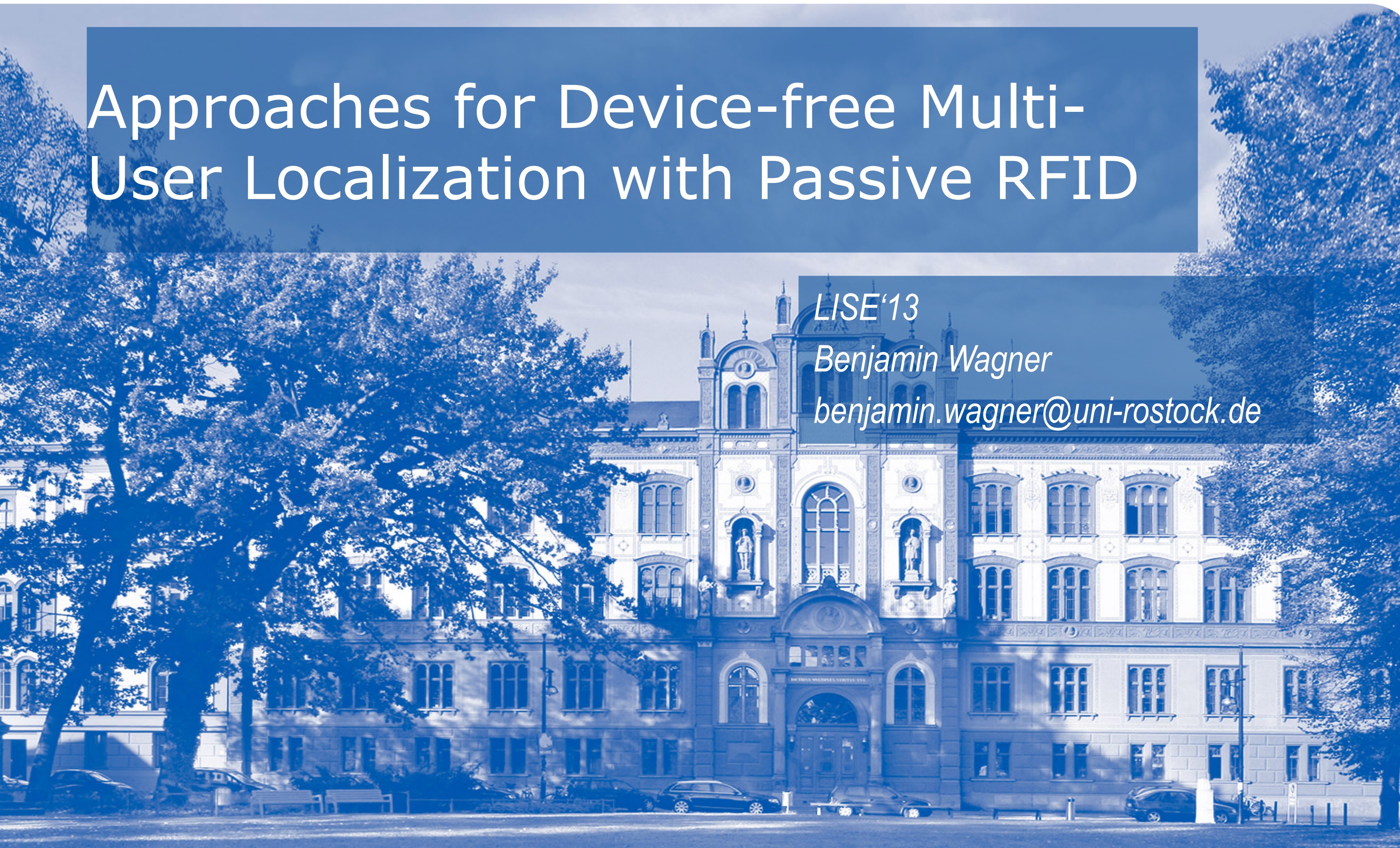
Universität Rostock — Traditio et Innovatio

MuSAMA — Multimodal Smart Appliance Ensembles for Mobile Applications



Approaches for Device-free Multi-User Localization with Passive RFID

LISE'13

Benjamin Wagner

benjamin.wagner@uni-rostock.de

Agenda

- Motivation
- Approach
- Multi User Problem
- Approaches
- Experiment

Agenda

- **Motivation**
- Approach
- Multi User Problem
- Approaches
- Experiment

Multimodal Smart Environments - MuSAMA

Main research areas:

- Context sensing and Analysis
- Multimodal Interaction and Visualization
    - Intention Recognition and Strategy Generation
    - Data Management, Resources and Infrastructure Management
    - Main scenario:

      Smart Conference room

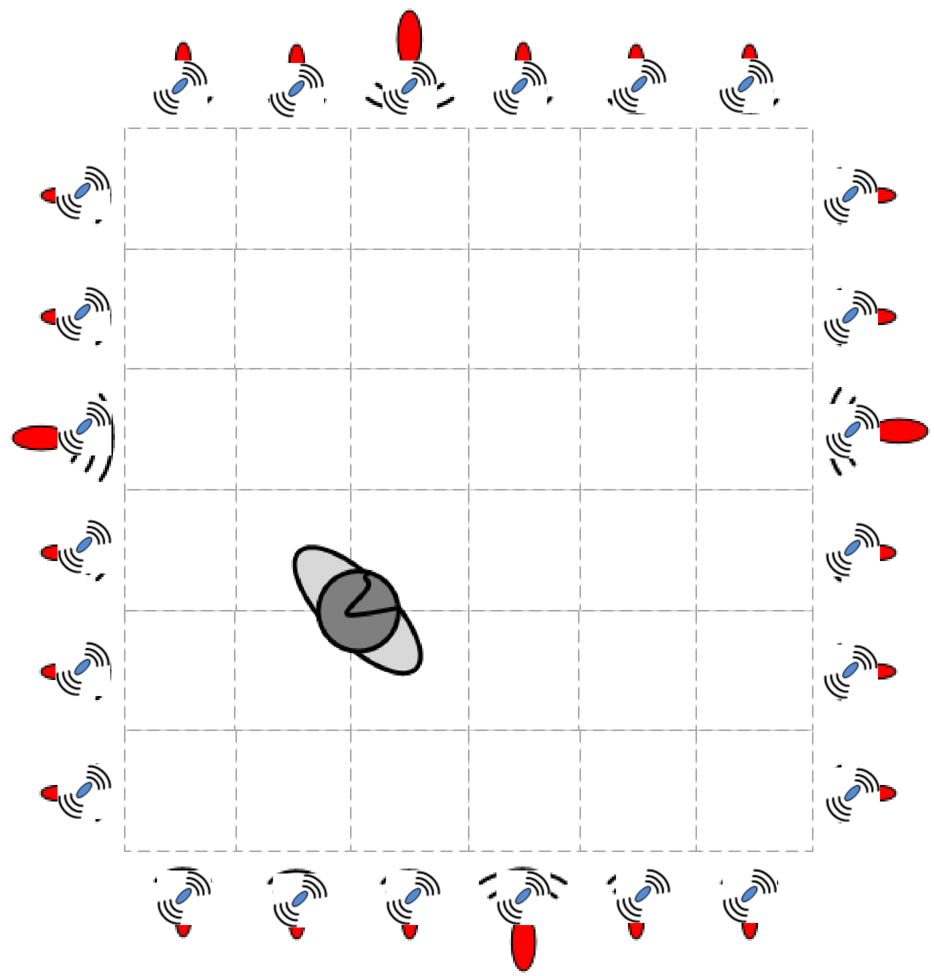
Motivation

- User position as main information source for ubiquitous proactive assistance
- Ubisense:
  - high costs
  - tag based
  - complex deployment

- SensFloor®/NaviFloor®:
  - high costs
  - Complex deployment

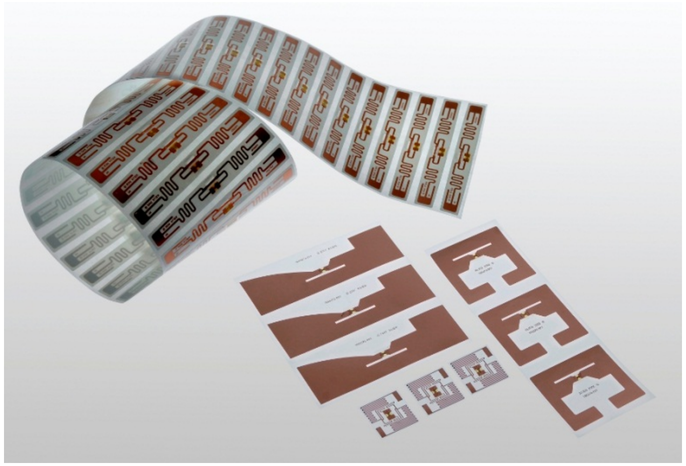
Motivation

- User influences RF communication links
- Utilizing attenuation / scatter for user localization
- User do not need to wear hardware



Motivation

- Innovation: Use of passive RFID-tags
  - low cost
  - easy deployment
  - adaptive densities possible



Agenda

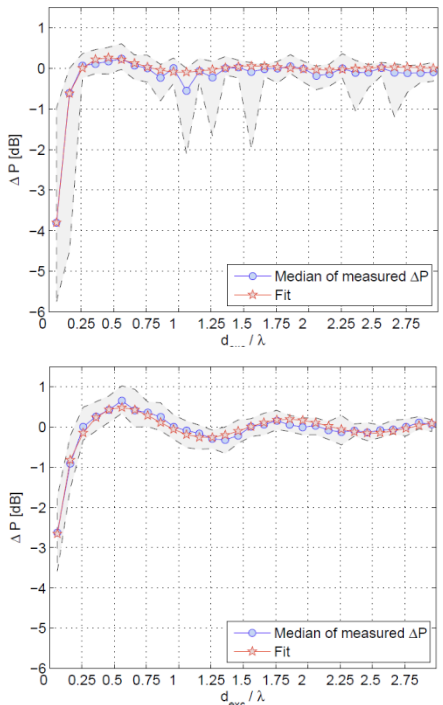
- Motivation
- **Approach**
- Multi User Problem
- Approaches
- Experiment

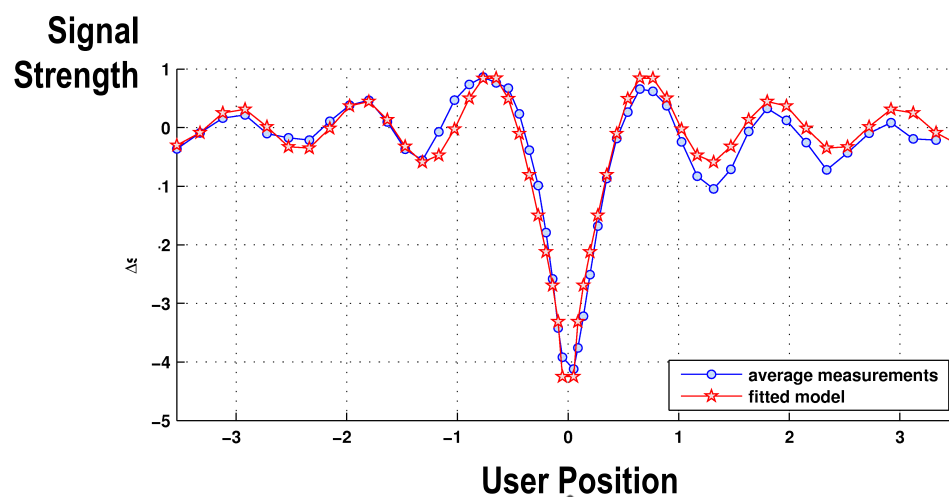
Universität Rostock — Traditio et Innovatio

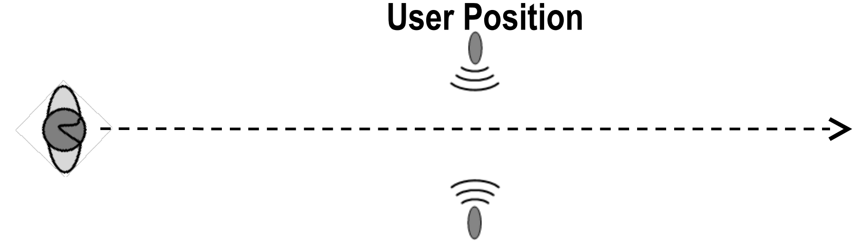
MuSAMA — Multimodal Smart Appliance Ensembles for Mobile Applications

Methodology

- Human Influence on Passive Bistativ RFID







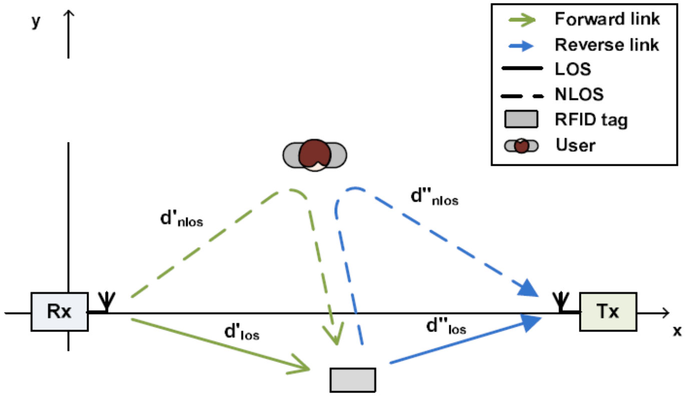
Methodology

- Physical model

$$\Delta\tilde{s}(d_{exc}) \approx A d_{exc}^{B} \cos\left(\frac{2\pi}{\tilde{\lambda}} d_{exc} + \phi_{refl}\right)$$

- Path difference

$$d_{exc} = d'_{nlos} + d''_{nlos} - d_{los}$$



Passive RFID Tomography

- Model

$$\Delta P = W \Delta x + n$$

- Difference between WSN and this pRFID approach

$$n_{tx} \gg n_{rx}$$

- 2 phase measurement: without user presence as calibration matrix

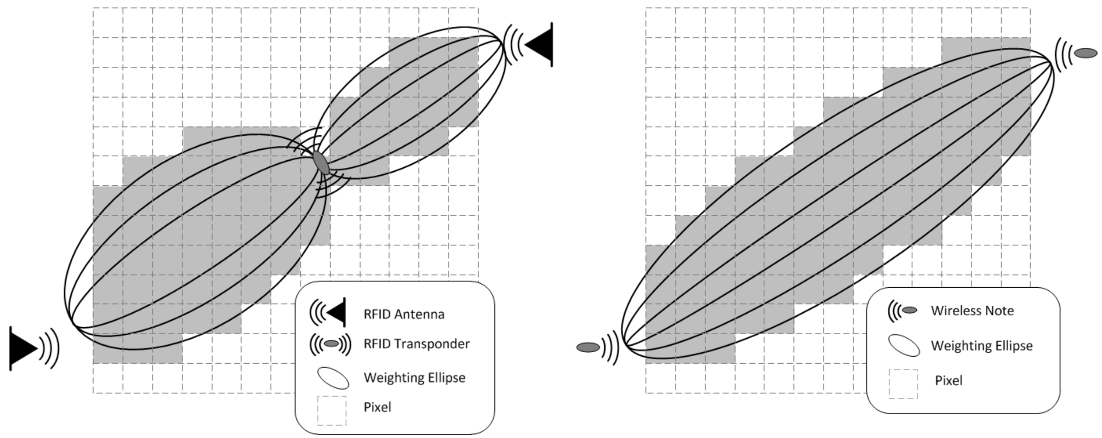
$$\Delta P = P_{meas} - P_{cal}$$

- Image Calculation

$$\Delta x = (W^T W + {C_x}^{-1})^{-1} W^T \Delta y \quad \text{with} \quad C_x = {\sigma_x}^2 e^{-d/\delta}$$

Passive RFID Tomography

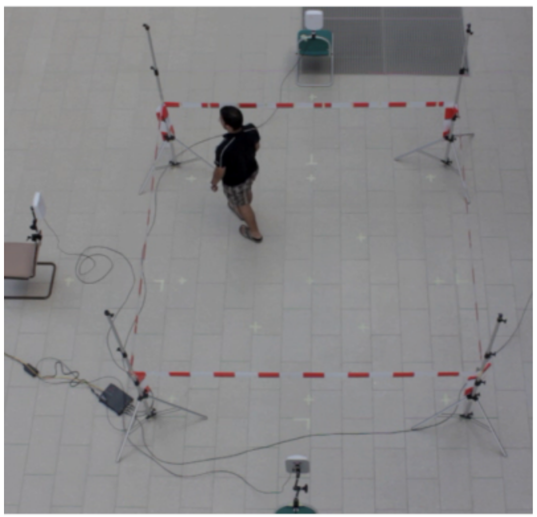
- Weighting Matrix for radio tomography

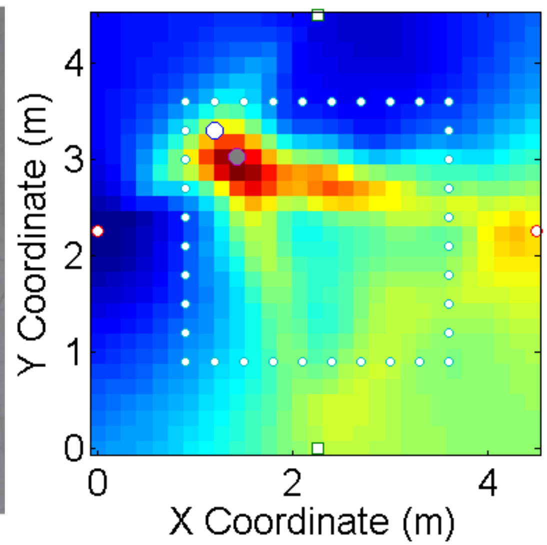


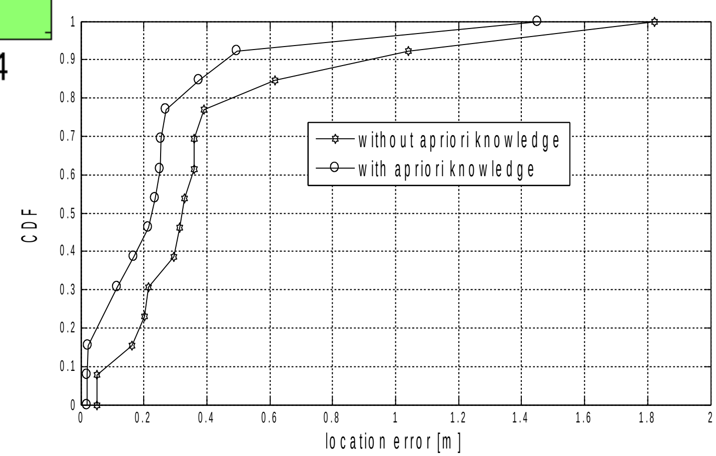
Forward: $$w_{ij} = \frac{1}{\sqrt{d_{tx(i)\,t(i)}}} \begin{cases} 1 \;\; if\; d_{tx(i)\,j} + d_{j\,t(i)} < d_{tx(i)\,t(i)} + \lambda_{forw} \\ 0 \qquad otherwise \end{cases}$$

Backward: $$w_{ij} = \frac{1}{\sqrt{d_{t(i)\,rx(i)}}} \begin{cases} 1 \;\; if\; d_{t(i)\,j} + d_{j\,rx(i)} < d_{t\,rx(i)} + \lambda_{backw} \\ 0 \qquad otherwise \end{cases}$$

Passive RFID Tomography





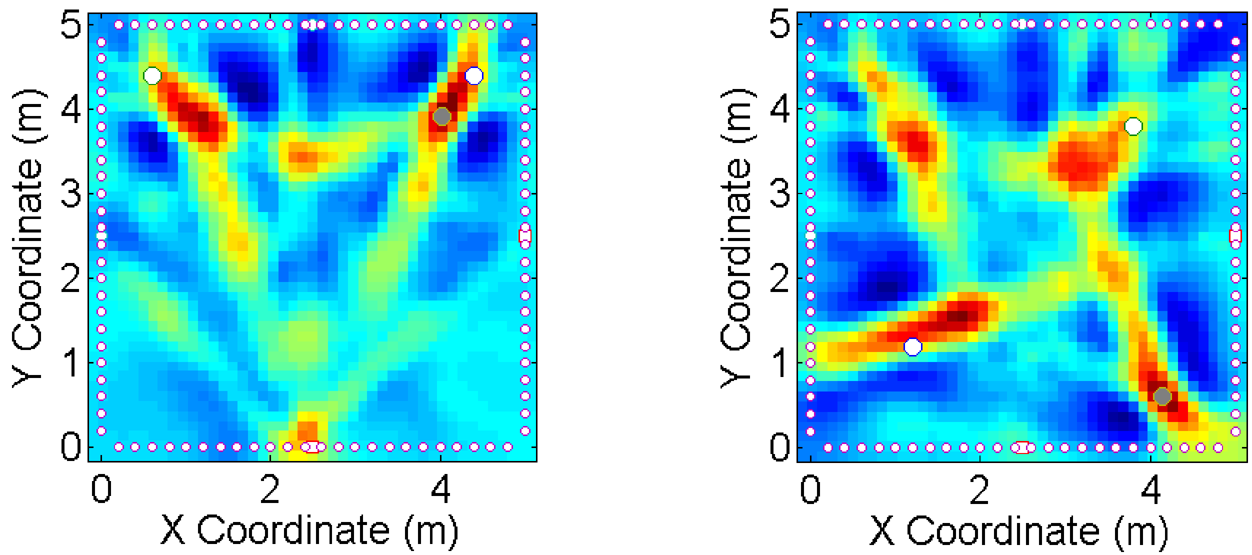


Agenda

- Motivation
- Approach
- **Multi User Problem**
- Approaches
- Experiment

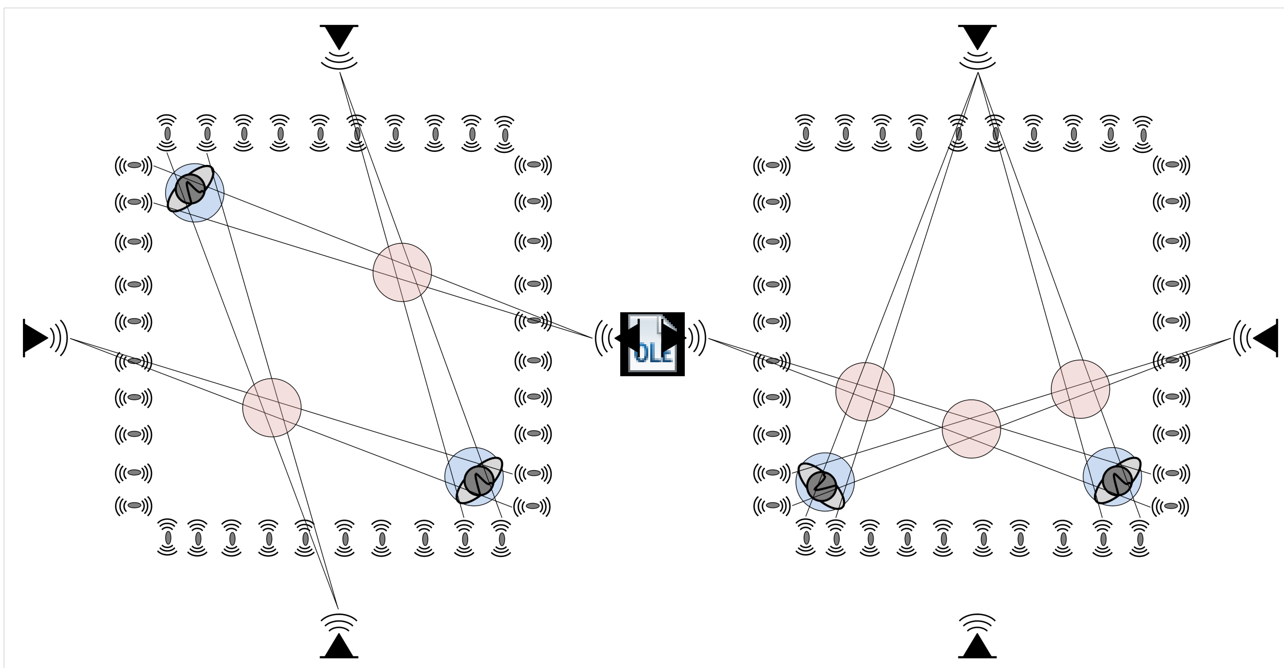
Multi User Problem

- Ghost hotspots



Multi User Problem

- Ghost hotspots



Agenda

- Motivation
- Approach
- Multi User Problem
- **Approaches**
- Experiment

Maximum Removal Iteration (MRI)

- Choose Maximum

$$E(p) = arg\max(\Delta x)$$

- Calculate Correlating Link Matrix

$$i_{corr} = \forall i : (d_{t(i)E(p)} + d_{E(p)rx(i)} - d_{t(i)rx(i)} < \lambda_{backw})$$

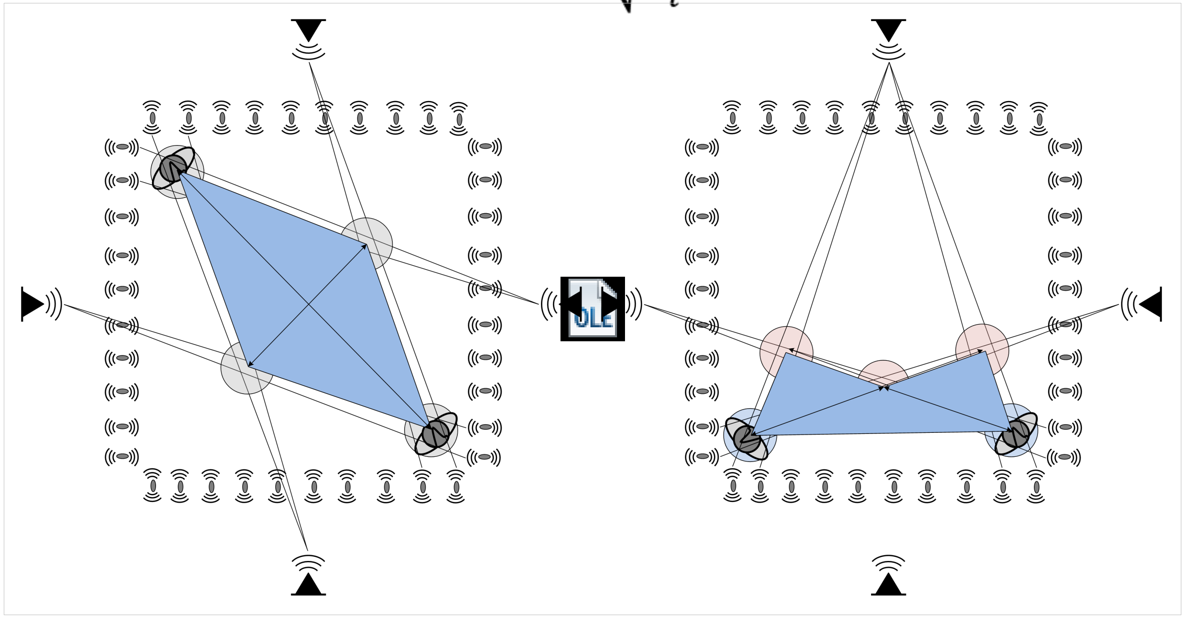
- Replace with Calibration Value

$$\Delta y(i_{corr}) = y_{cal}$$

Polygon Distance Estimation (PDE)

- Polygon n_e edge point calculation

$$E(p,e) = \arg\max\left(\sqrt{\sum_i (n_e(1) - n_e(2))^2}\right)$$

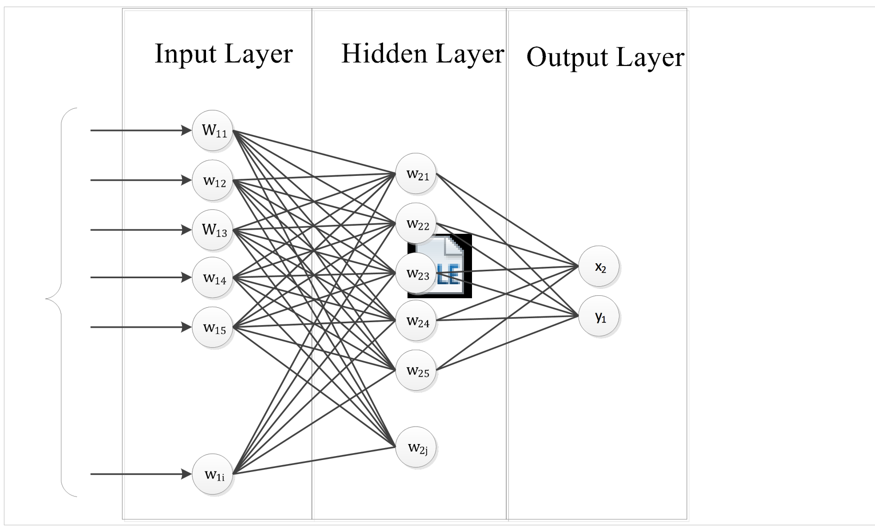


Multi-layer Perceptron Estimation (MPE)

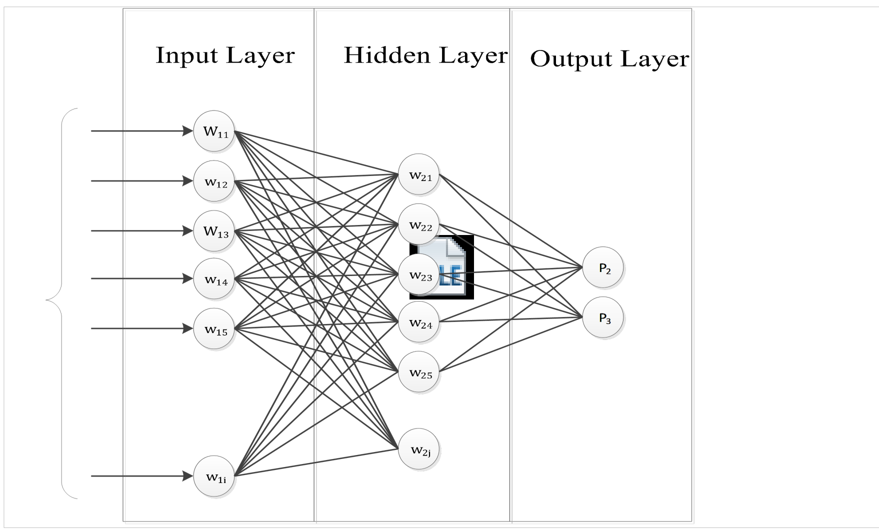
- Multi-layered Perceptrons (MLP)

$$out = t(W \times in + B)$$

Continuous output

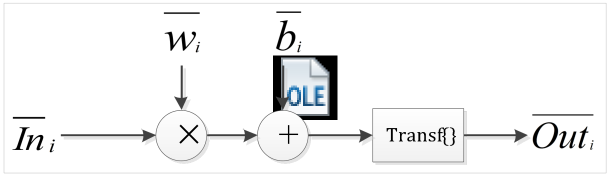


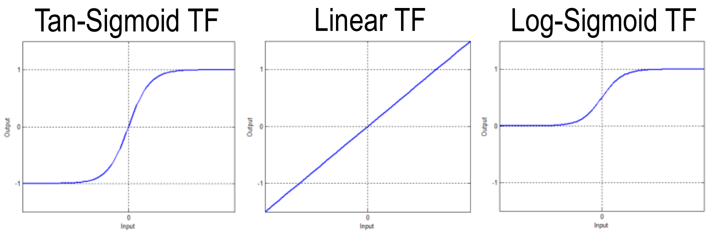
Symbolic output



Multi-layer Perceptron Estimation (MPE)

Neuron Structure





Backpropagation Learning

$$\Delta w_i = f(Err_{Out}, \mu)$$

Input layer neurons	160
Hidden layer neurons	10
Training iterations	1k

Agenda

- Motivation
- Approach
- Multi User Problem
- Approaches
- **Experiment**

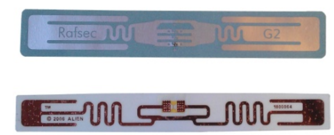
KATHREIN RFID

Hardware

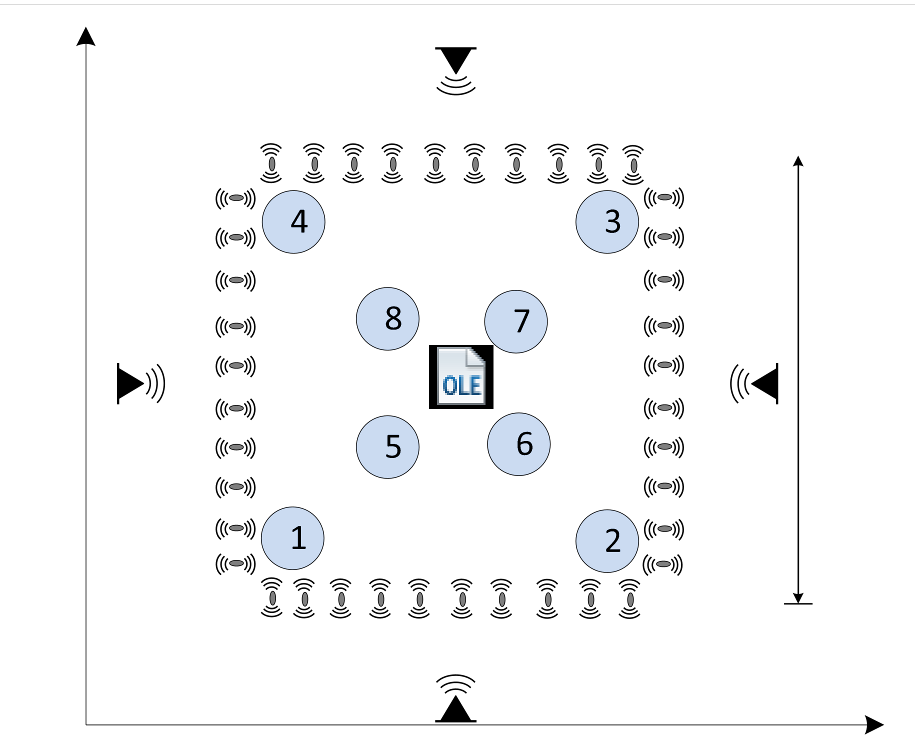
Kathrein
RRU4 UHF Reader

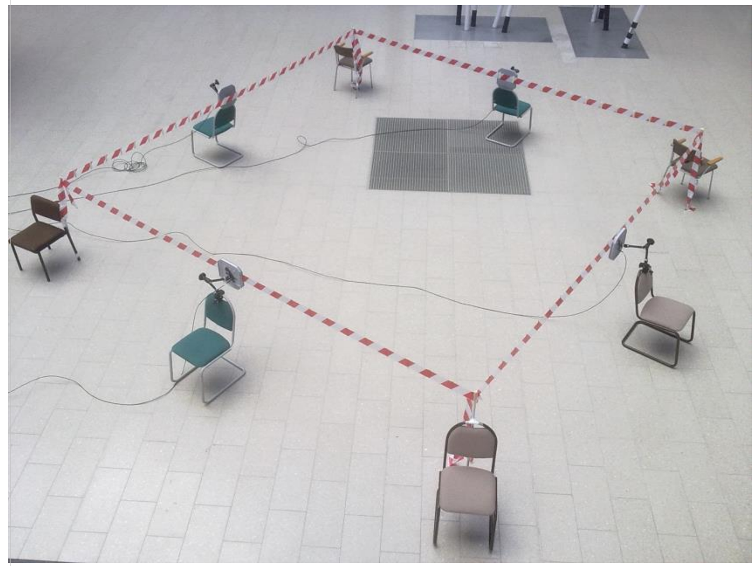
UHF Wide Range Antenna
70° ETSI 868 Mhz

UHF Transponder
„Squiggle“



Setup





Results

- Transponders: 40
- Evaluation Position Combinations: 4

  {(1,3);(2,4);(5,7);(6,8)}

- Measurement: ~ 40s à ~80 Readings/s
- Answer rate: ~ 90%

Approach	Mean error [m]
MRI	1.2759
PDE	0.2964
MLPE – Cont.	0.1154
MLPE – Symb.	0 %

Thank you !

Questions ?

benjamin.wagner@uni-rostock.de