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Investigation of Multipath Effects on Phase-based Ranging

IPIN 2019, Pisa, Italy

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Institute of Operating Systems and Computer Networks, TU Braunschweig, Germany

Motivation

- Multipath propagation imposes **challenges** on any radio communication

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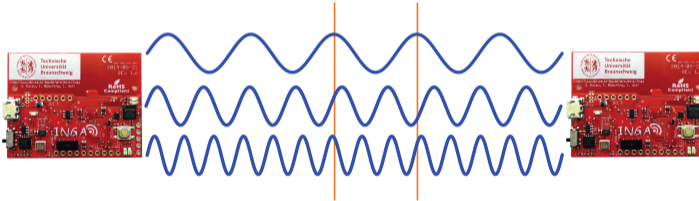- UWB and Phase-based Ranging are no exceptions

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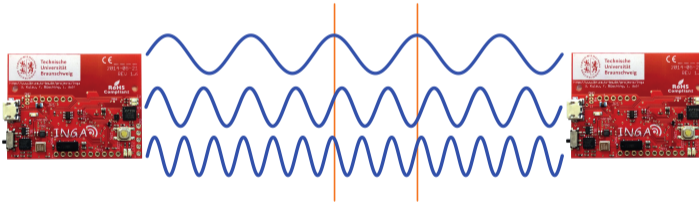- **Realistic scenarios are mostly indoors** with lots of multipath propagation

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Phase-based Ranging

- Obtain **distance in meters** between **two wireless sensor nodes**

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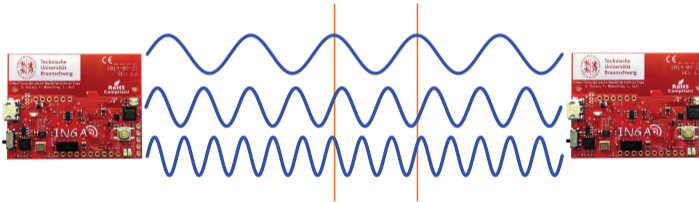and Computer Networks

Phase-based Ranging

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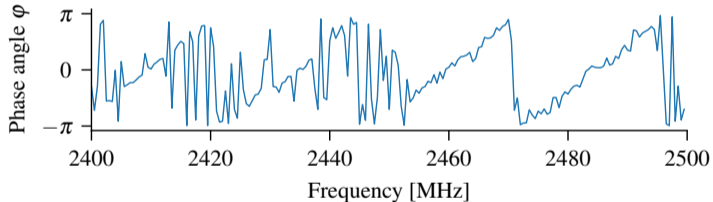
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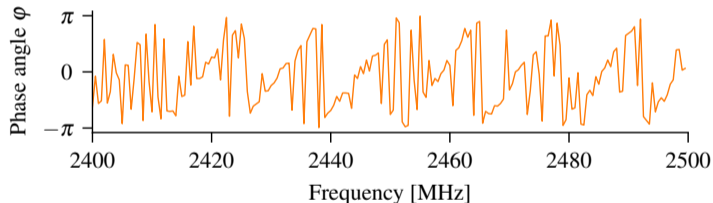
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- Exemplary phase data for 5 meter distance:

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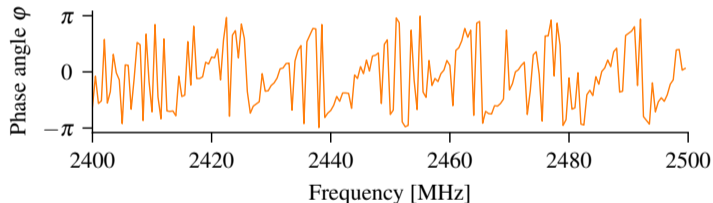
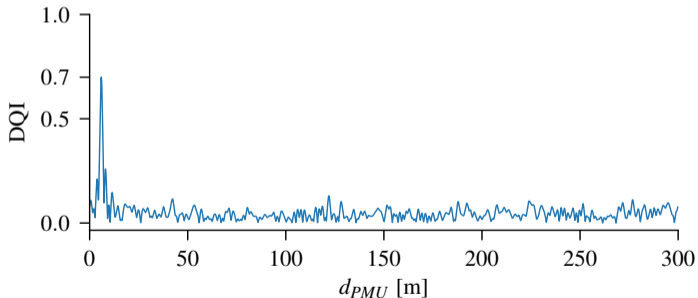- Distance is **proportional to slope/frequency** of phase response

Complex-valued Distance Estimation (CDE)

- Compute **Fast Fourier Transform (FFT)** from complex signal

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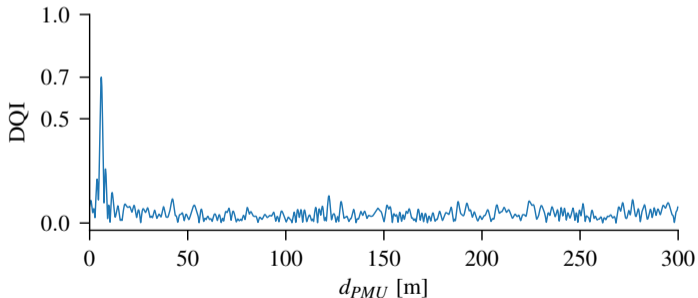- Result is the **time-domain impulse response** of the radio channel
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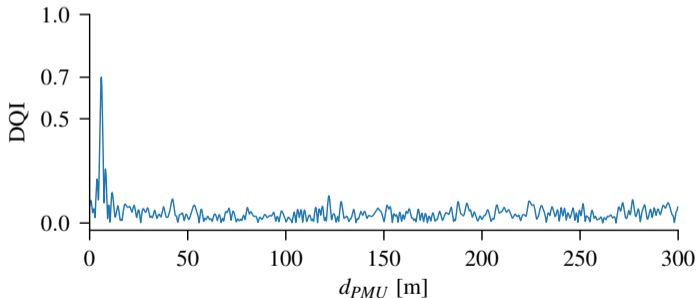
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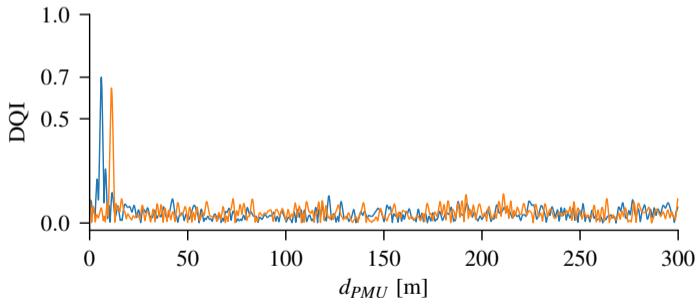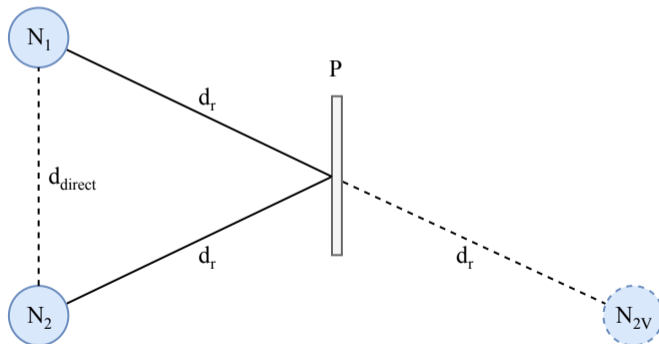and Computer Networks

Complex-valued Distance Estimation (CDE)

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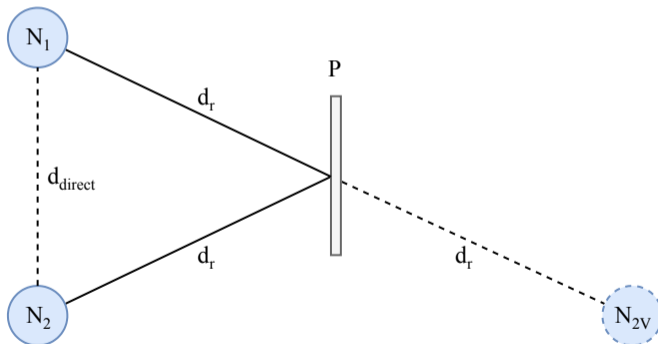
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Research Questions

- How does multipath propagation interact with the measurement?

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- Do we measure d_{direct} or $2 \cdot d_r$?

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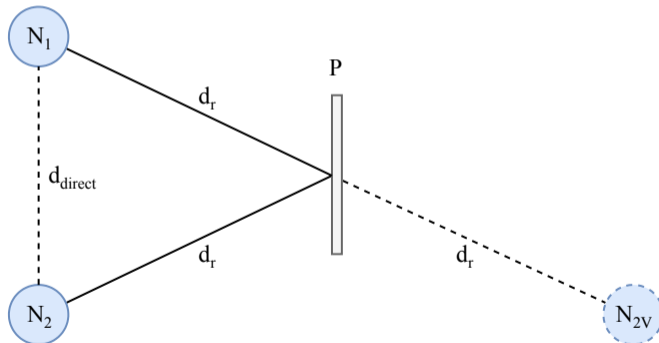Braunschweig

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Research Questions

- How does multipath propagation interact with the measurement?
- Do we measure d_{direct} or $2 \cdot d_r$?
- Or something completely different?

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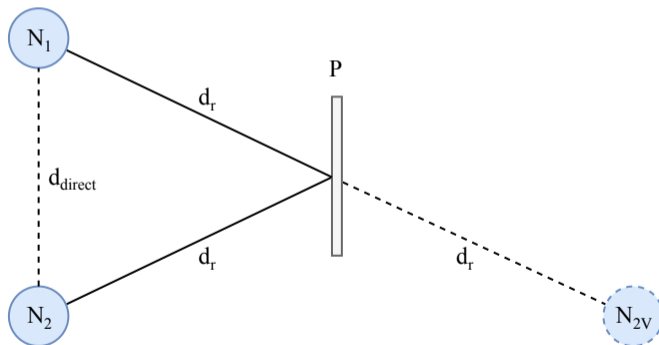Institute of Operating Systems
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N_1 N_2 P d_r d_r d_{direct}

Experiment in Controlled Environment

- 1000 measurements with/without reflective surface

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- $d_{direct} = 10\,\text{m}$

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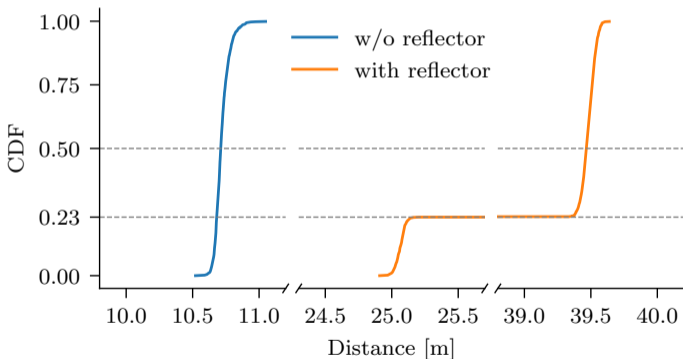# Experiment in Controlled Environment

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Detailed Results

- Median FFT of 1000 measurements

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Detailed Results

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- Without reflective surface: distinct peak

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- With reflective surface: **multiple peaks**

Detailed Results

- Median FFT of 1000 measurements
- Without reflective surface: distinct peak
- With reflective surface: **multiple peaks**
- Correct peak is not the highest one → **CDE fails!**

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Experiment in Realistic Environment

- 10 sensor nodes, 9 links each, 1000 measurements per link
  → **90000 measurements**

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Line-of-Sight

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Multipath

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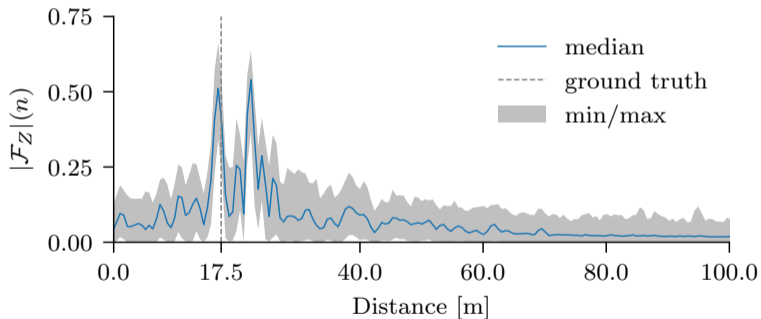# Experiment in Realistic Environment

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Non-Line-of-Sight

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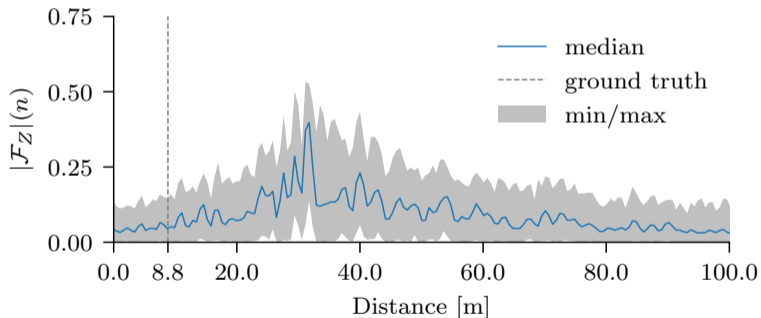
Mitigation: Idea

- Find **first peak** instead of highest peak

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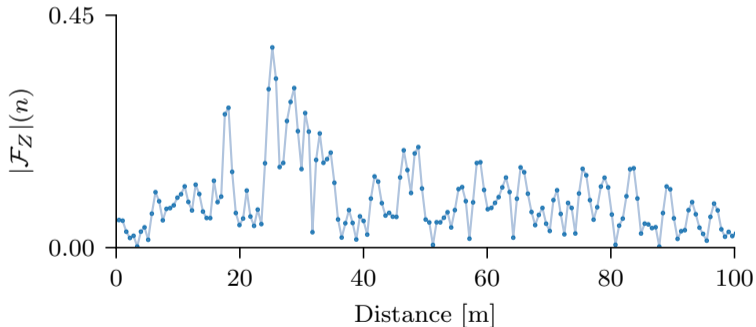
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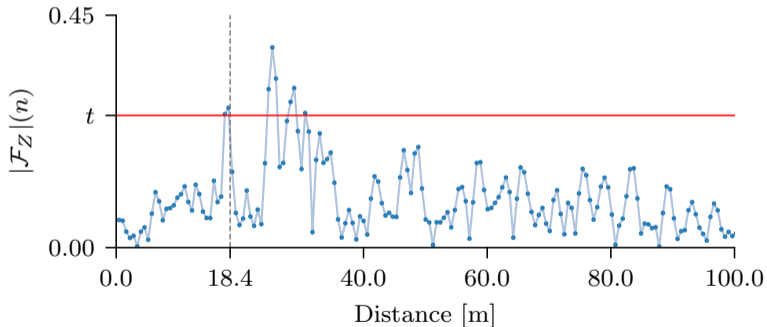
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- → **Multipath-aware** iCDE (MP iCDE)

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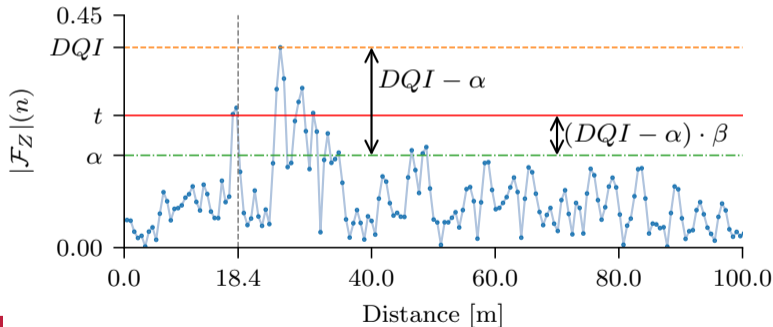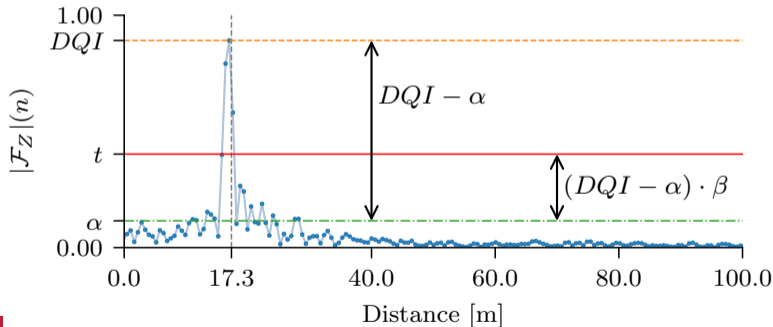
Evaluation Results: LOS

- **similar results** in LOS conditions

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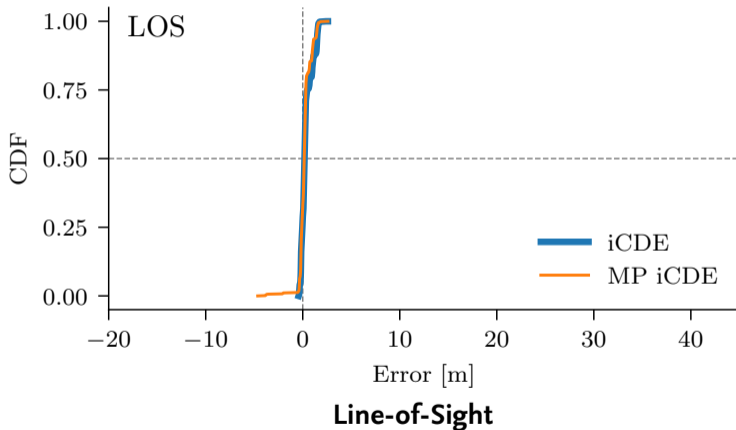
Evaluation Results: NLOS

- **similar (adverse) results** in NLOS conditions
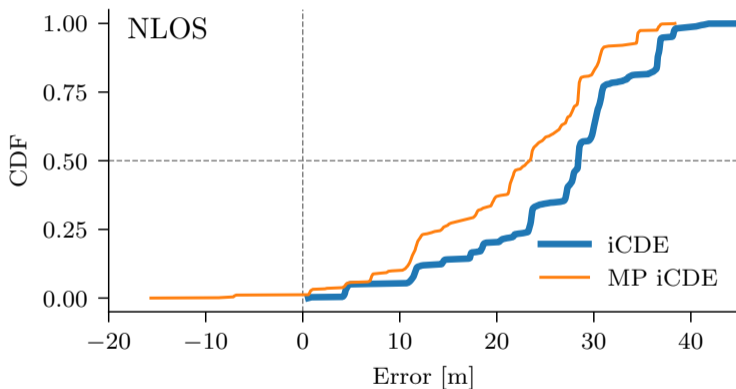
Non-Line-of-Sight

Evaluation Results: Multipath

- **better results** in Multipath conditions: Mean Absolute Error (MAE) from **4.3 m to 2.1 m**
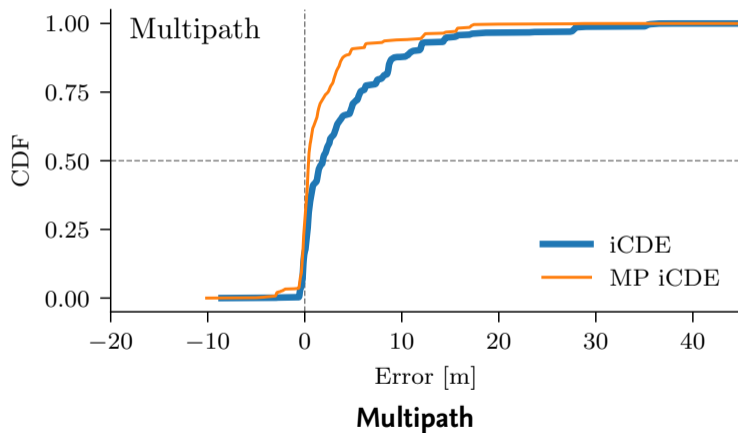
Multipath

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Conclusion

- **Multipath Effects** on Phase-based Ranging experimentally shown

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Thank you for your attention!

Errors of the Multipath Category

- **MAE reduced by 51 %**

	min. [m]	max. [m]	median [m]	MAE [m]	σ [m]
iCDE	**-8.576**	155.616	1.863	4.347	6.518
MP iCDE	-10.108	**152.760**	**0.524**	**2.138**	**3.834**

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