Prof. Dr.-Ing. Oliver Michler

Chair of Transport Systems Information Technology, Director Institute of Traffic Telematics
Faculty of Transportation and Traffic Sciences “Friedrich List” , Technical University of Dresden

A Information Technology View from UWB to mmWave up to VLC in Traffic Telematics Applications

International Conference of Modern Systems Engineering Solutions - IARIA MODERN SYSTEMS 2023

November 13 to November 17, 2023 - Valencia, Spain

Agenda

1) **CV, Chair and Topics of University Research**
2) Introduction - Modern Systems and ICT-based Goal Formulation
3) Information Technology Aspects im Context of Communication
4) Information Technology Aspects im Context of Localization and Sensing
5) Complex Research Example – Parking Project IDEA „Innovative Depot Automation“
6) Conclusion and Future Outlook

1 CV Oliver Michler, University Full Professor

Scientific and Professional Positions (since 1993)

1993 - 1997	Scientific Staff and PhD-Research of TU Dresden, Faculty of Electrical and Computer Engineering
1997 – 2000	Scientific Project manager at Video-Audio-Design GmbH as a Telkom-Partner
2000 – 2005	Scientific Staff at Fraunhofer Institute for Transportation and Infrastructure Systems Dresden (FhG-IVI)
2005 – 2008	Professor at University of Applied Sciences Dresden in Signal Processing and Electronic Measurement Techniques
2010 – 2017	Head of department of TUD-Researchgroup at FhG-IVI
2008 –	Full Professor at TU Dresden in Systems Information Technology, Faculty of Transportation and Traffic Sciences
2019 -	Director of TU Dresden of Institute of Traffic Telematics
2017 -	Scientific advisory board member of MRK AG, Metirionic and ISCons GmbH as a knowledge transfer research

Research topics

data-driven and model-based approaches, wireless mobility systems over all traffic carriers and services, autonomous driving, intelligent vehicle, next generation technologies based of communication/localization/sensing, software defined radio

1 TU Dresden (TUD) ⇒ Campus Overview

- Germany
- Saxony
- Dresden / Capital of Saxony: Dresden

- The Technische Universität Dresden dates back to the Technische Bildungsanstalt Dresden, founded in 1828 and, thus, ranks among the oldest technical-academic educational establishments in Germany.
- The TU Dresden has about 35.000 students and almost 5.000 permanent employees (excepting the Faculty of Medicine), about 400 professors among them, and, thus, is the largest university in Saxony, today.
- TU Dresden now is a multi-discipline university, also offering humanities and social sciences as well as medicine. There are only few universities in Germany which are able to match this broad scientific spectrum.

1 University of Technology in Dresden (TUD)
The “Friedrich List” Faculty of Transport and Traffic Sciences

A unique, interdisciplinary competence center for transportation sciences

- Dresden Institute of Automobile Engineering
- Institute of Railway Vehicles and Railway Technology
- Institute of Railway Systems and Public Transport

- Institute of Logistics and Aviation
- Institute of Transport Planning and Road Traffic
- Institute of Traffic Telematics
- Institute of Transport and Economics

ITVS Informationstechnik für Verkehrssysteme

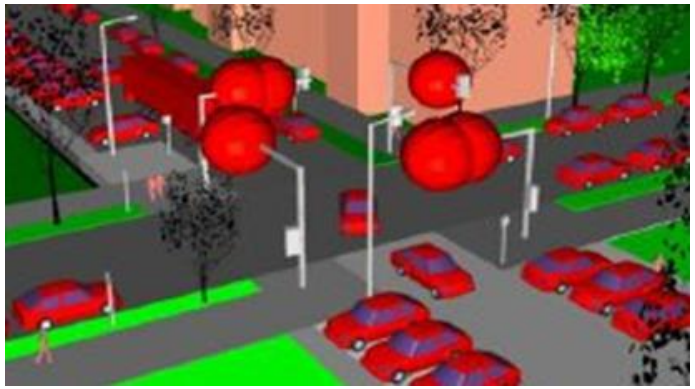
Technological and Market Progress in Transportation & Mobility

Changed Education in Transportation Economy and Transportation Engineering

1 Faculty of Transportation and Traffic Sciences „Friedrich List“
⇒ Selected laboratories at the faculty

- **Laboratories Traffic Control, Process Automation and ITS**

Traffic Control Center



Car2X-Wireless Simulation

Automatic Train Driving

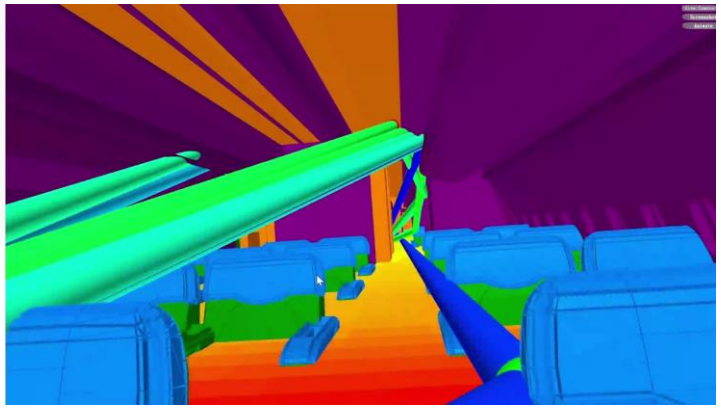
Driving Simulation (Tram)

Test Cars / Vehicle

Automatic Car Driving

1 Faculty of Transportation and Traffic Sciences „Friedrich List“
⇒ Selected laboratories at the faculty

- **Aviation lab / Airbus 320 Simulator**



Application / operation purpose

- Research fields: Trajectory Management and Safety Assessment
- Integration in teaching fields Cockpit Technologies and Navigation
- Training and performance / Aircraft wireless ICT Cabin

1 Traffic ICT and Research fields of Chair competence

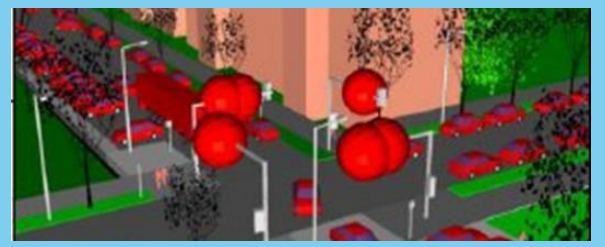
- **Overview:**

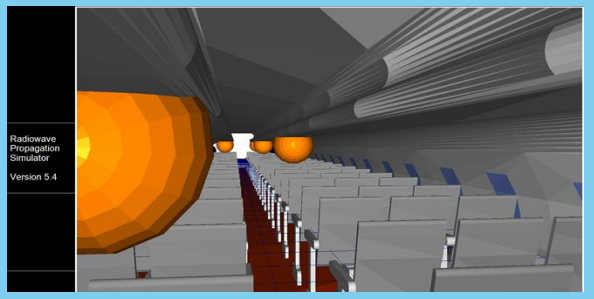
Simulation
Emulation
Radio planning

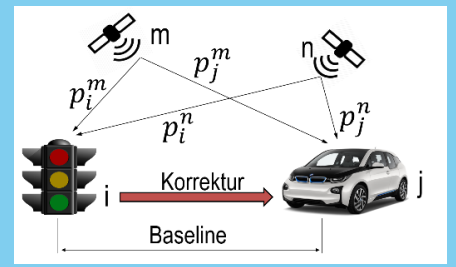
Networking
Localisation
Sensing

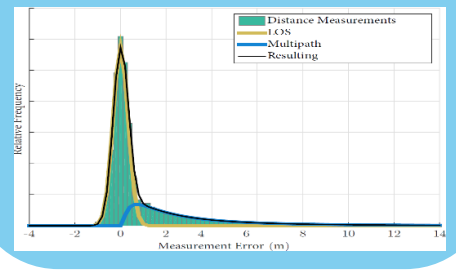
Lab Environment
Experimental -
Vehicles
Test fields

Big data
Statistics
Methodology
Procedures
AI/ML







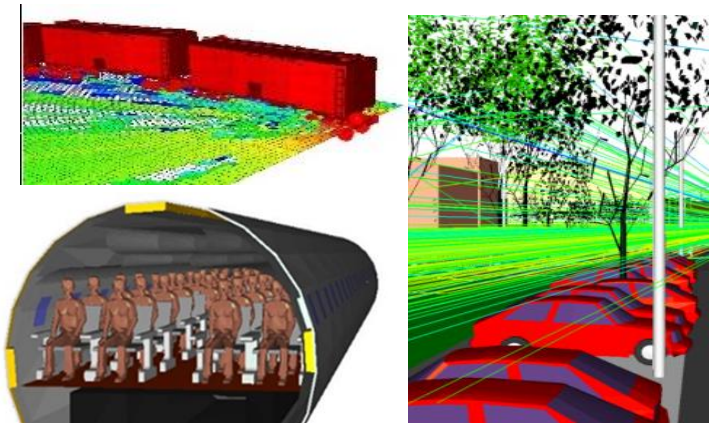


1 Research focus: Traffic carrier cross-modal vehicle environment signals

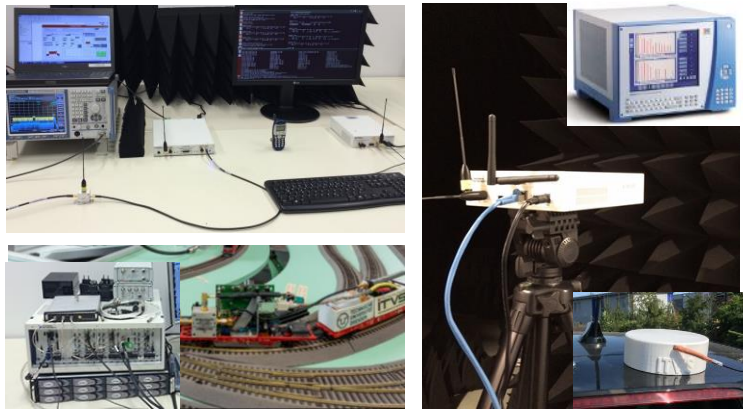
Telematics and IT - Platforms (RF, LF, Software, Protocols, Interfaces, HMI)

Modelling, Parametrisation | **Error analysis, Integrity**

Radio channel simulation (PC environment)



Signal environment generation (Lab environment)



Record/Playback Field measurements (Field-, long term tests)

Automotive ⇨ **Rail transport** ⇨ **Aviation / Aircraft cabin** ⇨ **Water transport**

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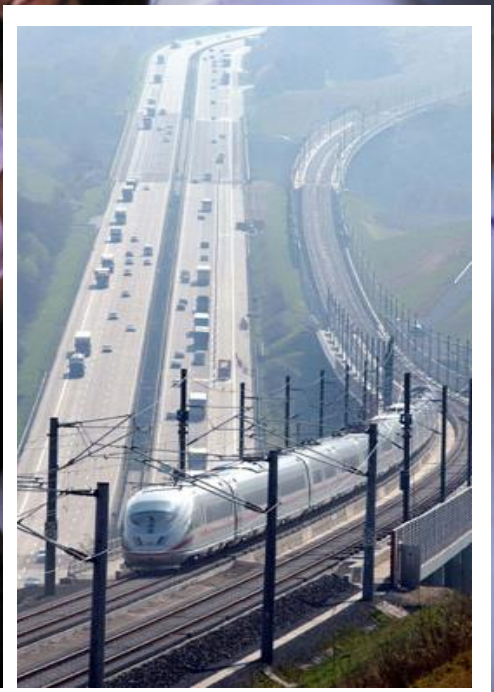
2 Introduction - Modern Systems and ICT-based Goal Formulation

Everything moves and all is Conneced



2 Important Mobility Trends for the Next Decade

[1]

Use of personal data

Digitization

Real-time mobility marketplace

Decarbonization

[3]

E-Mobility

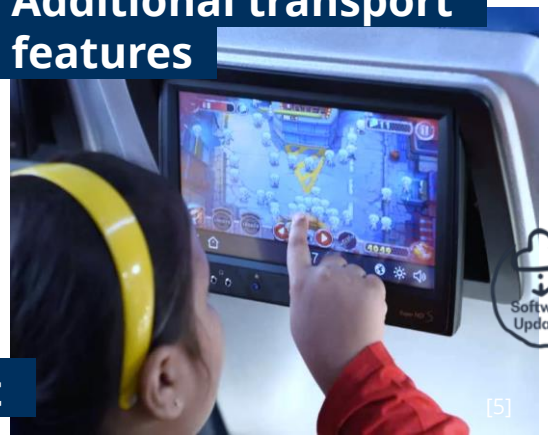
Integrated mobility concepts

[2]

[4]

Integrated and new forms of goods transport

Additional transport features



[5]

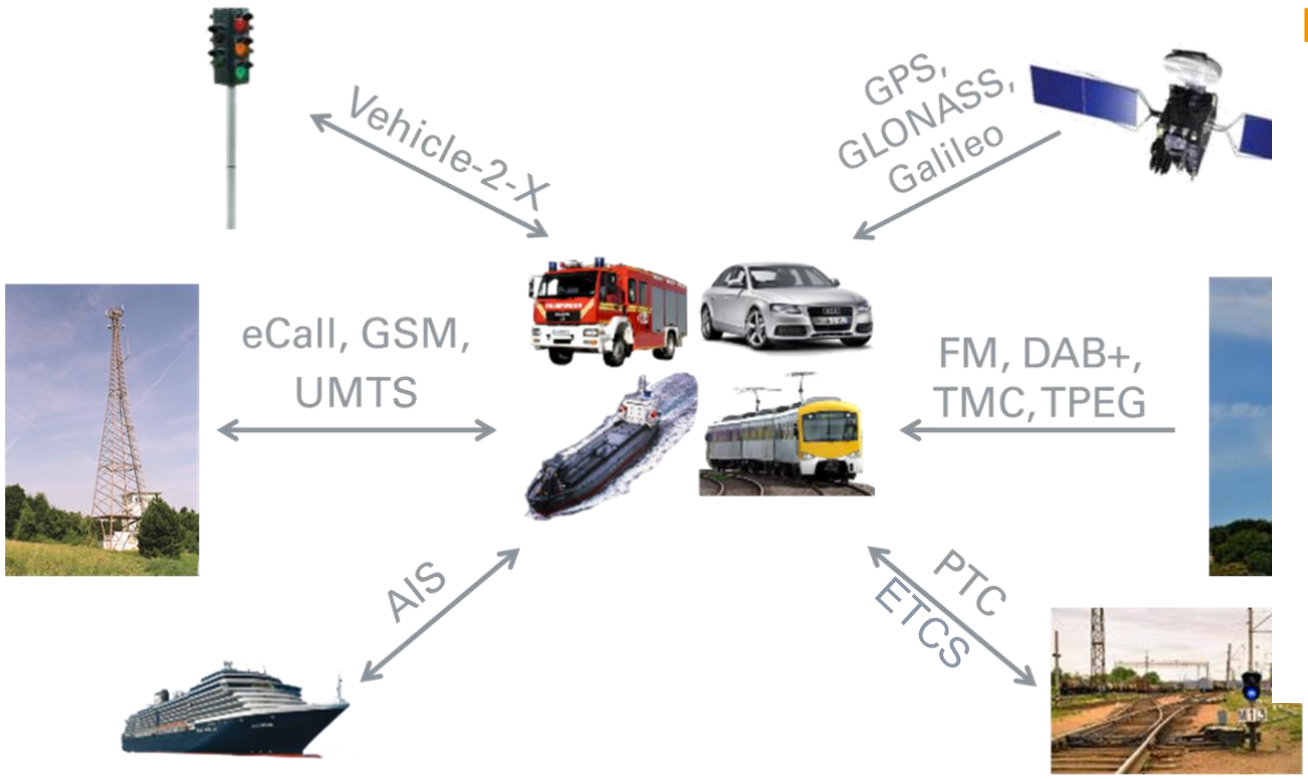
[6]

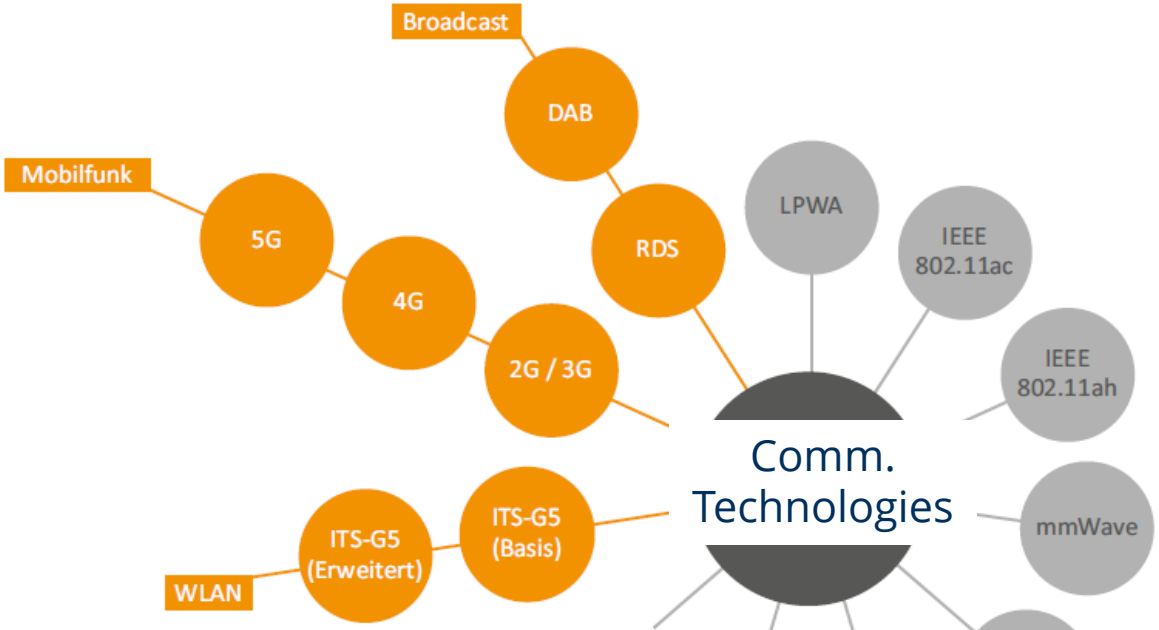
Addressing customer needs

[7]

Autonomous driving

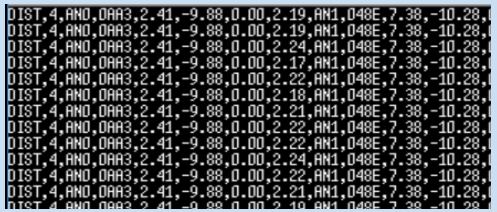
2 Variety of technologies and services



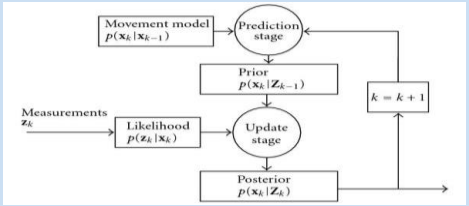


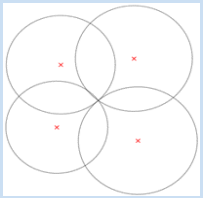
2 Information technology aspects and raw data (TUD-ITVS Framework)

Data input

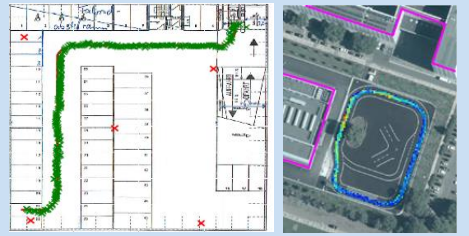


Communication / Positioning / Tracking / Sensing





Visualization

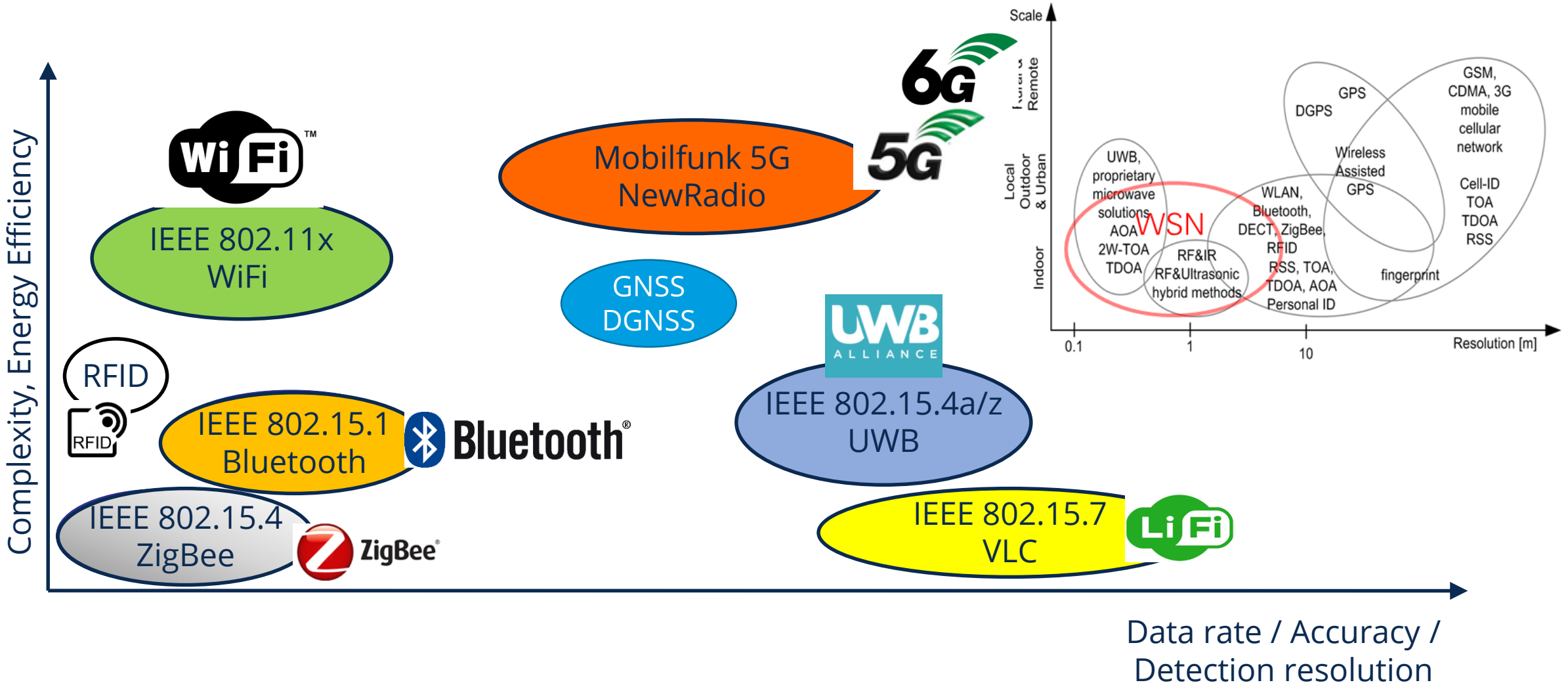


Client/Server -> Database Software

Technology Candidates:

IEEE 802.15.x (BLE, UWB, ZigBee, ...), IEEE 802.11.x (WiFi 2,4/5GHz); MobilComm (5G, 6G), IEEE 802.15.7 (LiFi)

2 IoT–Communication, Localization / Tracking and Sensing Cross Technolgies



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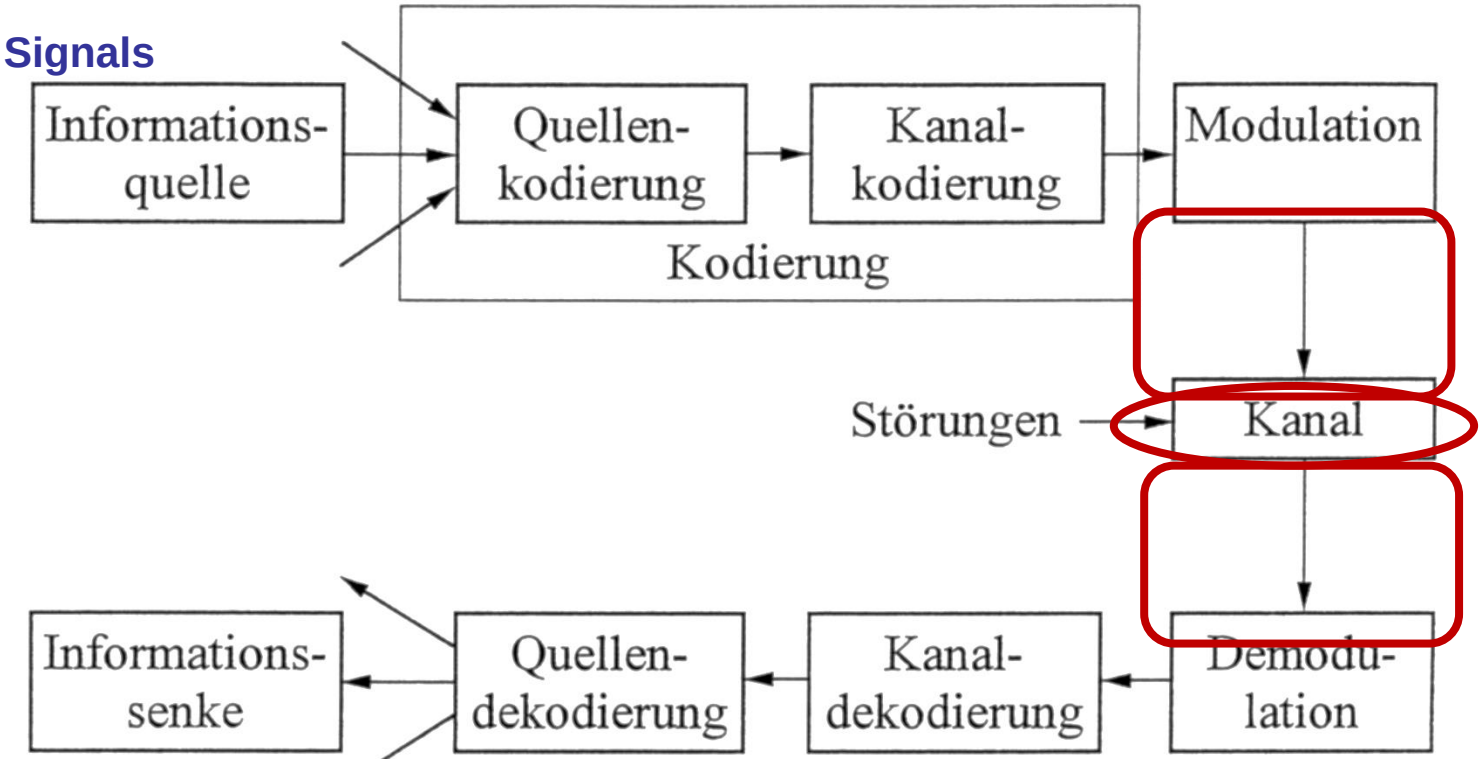
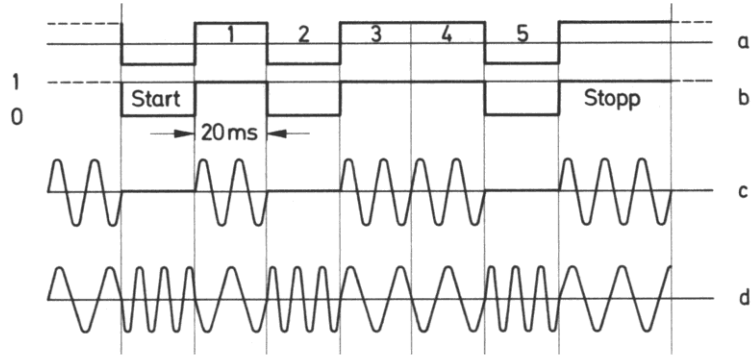
3 Information Technology Aspects im Context of Communication

Begin

Signals



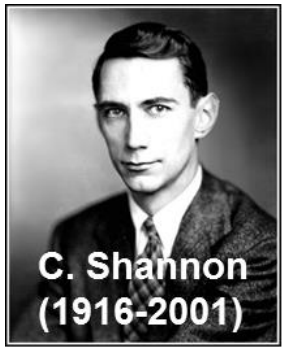
End



(Transmitting) Antenna

(Receiving) Antenna

3 Information Technology Aspects / Shannon



Shannon Channel Capacity Theorem (1948)

$$C = B \cdot ld\left(1 + \frac{P_S}{P_N}\right)$$

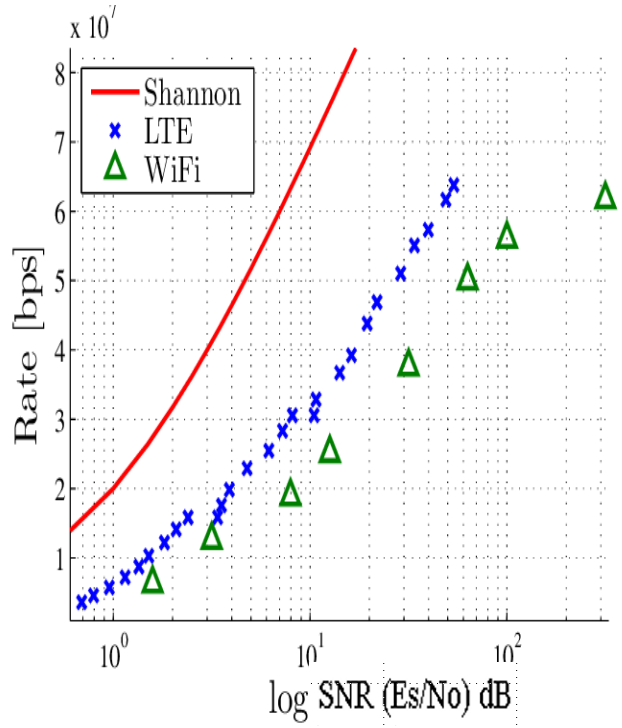
$$ld(x) = \frac{lg(x)}{lg\,2} \qquad \frac{P_S}{P_N} >> 1$$

$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$

Bandwidth
B / [MHz]

Channel capacity C max. Data rate [Mbit/s]

Signal-to-Noise Ratio SNR /[dB]



Quelle: https://www.researchgate.net/

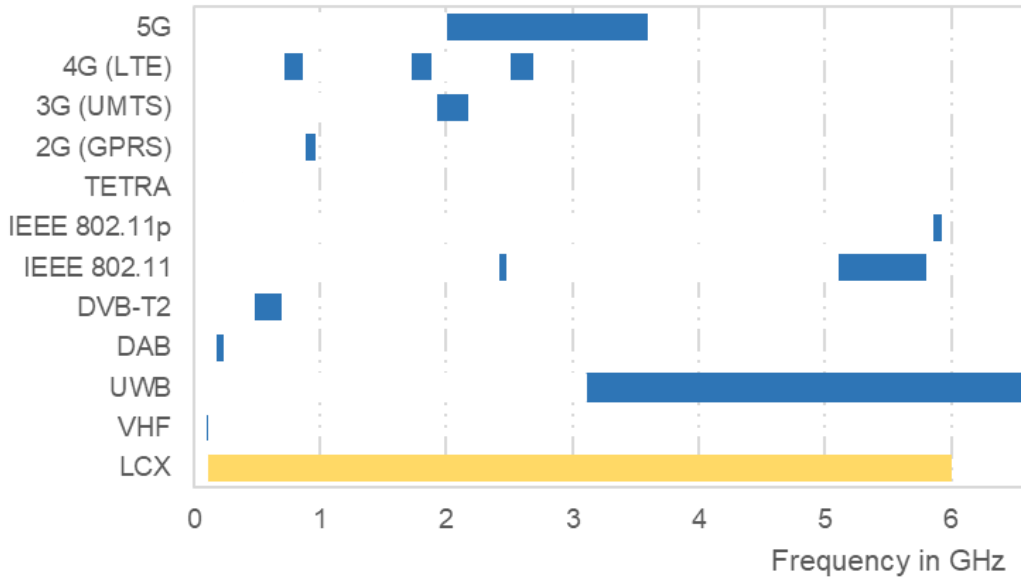
3 Information Technology Aspects / Optimization

$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$

$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$

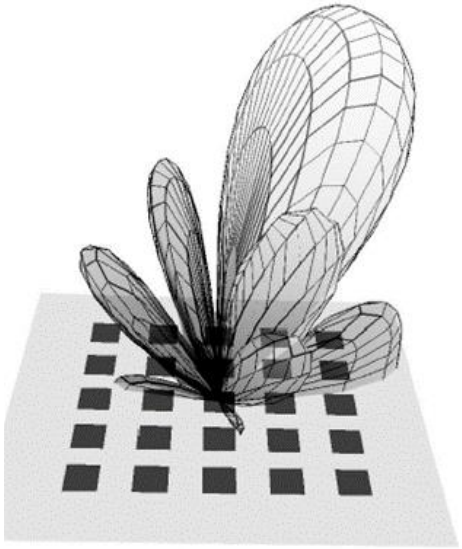
C ↑ = **Bandwith B ↑ / UWB, mmWave, VLC**

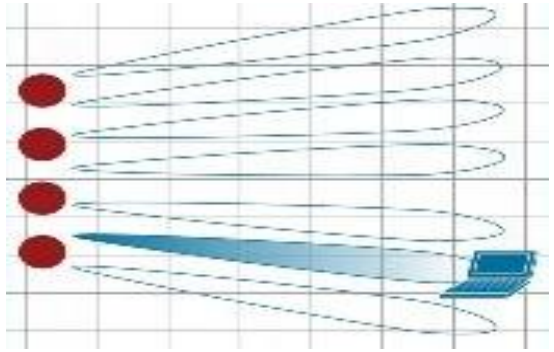
C↑ with **Link-Aggregation / Channel bundling**



C ↑ = **SNR ↑ Technology / UWB, mmWave, VLC**

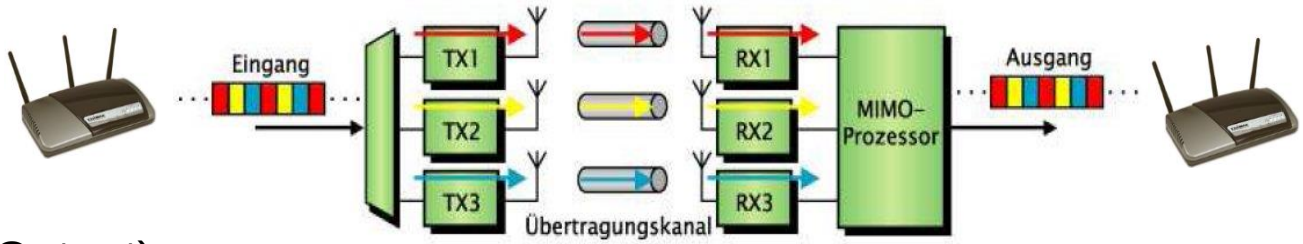
C ↑ with **Beamforming / Link-Focusing**





3 Information Technology Aspects / Optimization (1 + 2)

$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$



C↑ with **MIMO** (Multiple Input Multiple Output)

$$C = B \cdot ld\left(1 + \frac{P_S}{P_N}\right)$$

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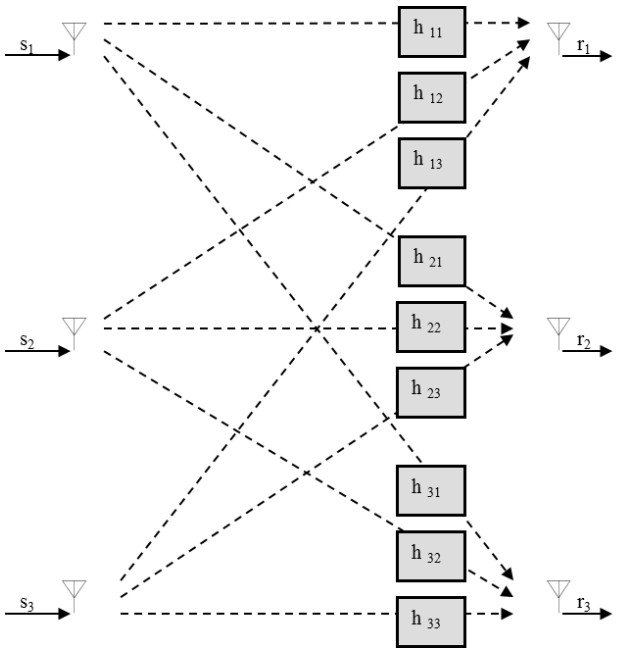


$$\underline{r} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \cdot \underline{s} = \underline{H} \cdot \underline{s}$$

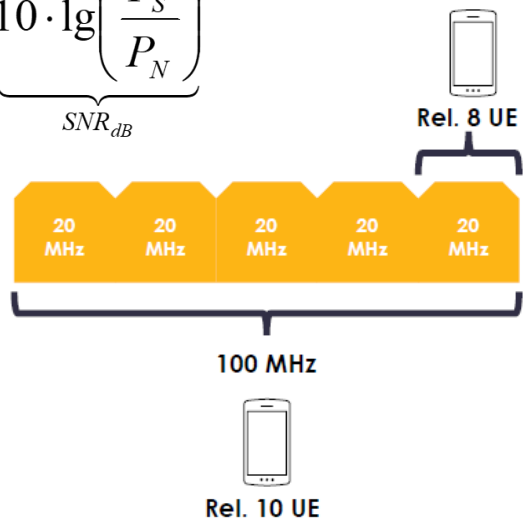
Bed.: non-singular
or invertible matrix

$$C_{MIMO} = 3x\, C_{Single}$$

3 Information Technology Aspects / 5G

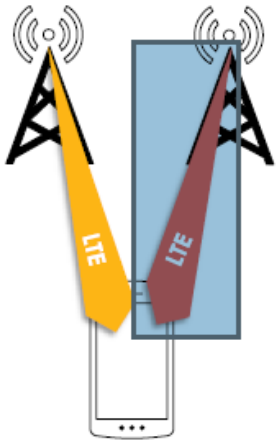
- Key features of 5G (NR - New Radio)
  - Higher data rates - up to 20Gbit/s per user
  - Significantly larger network capacity Networ slicing
  - Extremely low latency
  - Better energy efficiency

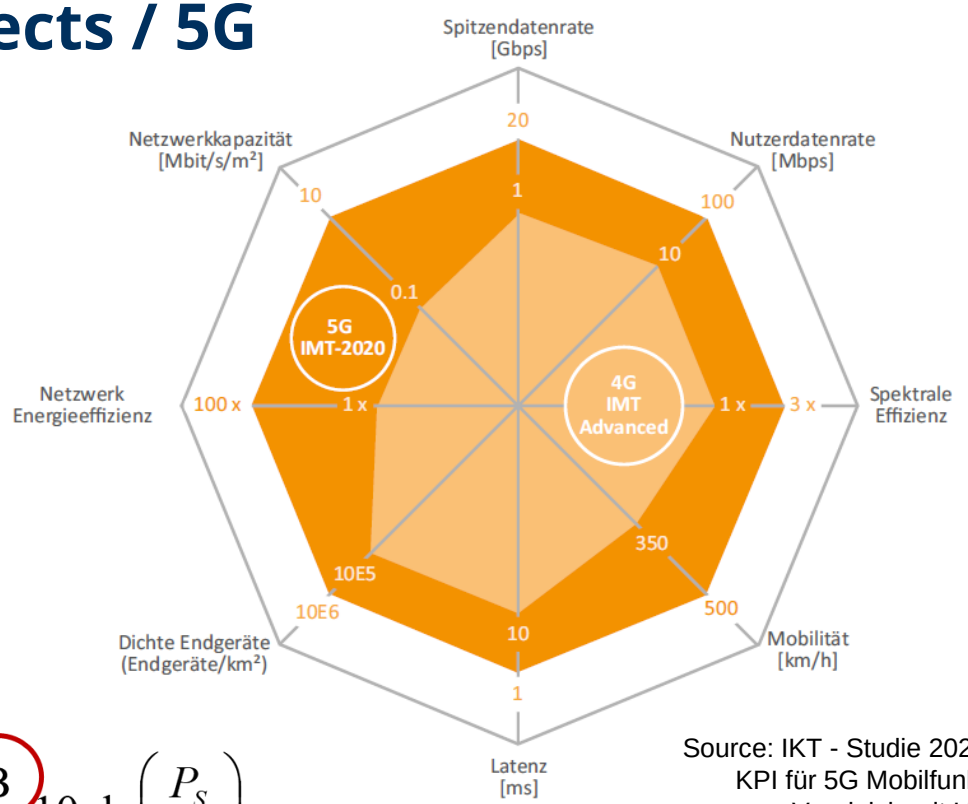
$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$



$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$

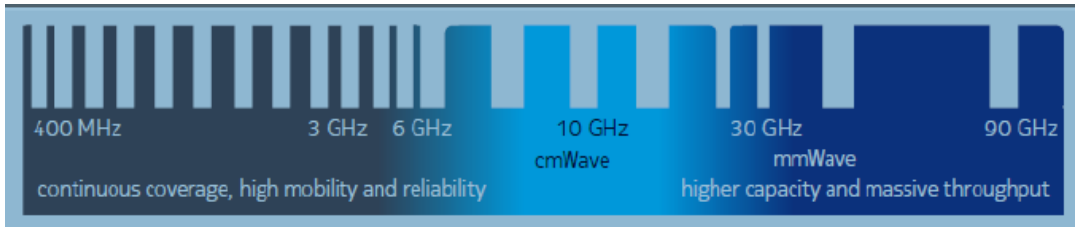
Licensed + Unlicensed





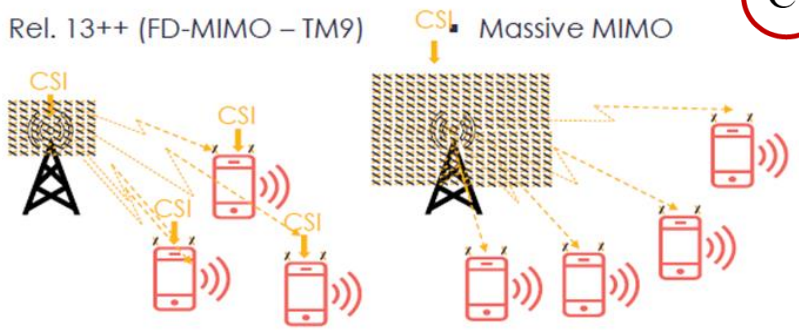
Source: IKT - Studie 2025 / KPI für 5G Mobilfunk – Vergleich mit LTE

$$C \approx \frac{B}{3} \cdot \underbrace{10 \cdot \lg\left(\frac{P_S}{P_N}\right)}_{SNR_{dB}}$$



3 Information Technology Aspects / 5G (2)

- Antenna-side innovations – Principles

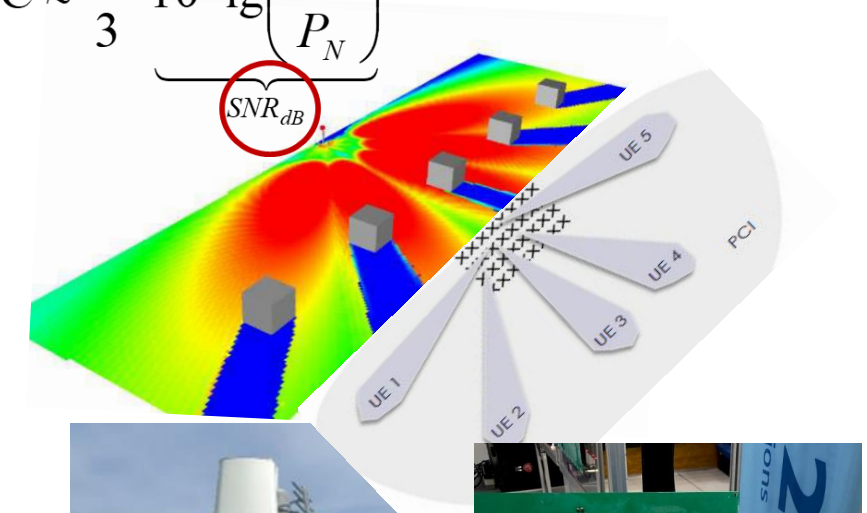


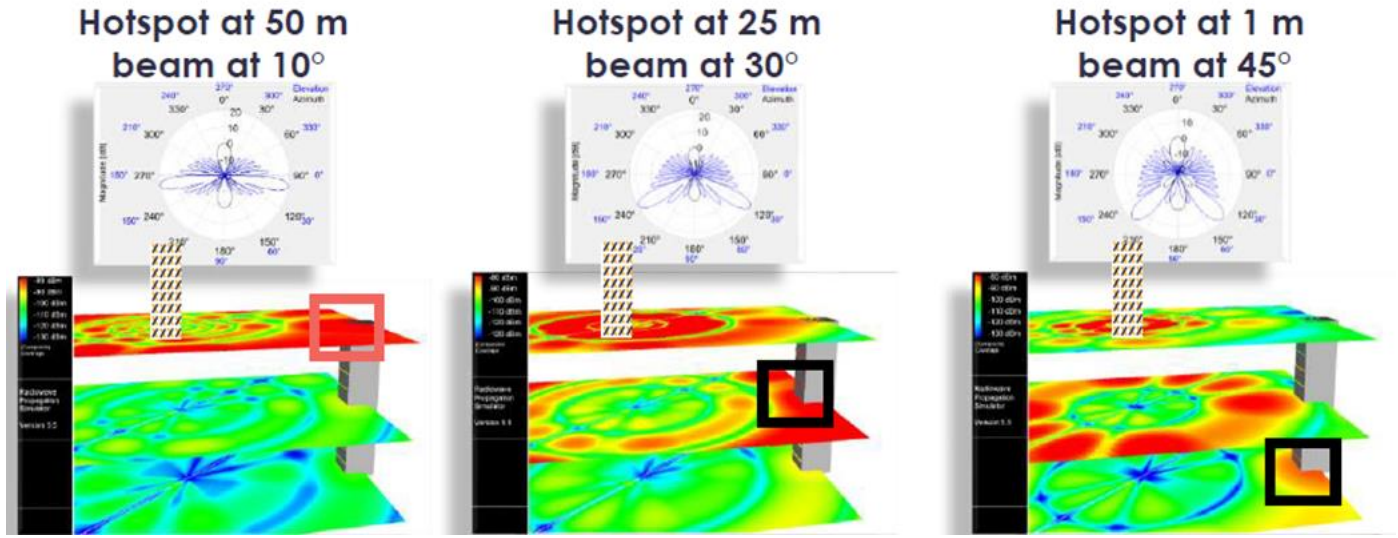
$$C \approx \frac{B}{3} \cdot 10 \cdot \lg\left(\frac{P_S}{P_N}\right)$$

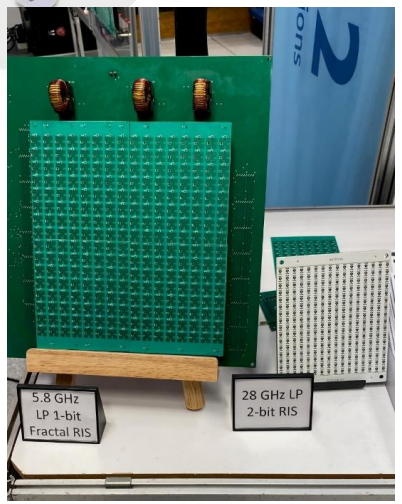
SNR_{dB}

$$C \approx \frac{B}{3} \cdot 10 \cdot \lg\left(\frac{P_S}{P_N}\right)$$

SNR_{dB}

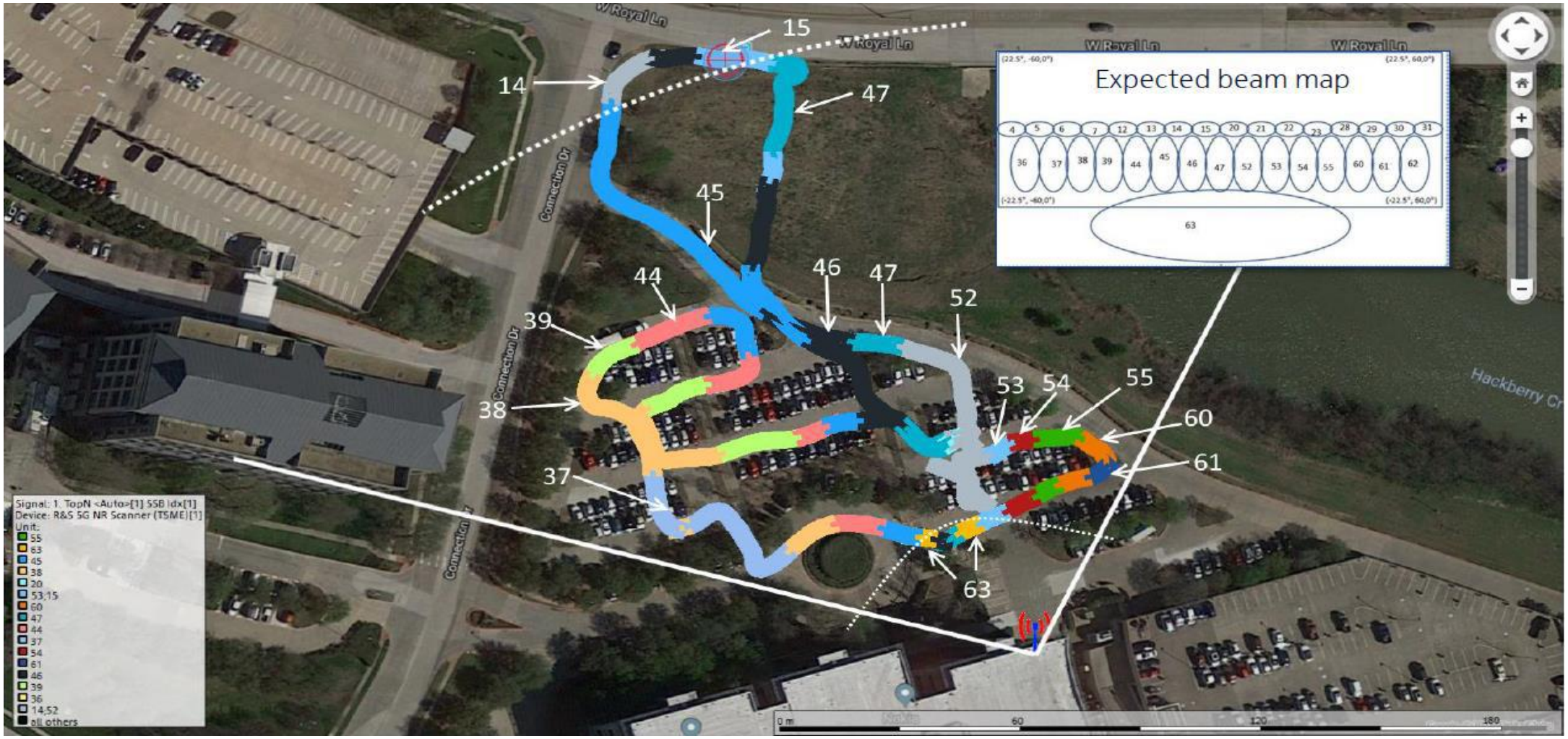






3 Information Technology Aspects / 5G (3)

- Antenna-side innovations - Field test results



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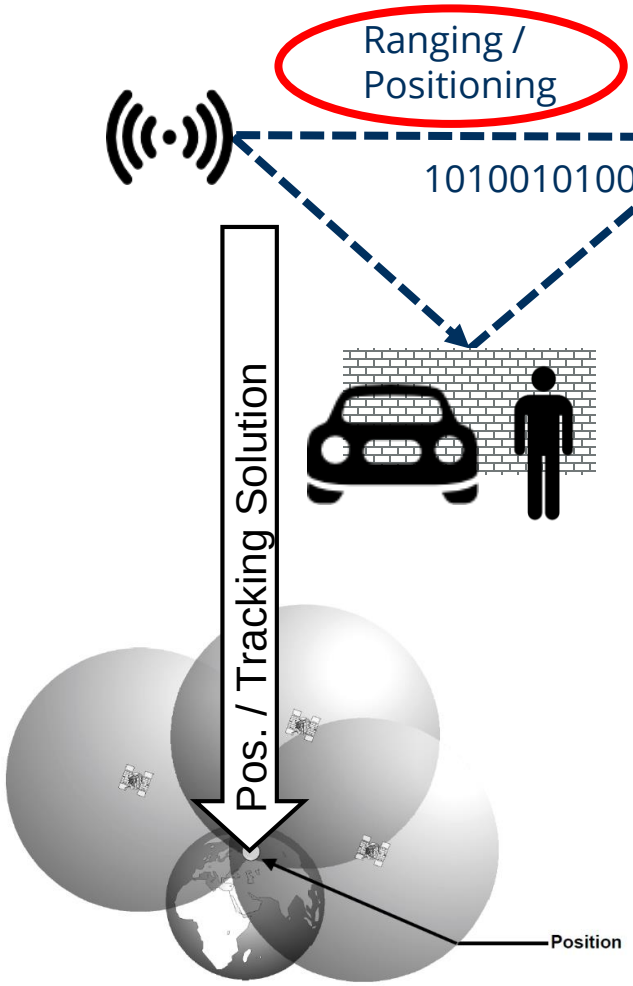
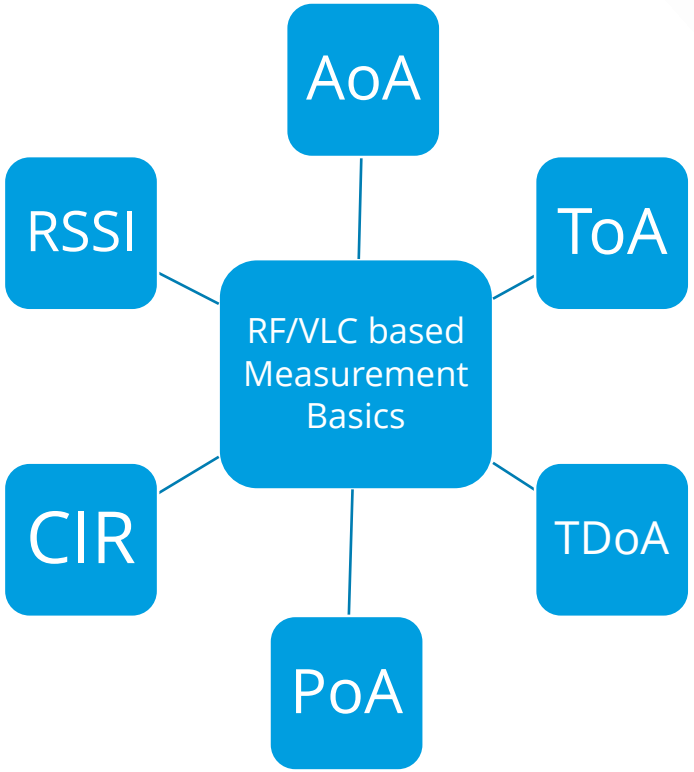
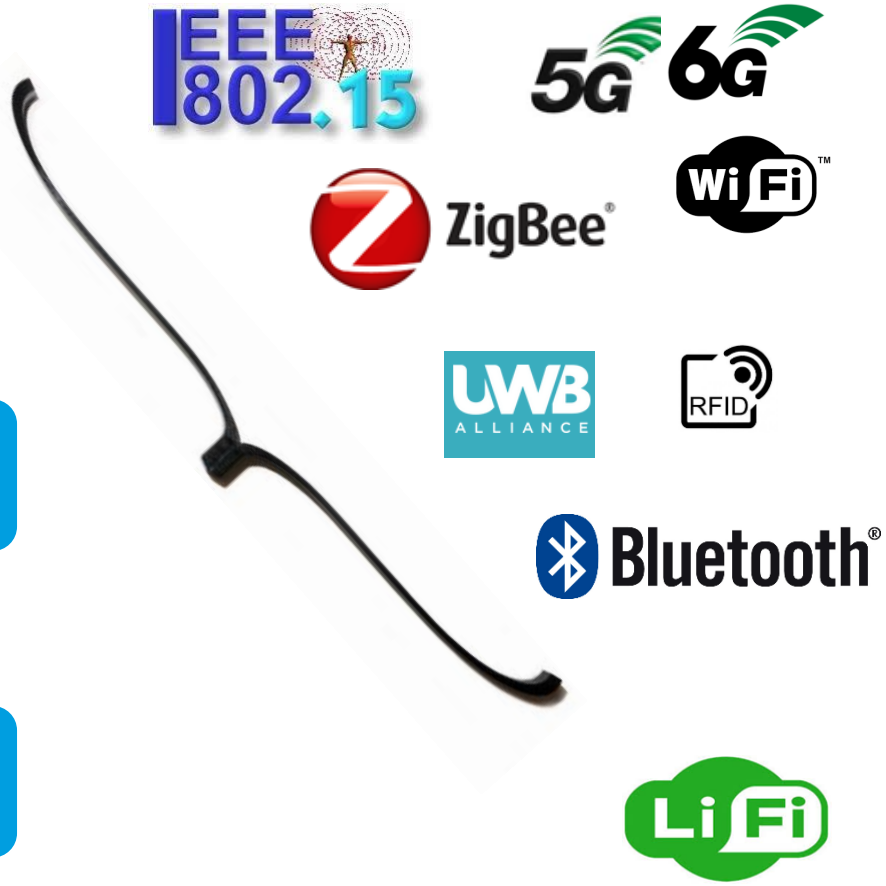
4 Information Technology Aspects im Context of Localization and Sensing

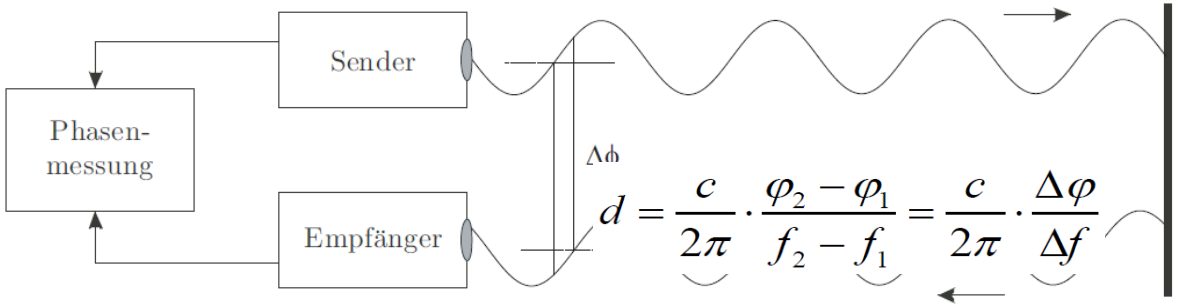




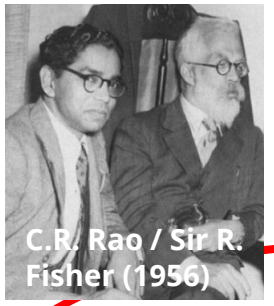


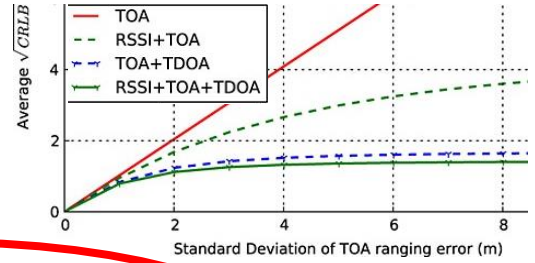
4 Information Technology Aspects / CRL-Bound

e.g.
Phase



Cramer Rao Lower (Fisher) Bound (1945/46)





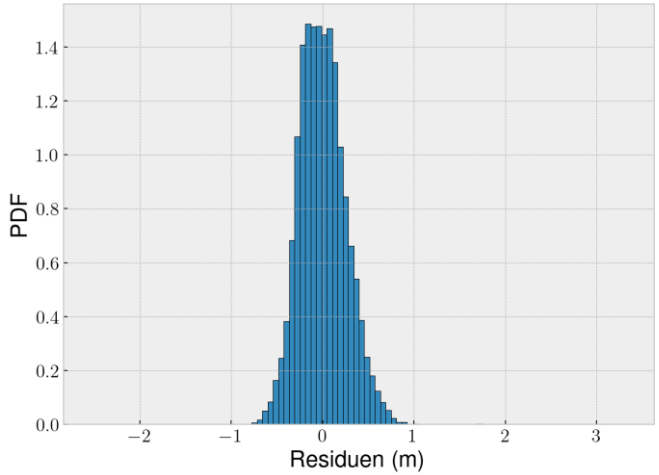
$$\sqrt{Var(d)} \geq \frac{c}{2\sqrt{2\pi}\sqrt{SNR}\,B}$$

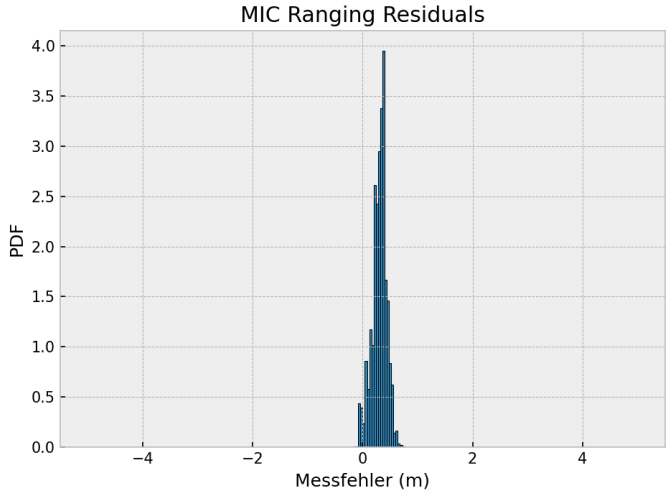
Signal-to-Noise Ratio

SNR

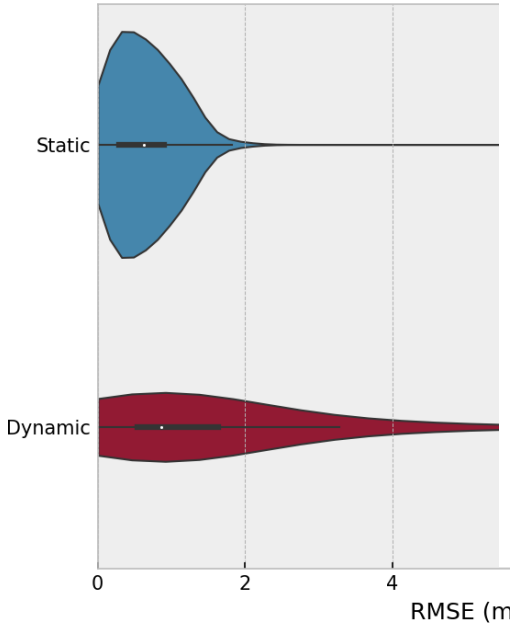
Bandwidth

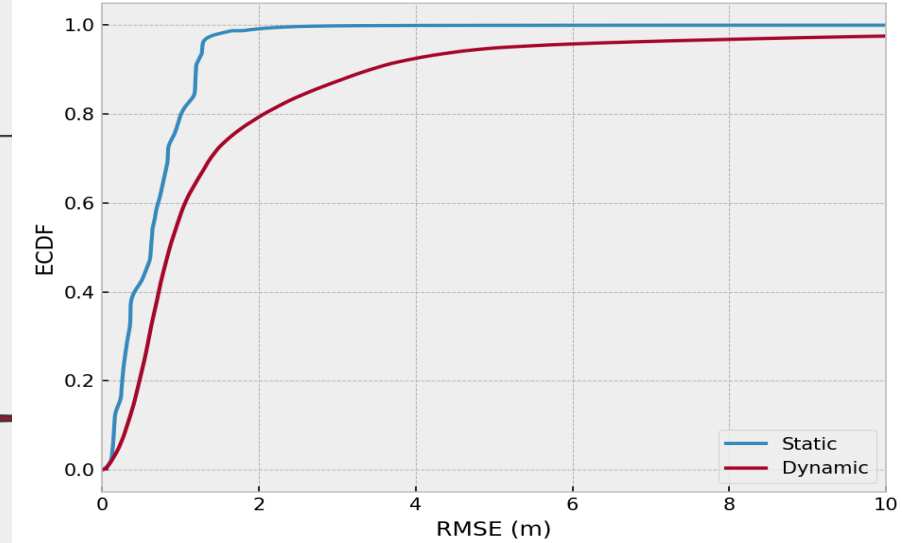
B

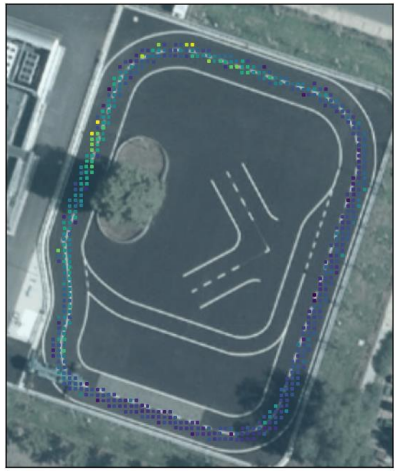


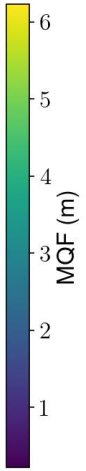


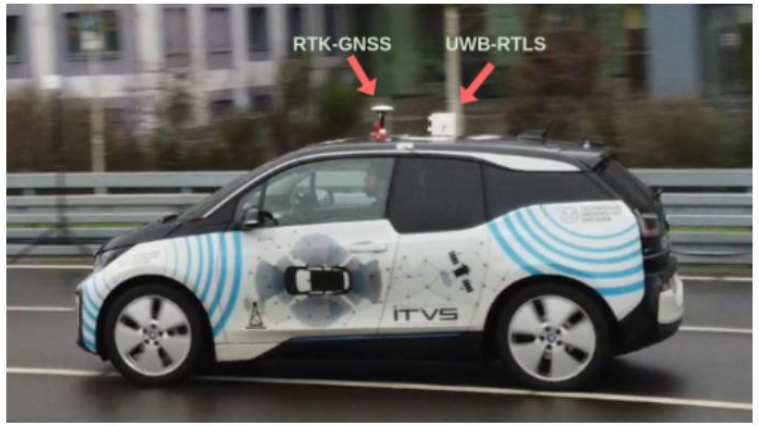
4 Information Technology Aspects / Real Conditions



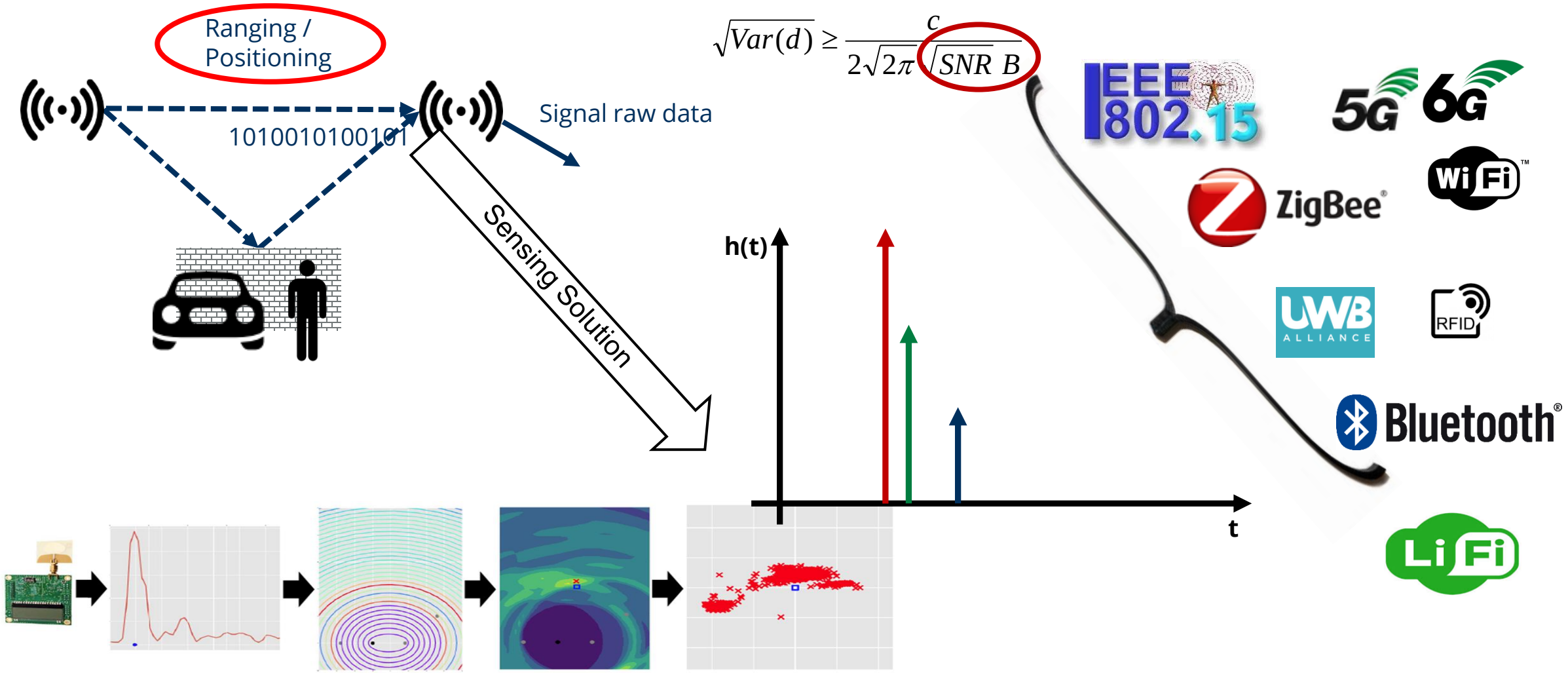


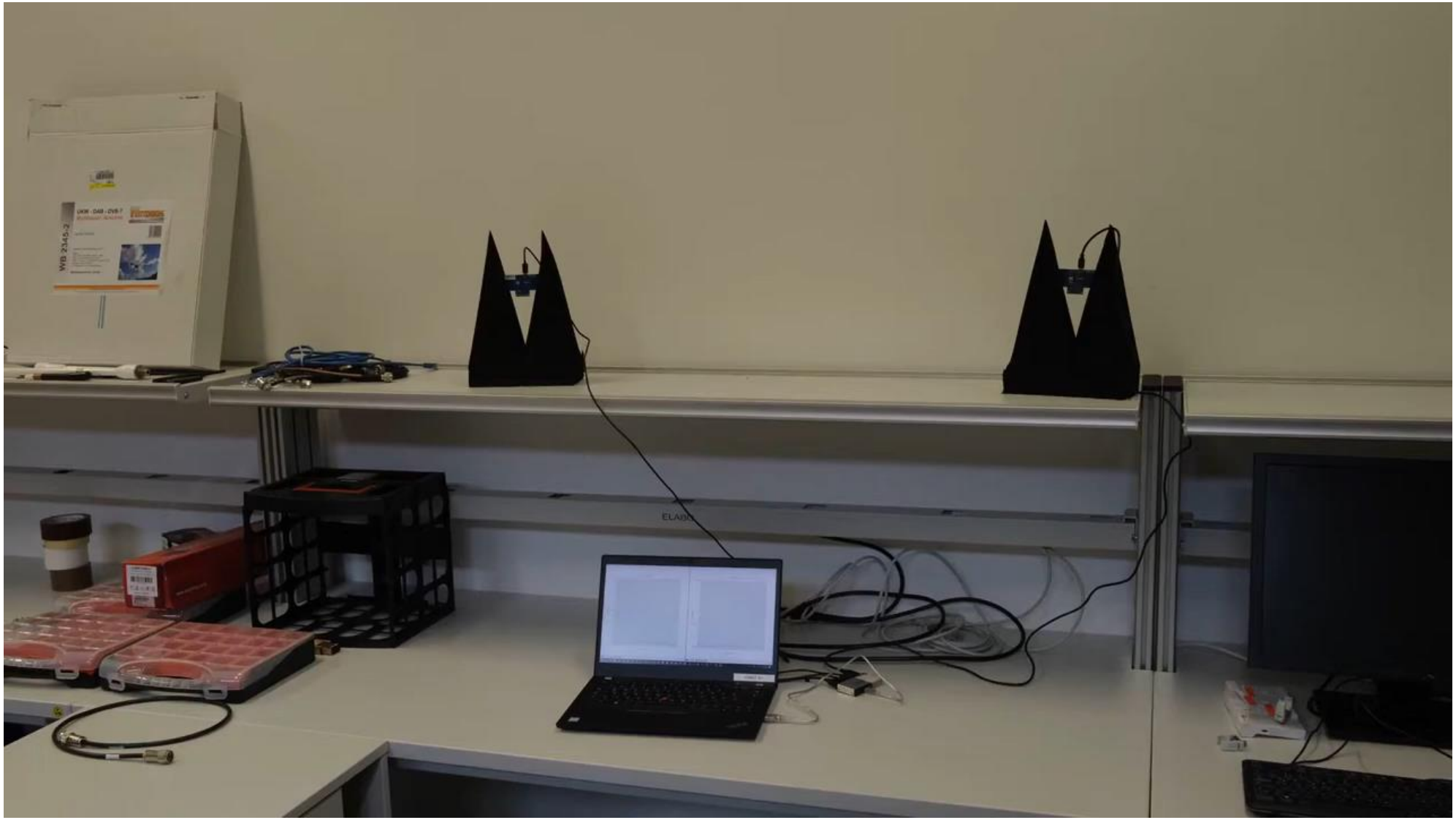






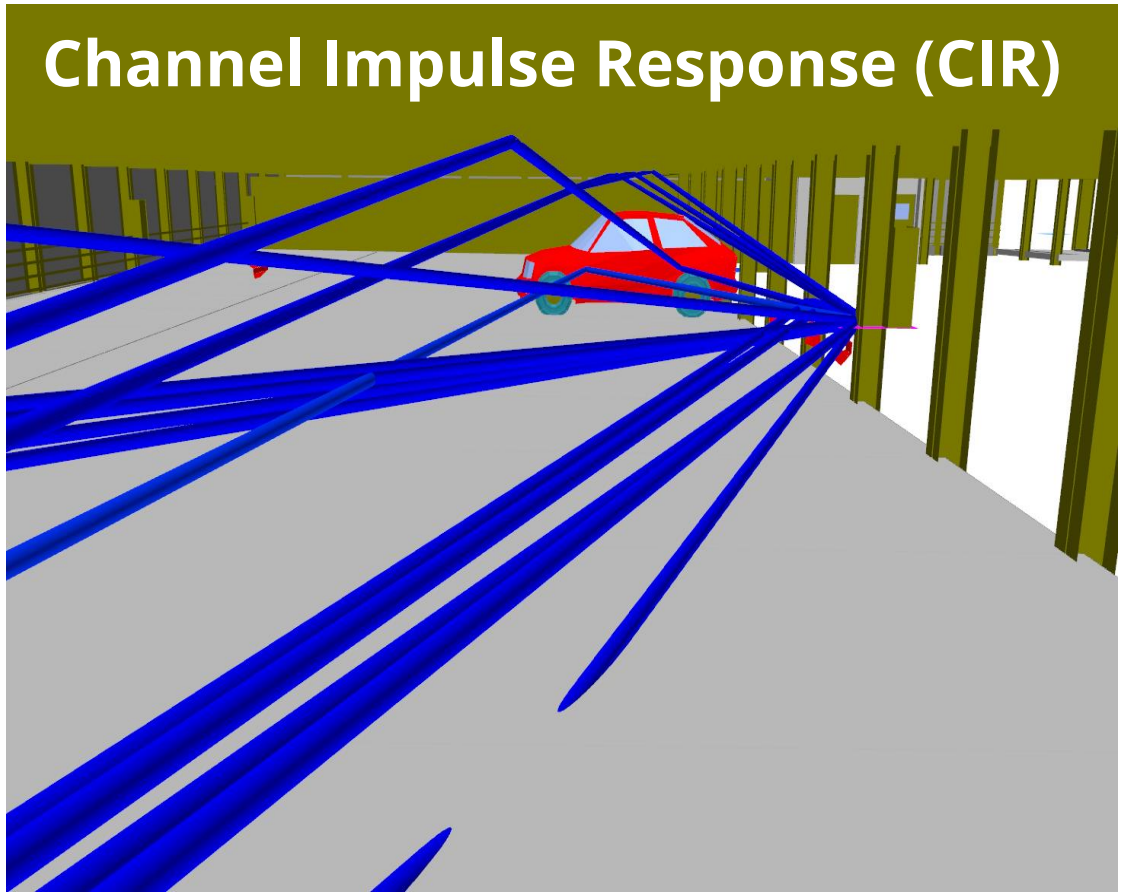
4 Information Technology Aspects im Context of Localization and Sensing



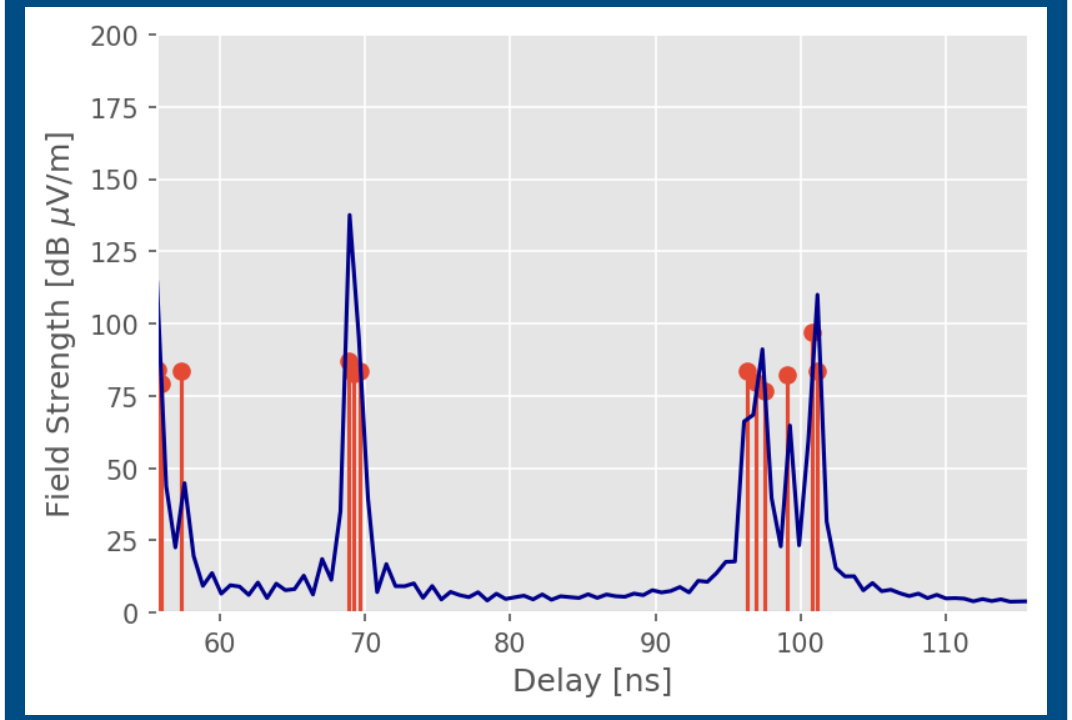


4 Approach for Multipath-assisted Radio Sensing

Example: Radio Sensing for Smart Parking Systems (2)

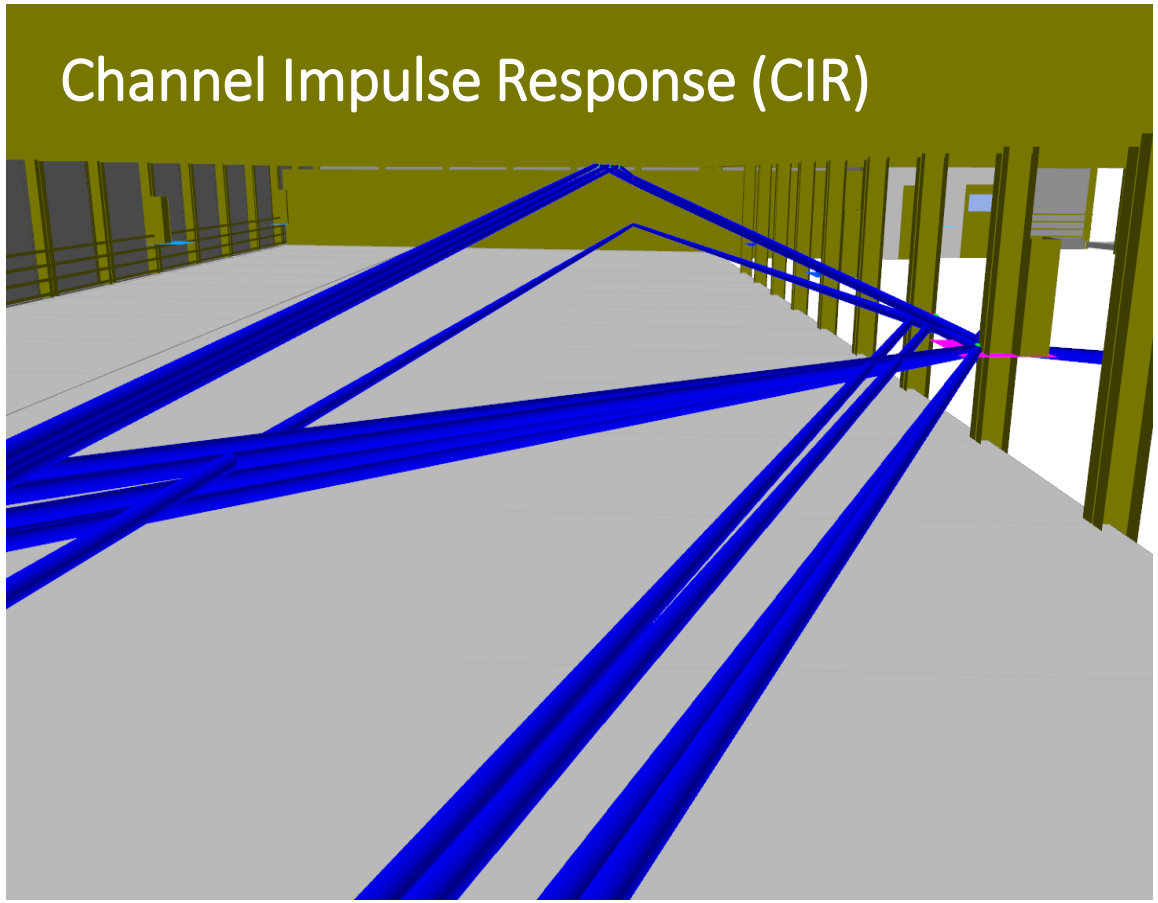


CIR - Subtraction

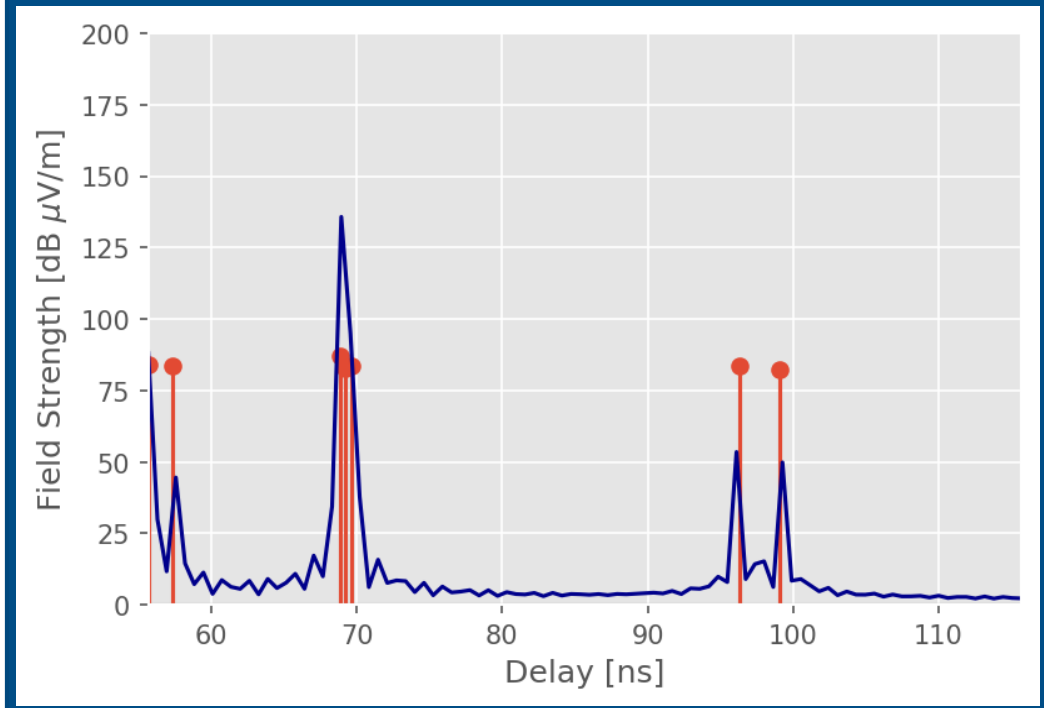


with vehicle

4 Approach for Multipath-assisted Radio Sensing



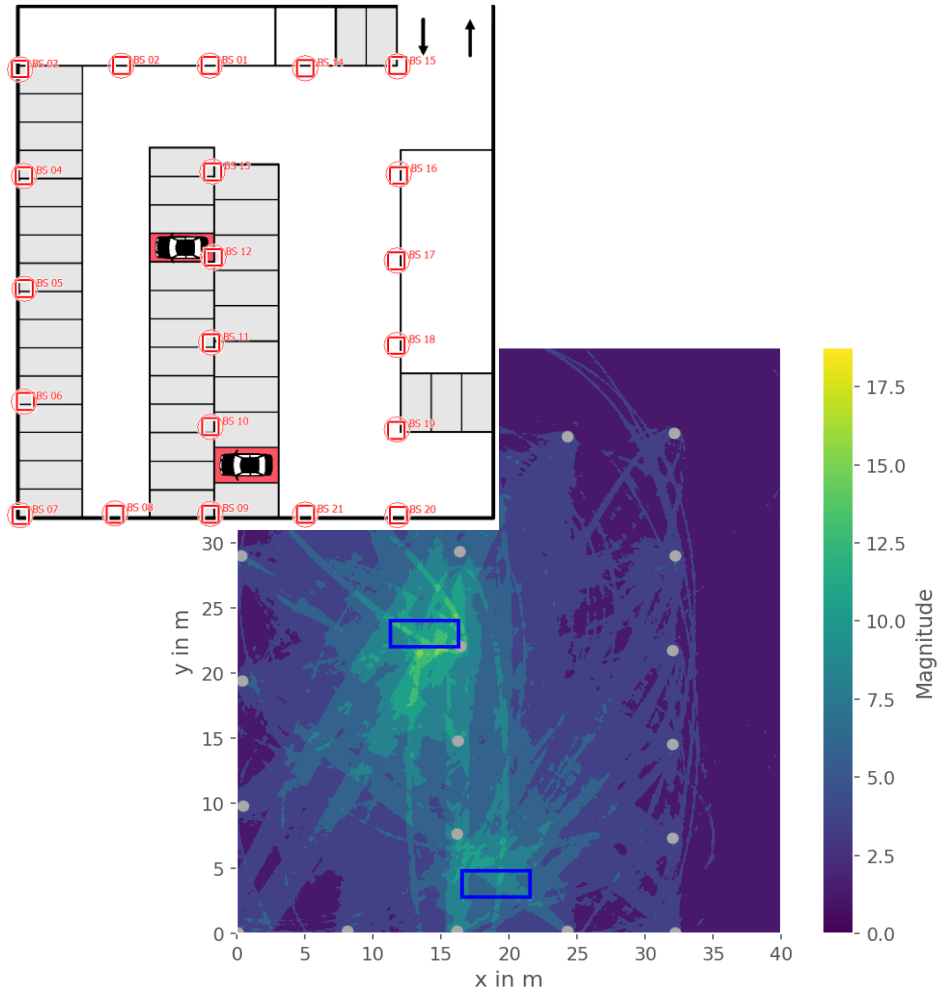
CIR - Subtraction

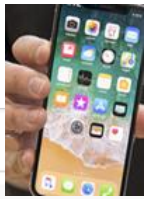


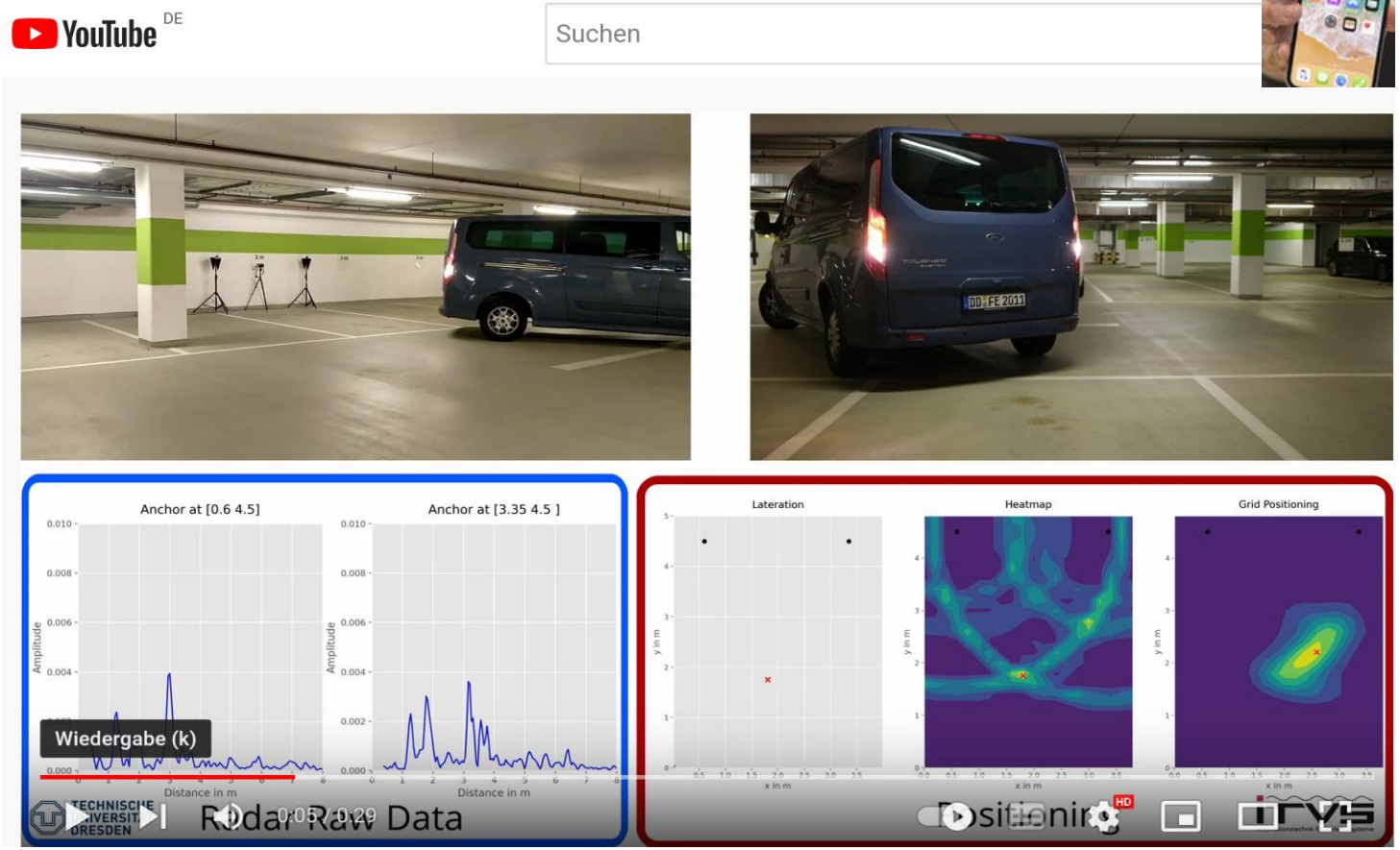
without vehicle

4 Approach for Multipath-assisted Radio Sensing

Example: Radio Sensing for Smart Parking Systems ⇒ Result/Service





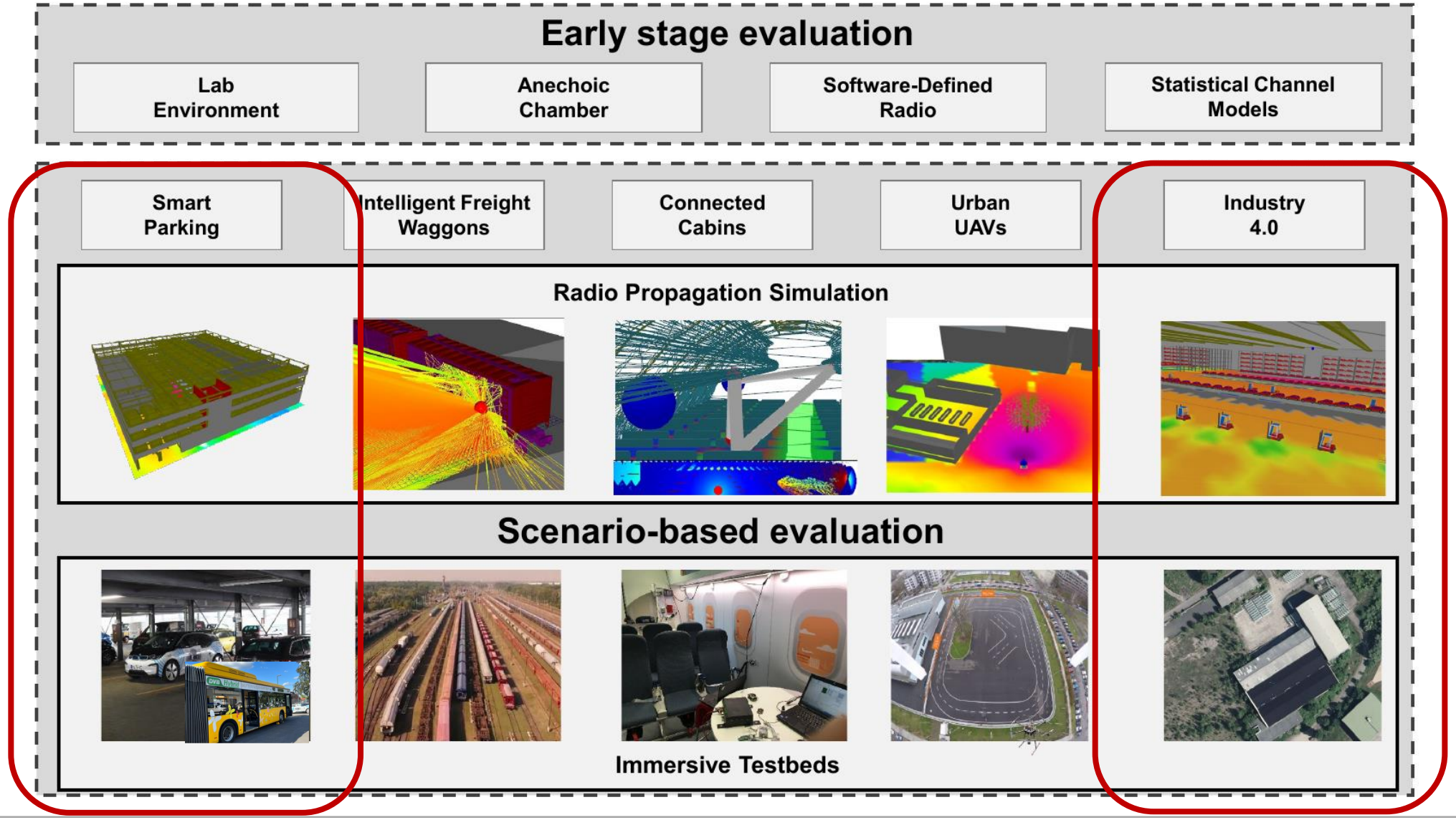


Parking Lot Occupancy Detection with UWB Radar

Agenda

1) CV, Chair and Topics of University Research
2) Introduction - Modern Systems and ICT-based Goal Formulation
3) Information Technology Aspects im Context of Communication
4) Information Technology Aspects im Context of Localization and Sensing
5) **Complex Research Example – Parking Project IDEA „Innovative Depot Automation“**
6) Conclusion and Future Outlook

5 Complex Research Example – Project IDEA „Innovative Depot Automation“



5 Complex Research Example – Project IDEA / Overview

IDEA - Innovative Depot Automation

INNONT
INNOVATIVE NETZTECHNOLOGIEN

Gefördert durch:

Bundesministerium für Digitales und Verkehr

aufgrund eines Beschlusses des Deutschen Bundestages

idea
INNOVATIVE DEPOT AUTOMATION

MRK MANAGEMENT CONSULTANTS

TECHNISCHE UNIVERSITÄT DRESDEN

FZM ITVS

PSI

Project duration: 01.04.2023 - 31.12.2024 (21 months)

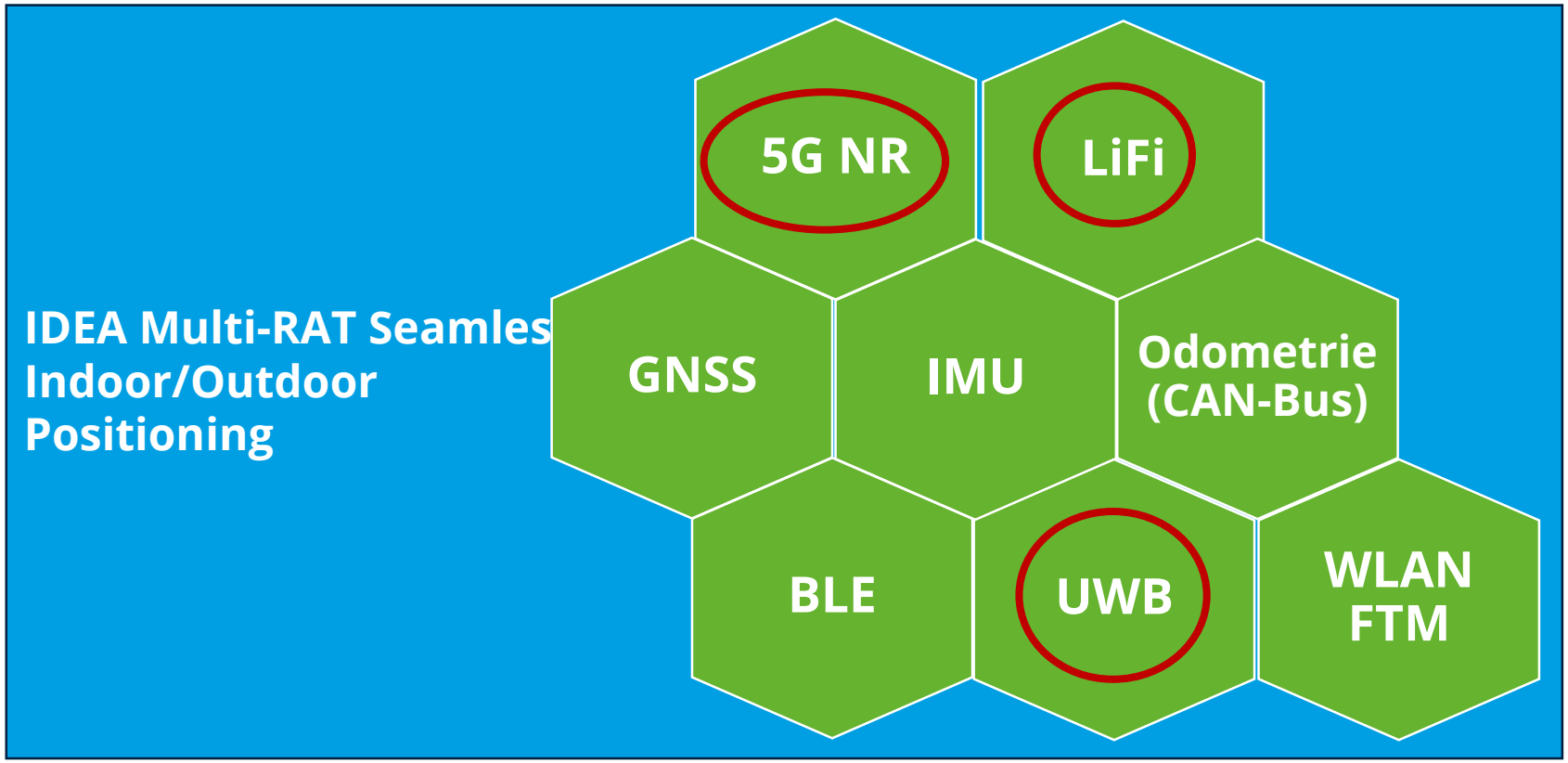
The project IDEA aims to research the automation of vehicle depots in transport companies by means of innovative, radio-based communication between autonomously moving vehicles and a depot management system via a 5G campus network, and to test and validate the solutions developed with real vehicles in a laboratory environment.

Grantor: TÜV Rheinland Consulting GmbH on behalf of the Federal Ministry for Digital and Transport (BMDV)

Funding call: Innovative Netztechnologien (InnoNT) of the Federal Ministry for Digital and Transport (BMDV)

https://www.youtube.com/watch?v=jwH3PtwqblQ

5 Complex Research Example – Project IDEA / Technologies



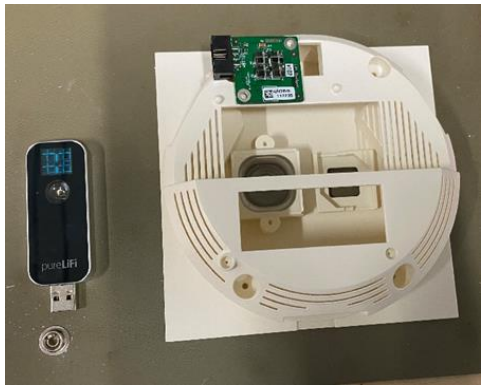
Advantages for positioning:

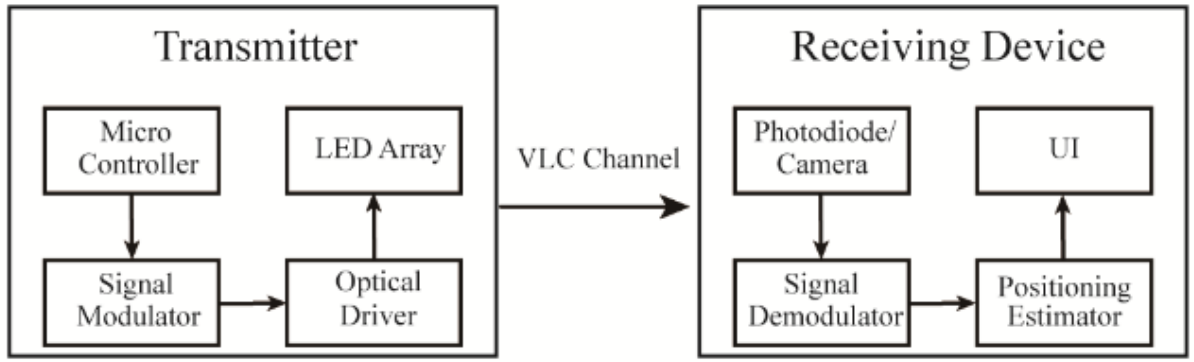
Increase in:

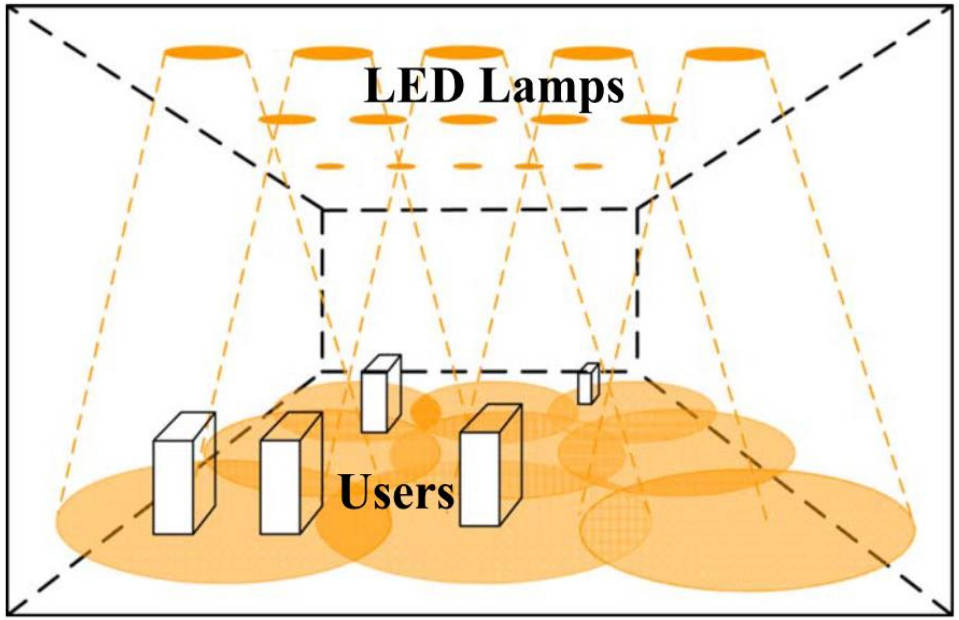
- Availability (physical)
- Redundancy
- Interoperability
- Accuracy
- Integrity

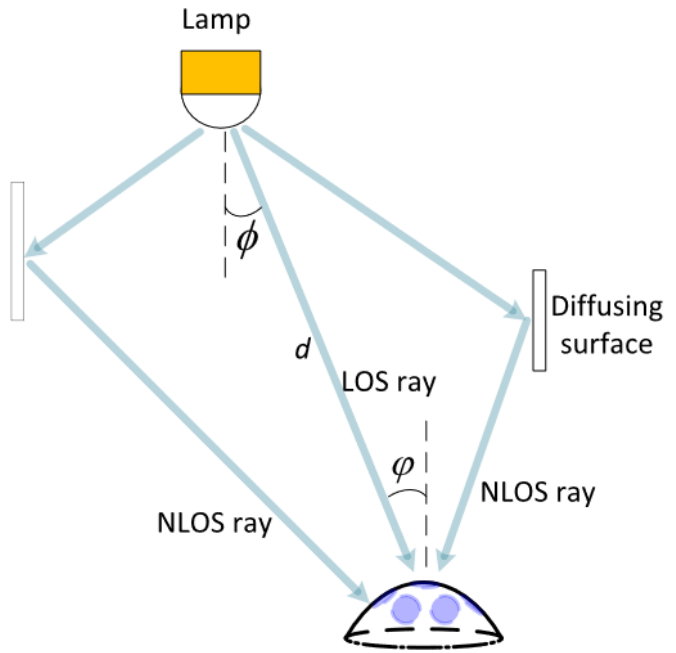
5 Complex Research Example – Project IDEA / VLC – LiFi Content

- **LiFi Positioning System**
- **Channel Model (LOS, NLOS)**
- **Ranging approachs**
  - RSS-based
  - TOA-based
- **Localization**





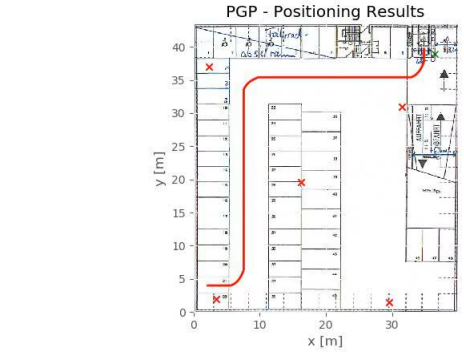


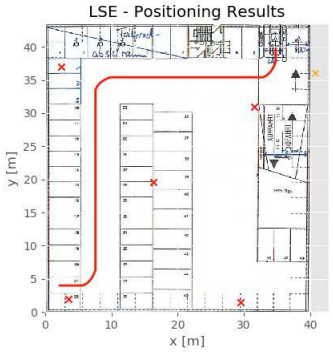


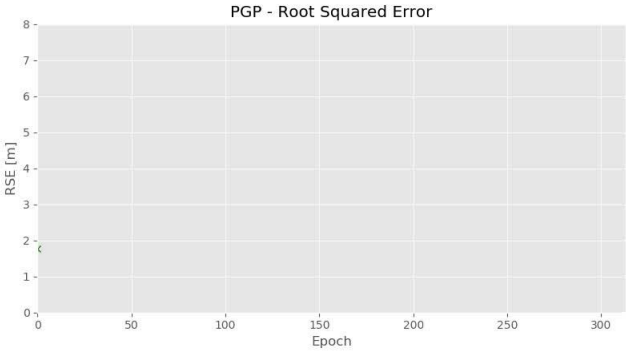
5 Complex Research Example – Project IDEA / Fieldtest-Area Torgau

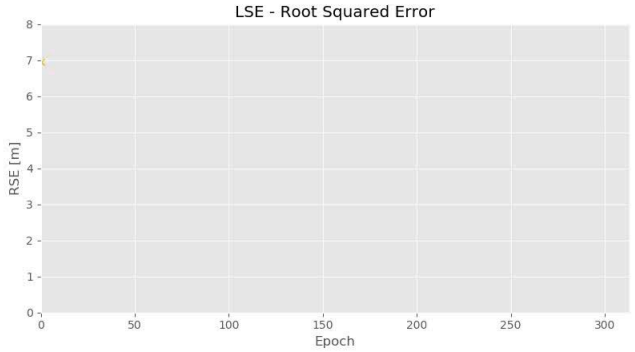
5 Complex Research Example – Project IDEA / Usable Expertice (1)

⇒ Autonomous Driving / Leading ⇒ Video:









5 Complex Research Example – Project IDEA / Usable Expertice (2)

⇒ Autonomous Driving / Leading + Parking ⇒ Video:

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6) **Conclusion and Future Outlook**

6 Conclusion and future outlook

- Modern (and innovative) wirless ICT Technologies (e.g. UWB, 5G/6G/ mmWave) will continue to play a fundamental role in the next generations Telematic Systems

- The scalable Communication, Positioning and Sensing Algorithm are strong Raw Data sensitive and principle adaptable to future Technologies

- The same principle will also apply (with hight Potential) to the optical free-space communication sector VLC or LiFi

  $\Rightarrow$ 3x VLC-Projects running