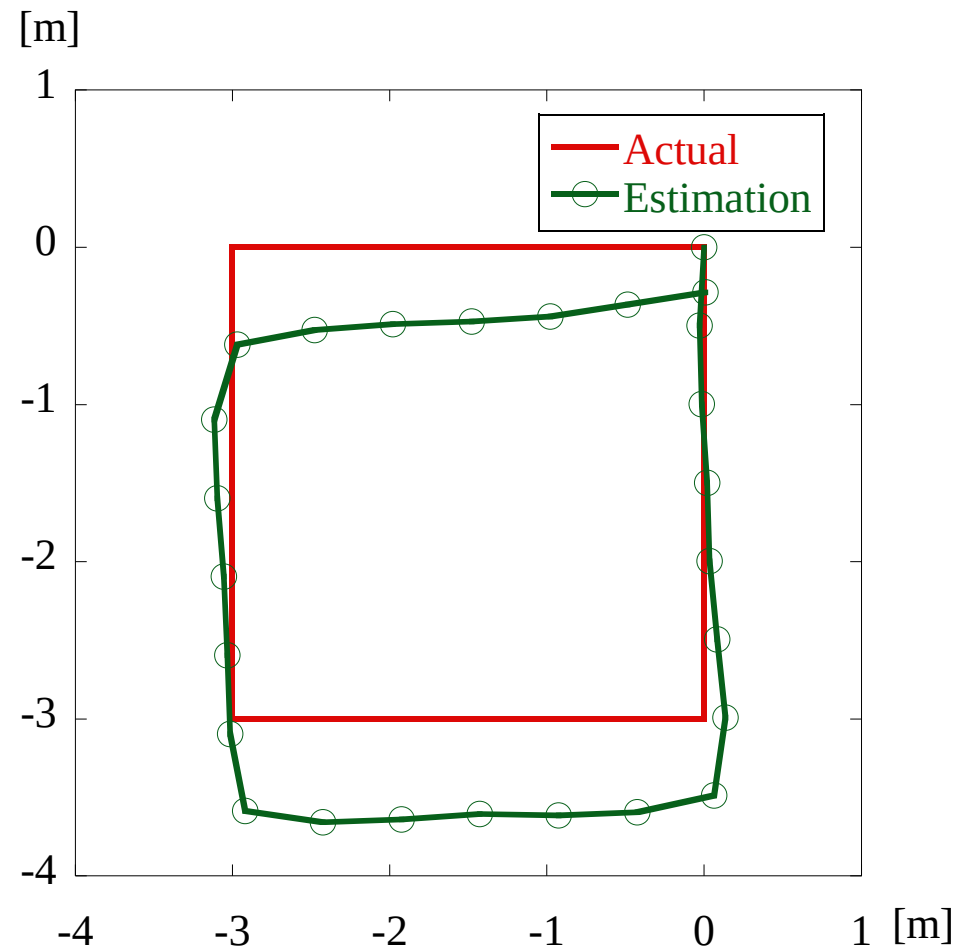
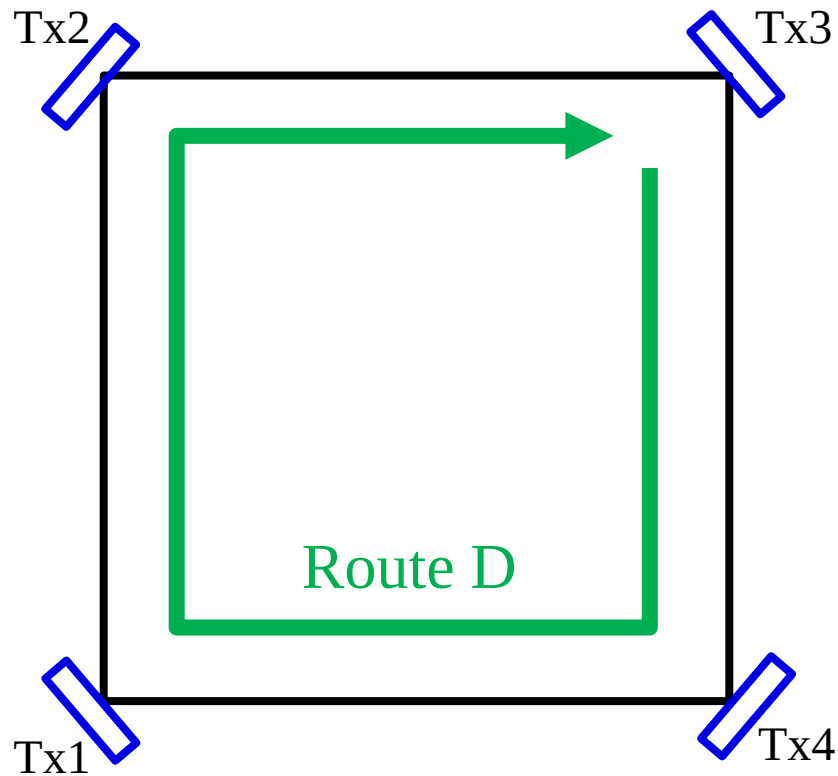


Footsteps are easily detected using COTS* device

*COTS: Commercially-off-the-shelf

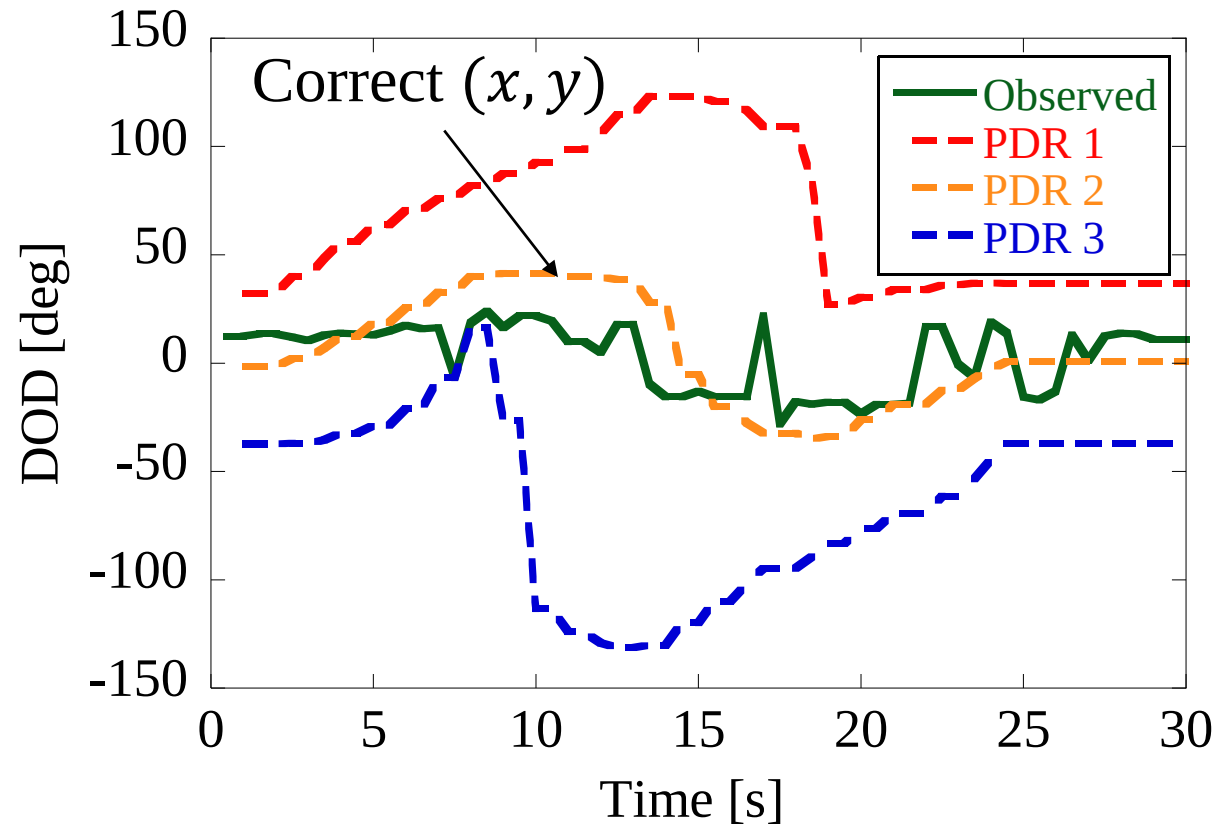
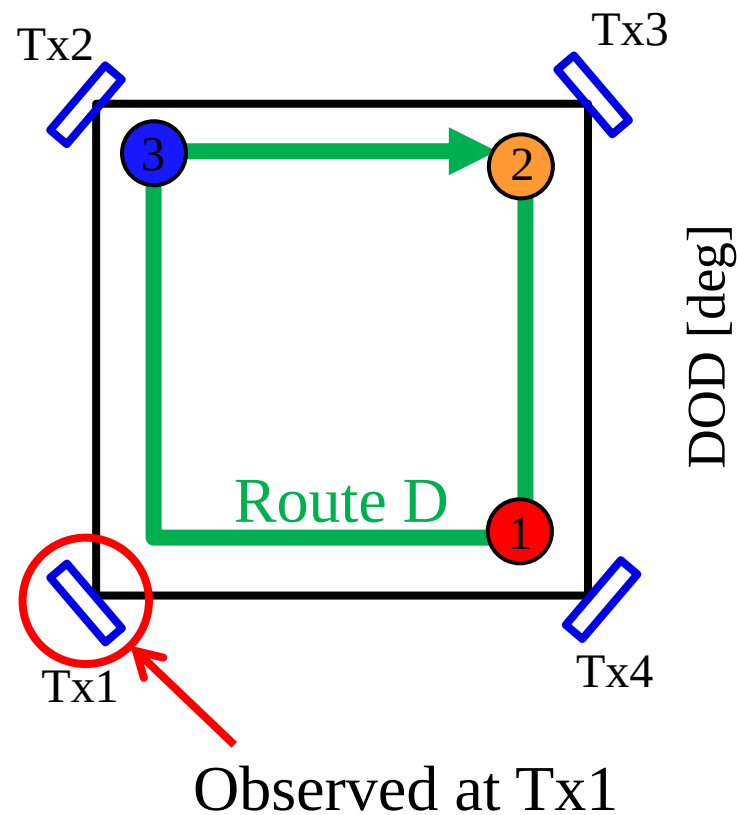
Faculty / Graduate School of Engineering, Iwate University, Japan

Route estimation by PDR only



Well estimate relative route

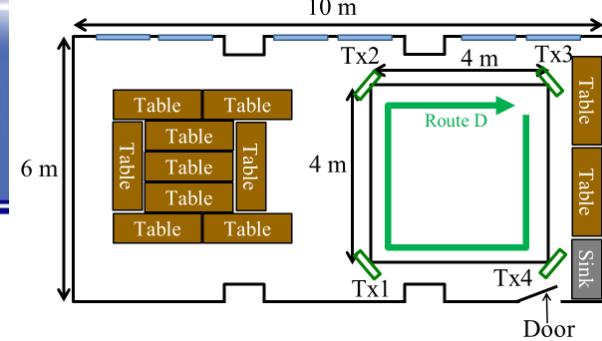
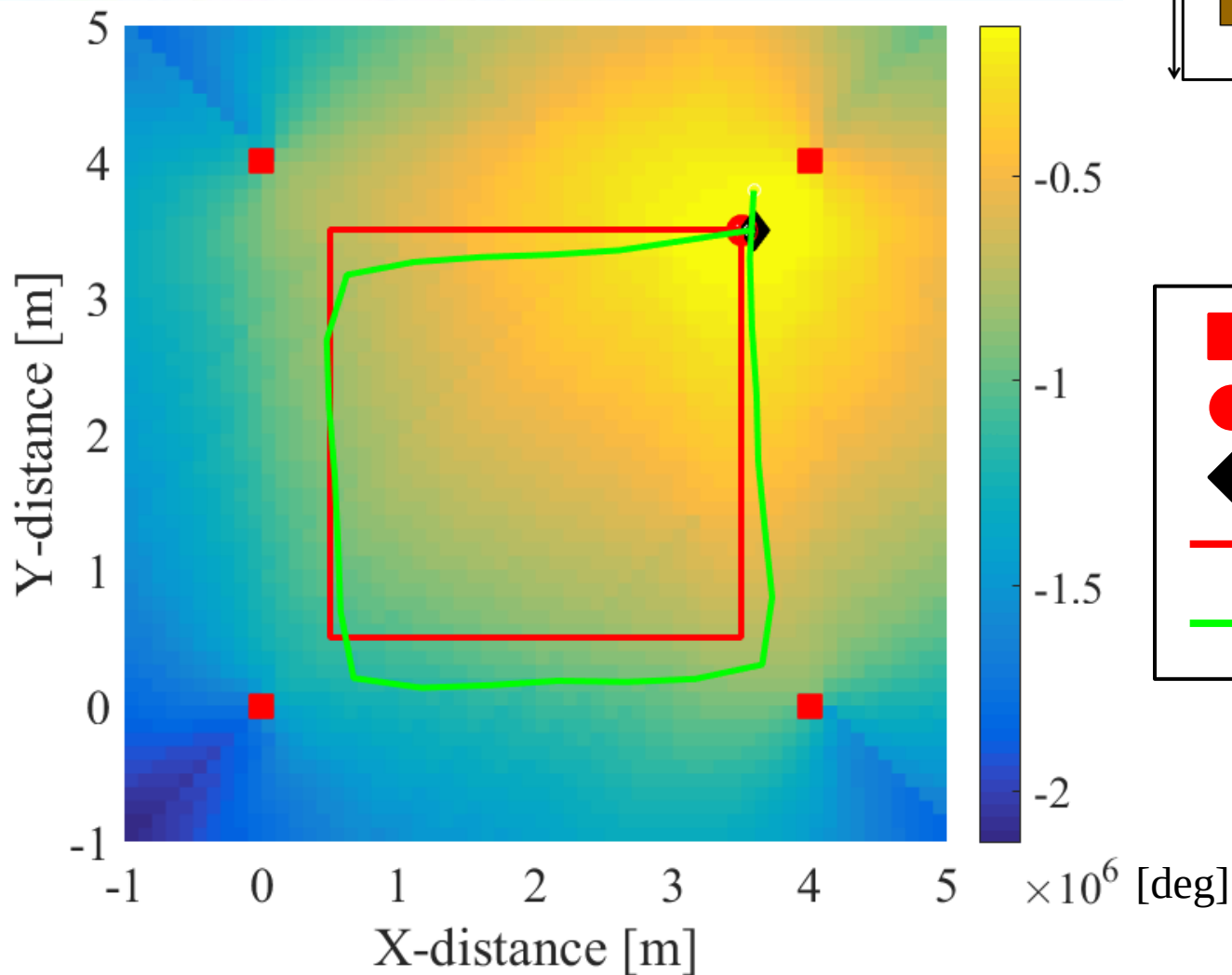
Estimating DOD transition



Examples of DOD transition

Correct route yields DOD transition similar to observed one

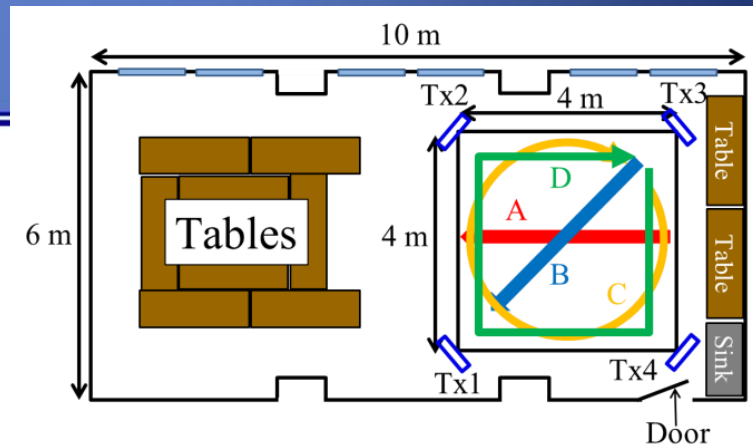
Estimation example



- Tx
- Actual pos.
- ◆ Estimated pos.
- Actual route
- Estimated route

Position is successfully estimated by proposed method

Accuracy comparison



Method	A	B	C	D	Average
Hybrid method	0.32 m	0.28 m	0.50 m	0.51 m	0.40 m
DOD only	0.41 m	0.88 m	0.58 m	1.99 m	0.97 m

Average 0.97 m (DOD only) → 0.40 m (hybrid): **two-fold improvement**



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Conclusion

Indoor-Positioning Using RSSI

RSSI-ranging technique vs. DOD-based technique

- Two RSSI-based methods are compared

- RSSI-ranging: RSSI is directly translated to distance
- DOD-triangulation: RSSI difference is translated to DODs

- Simulation

- DOD-triangulation yields five-fold higher accuracy @ $k = 10$ dB

- Experiment in indoor environment

- DOD only: Accuracy: 1.05 ~ 1.21 m @ 50%
- DOD+PDR: Accuracy: 0.4 m @ 50%



Thank you!

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Atsushi Miura, ERi, Inc.: [miura\[at\]erii.co.jp](mailto:miura[at]erii.co.jp)