KOMSENS-6G
Enabling Sensing in 6G Networks

Berlin 6G Conference | Joint session ICAS4Mobility + KOMSENS-6G
July 1, 2024 | Berlin | - public -

Presented by Jörg Huschke on behalf of the KOMSENS-6G project

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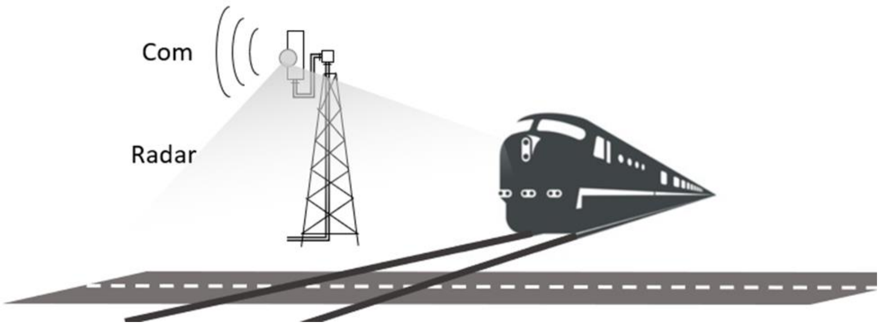
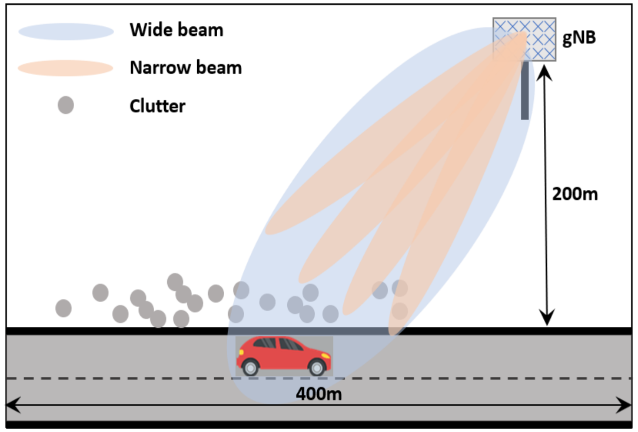
Use Cases

- Public Safety
  - Unmanned Aerial Vehicles (UAV) monitoring
  - Railroad blocker detection

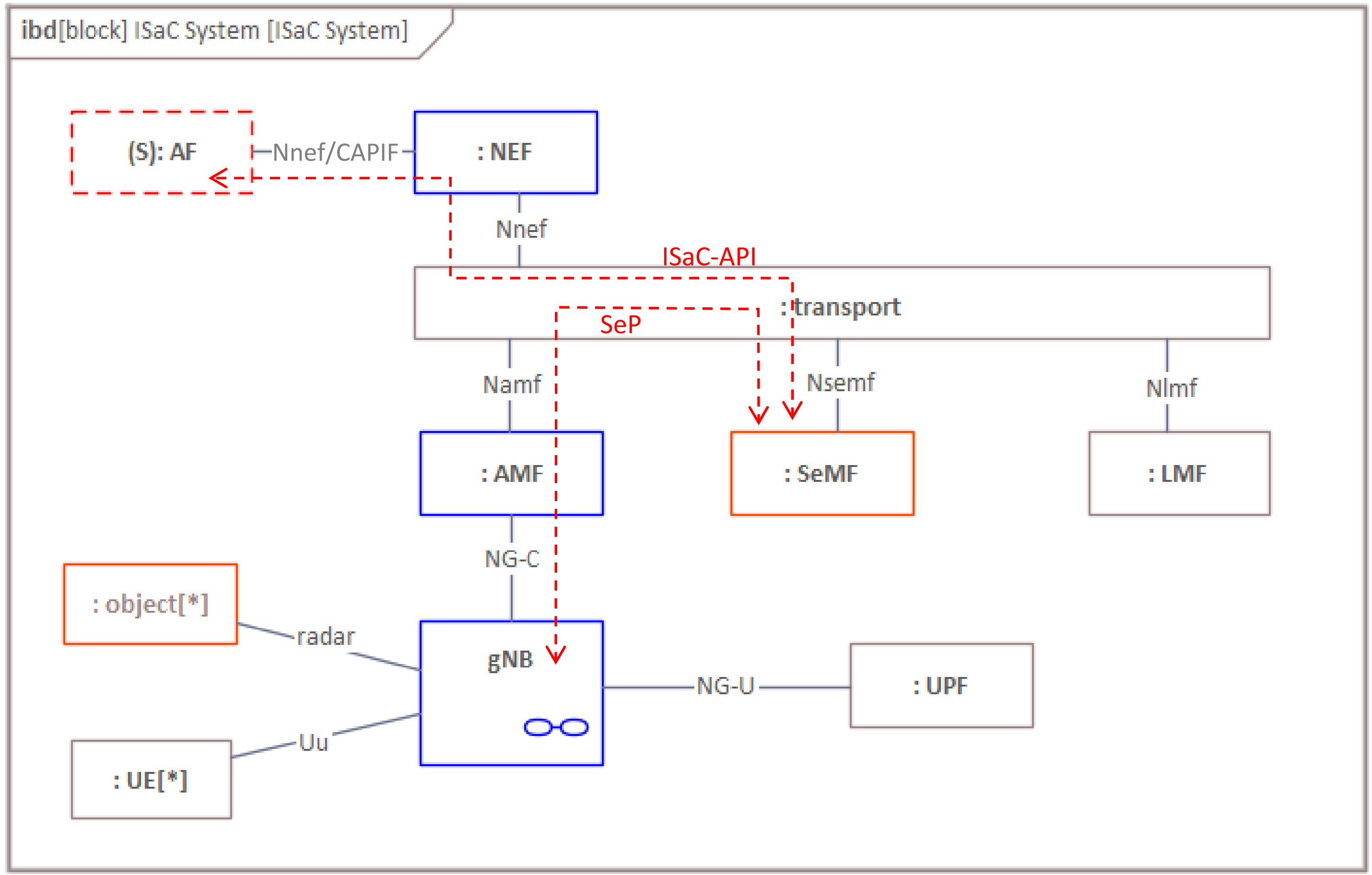


- Smart Logistics/Factory
  - Autonomous guided vehicles (AGVs) route planning
  - Scheduling of transport tasks on the shop floor

- Sensing aiding communications
  - Reduction of device-based measurement burden for maintenance of communication link
    - Beams, handovers, ...



Logical System Architecture for ISaC



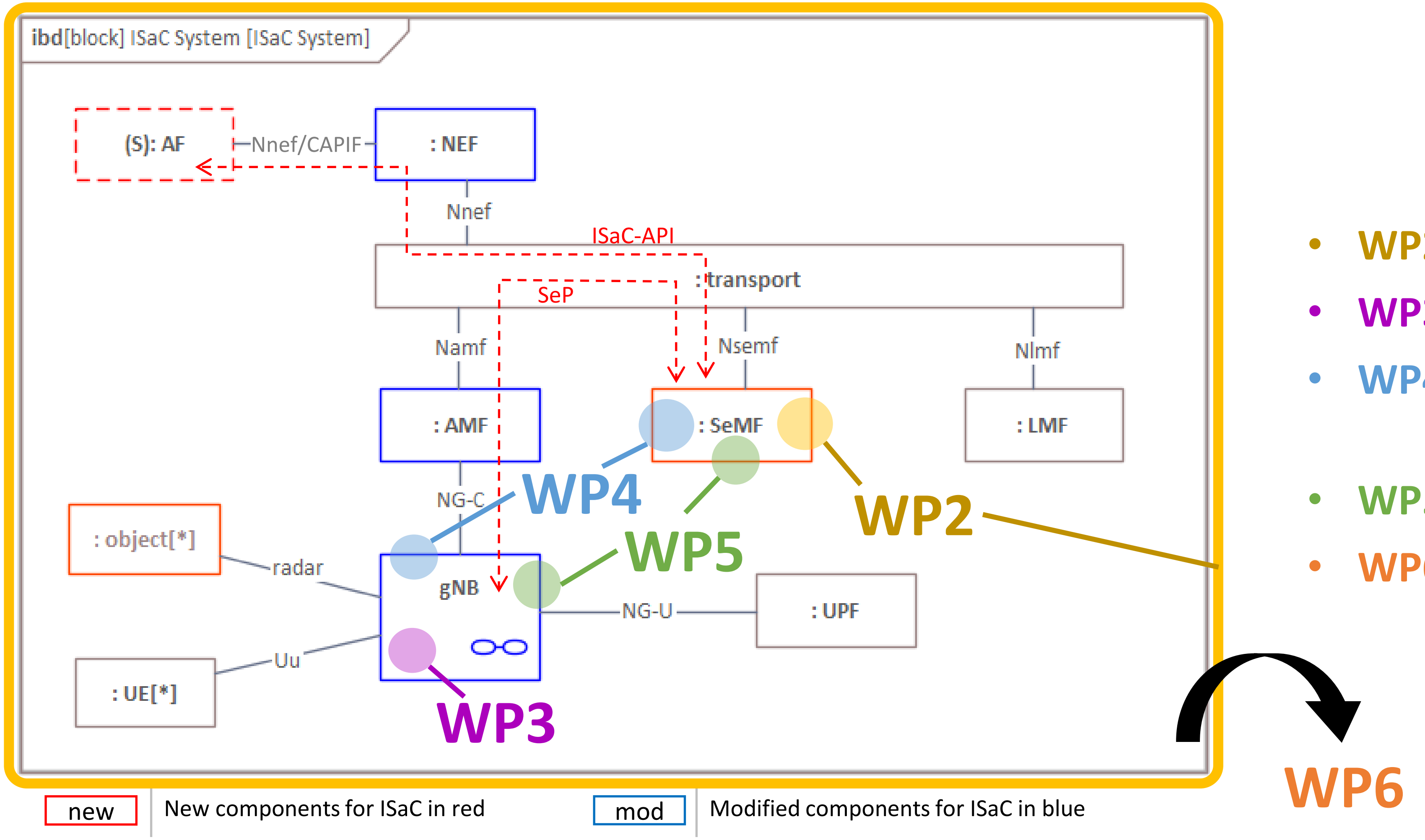
new | New components for ISaC in red

mod | Modified components for ISaC in blue

- **3GPP Rel-18 architecture** was taken **as starting point** for the ISaC extension
- Besides the Logical System Architecture, **more details exist in KOMSENS-6G** (message sequence, message structure, gNB logic, ISaC-API, and more …)
- **Security & Privacy concepts** (part of SeMF, in discussion) are integrated

SeMF	Sensing Management Function
NEF	Network Exposure Function
AMF	Access & Mobility Mgmt. Function
AF	Application Function
ISaC	Integrated Sensing and Communication
ISaC-API	ISaC Application Programming Interface
SeP	Sensing Protocol
LMF	Location Management Function
UPF	User Plane Function

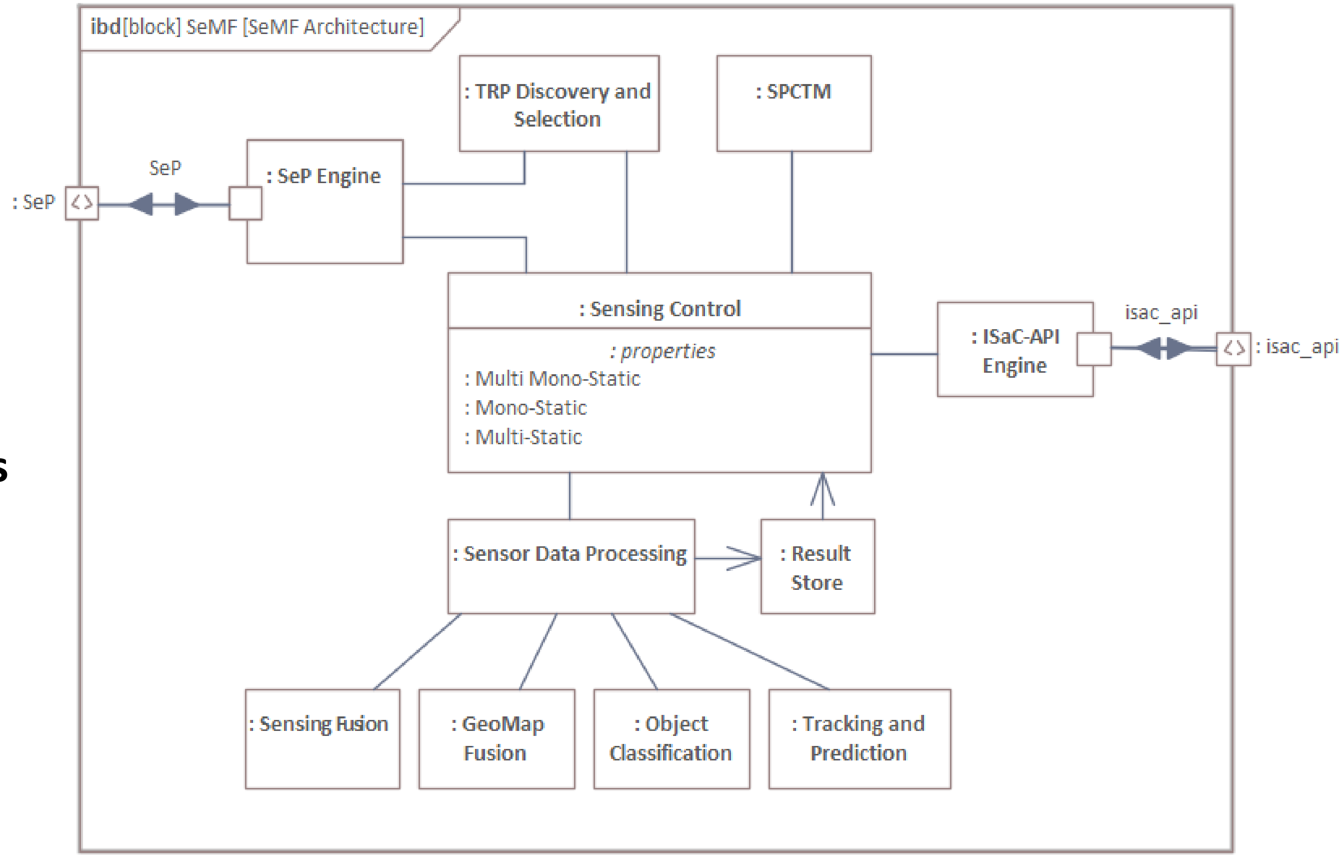
Logical System Architecture for ISaC



- **WP2: (Overall) Architecture**
- **WP3: Radio front-end & baseband**
- **WP4: Resource allocation, QoS, RAN protocols**
- **WP5: Knowledge inference**
- **WP6: Demonstrators**

SeMF Building Blocks

- **ISaC API & SeP protocol handling**
- **Discovery and selection of TRPs for sensing**
- **Sensing Policy, Consent & Transparency Management**
- **Control of sensing measurement with selective modes**
- **Sensing data processing and optimization options**
- **Result storage and forwarding to ISaC-API**



ISAC radios, same as radar?

Unfortunately, no

Radar optimized for sensing purposes

Classically horn, rotating antennas

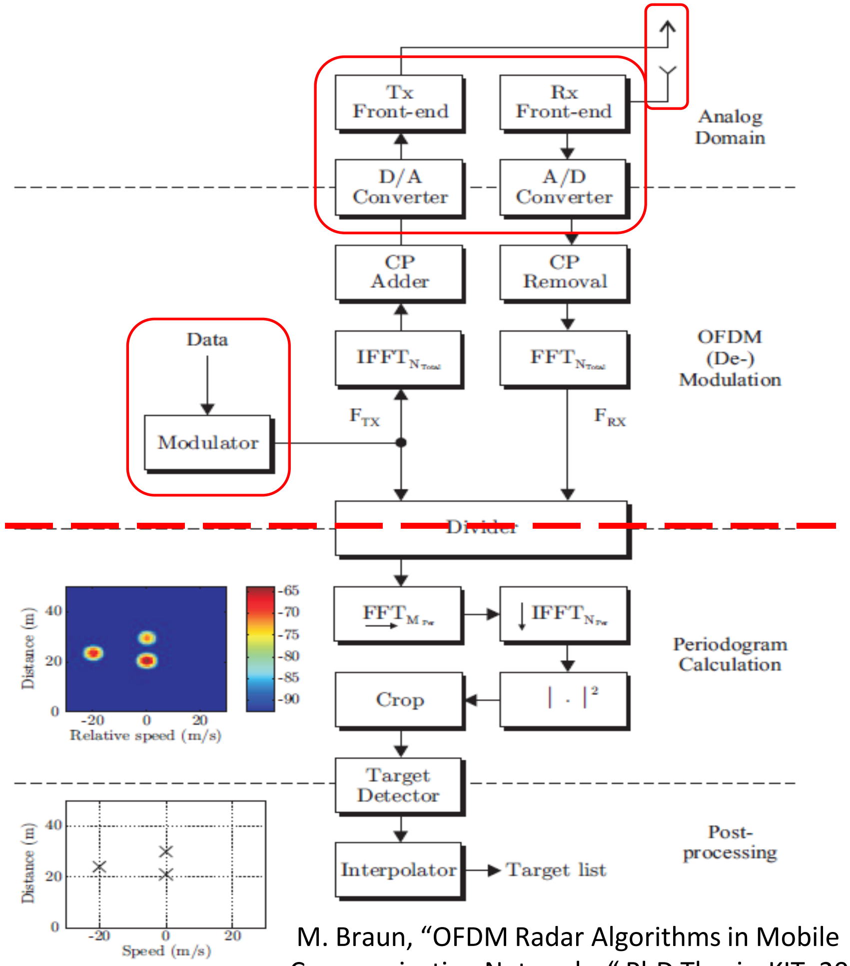
Full duplex

RF designed for sensing

No frame structure (free modulation)

Transparent interfaces for perception layer

But you can’t communicate ☺



M. Braun, “OFDM Radar Algorithms in Mobile Communication Networks,“ PhD Thesis, KIT, 2014.

ISAC built on communications

(Analog) antenna arrays

Half duplex

Synchronization issues

RF designed for comms

3GPP frame structure

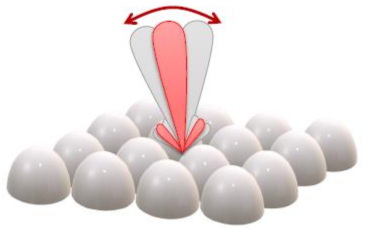
3GPP/ORAN interfaces

Researching algorithms dealing with the contstraints and radio hardware to benefit both sensing and comms.

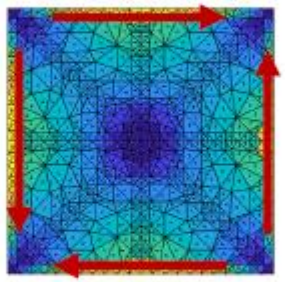
RF and L1 algorithm design efforts

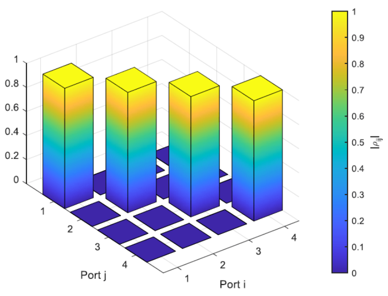
Full-duplex antenna design

140GHz active integrated dielectric lense antenna array

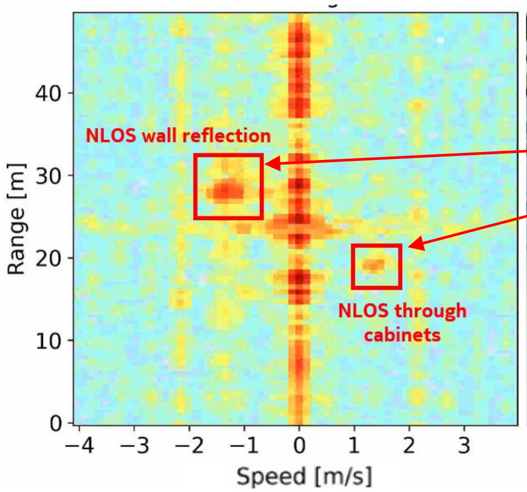


Multi-Mode Multi-Port Antennas for high inter-port isolation

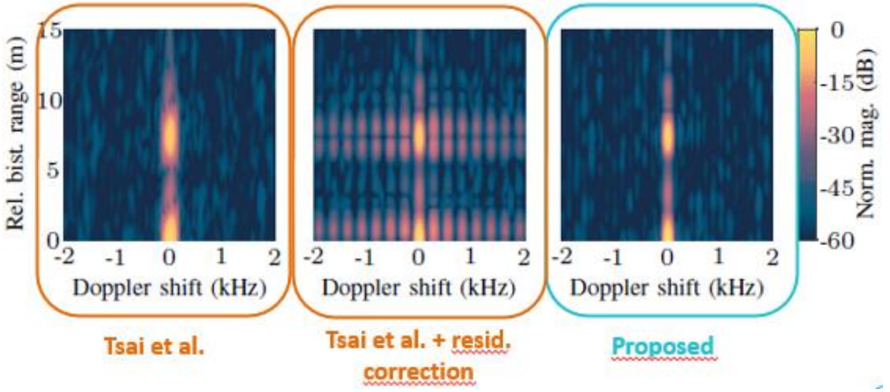




Algorithms for demonstrators

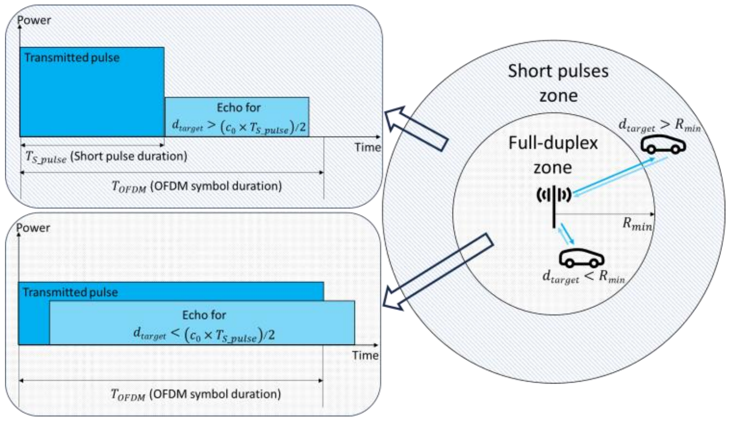


Synchronization for bistatic sensing

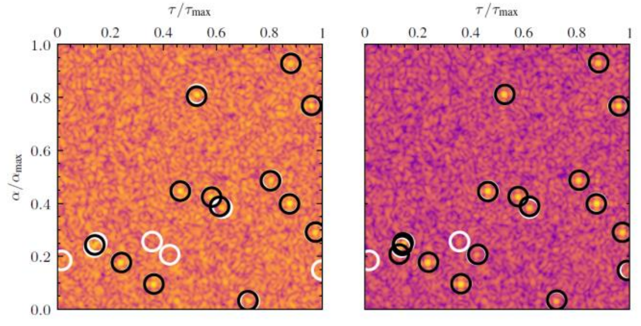


Questioning status-quo

Short pulse half duplex



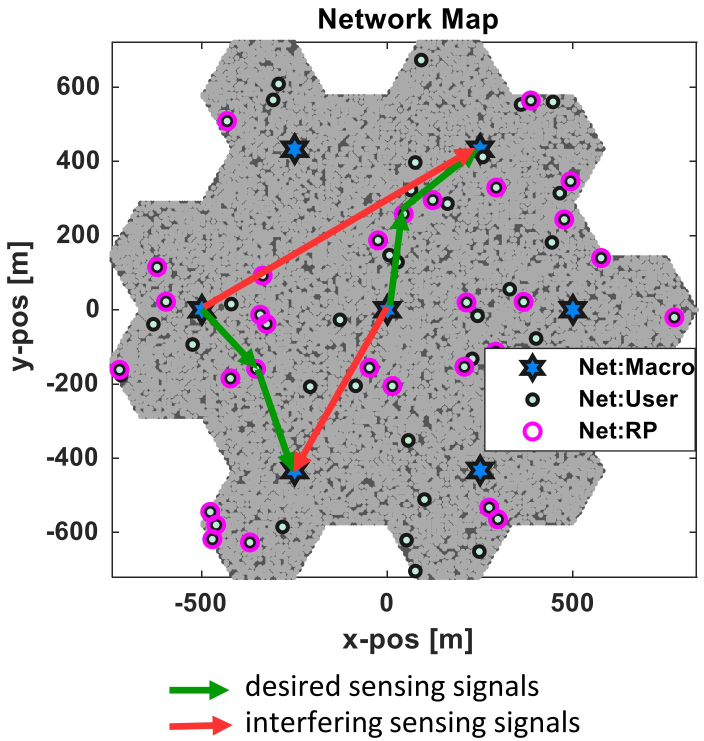
4D CNN detection & estimation

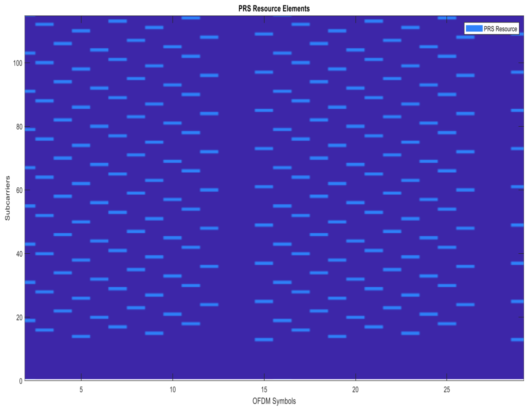


(a) SNR -5 dB, $\hat{P} = 13$ (b) SNR 0 dB, $\hat{P} = 17$

Resource allocation impact on sensing performance

- Intercell interference between sensing links, between communication links and between both link types. Sensing standalone or in DL communications slots
  - BS-BS bistatic sensing - Strong interfererence from surrounding BS
    - Manageable by using sensing signals that appear to victim BS like yet another radar target
- 3-BS multistatic sensing, multi-monostatic or monostatic+bistatic.
  - Same signal for sensing and communications, all BSs use same resources.
    - Minimize sensing error under comms SINR and TX power constraints
  - Coordinated orthogonal resources (CoMP-like) with range (and AoA) fusion
    - Realistic shapes and reflection parameters
- Investigating reuse of 5G NR RS
  - Non-periodic resource allocation, link level simulation
  - Resolving the ambiguities





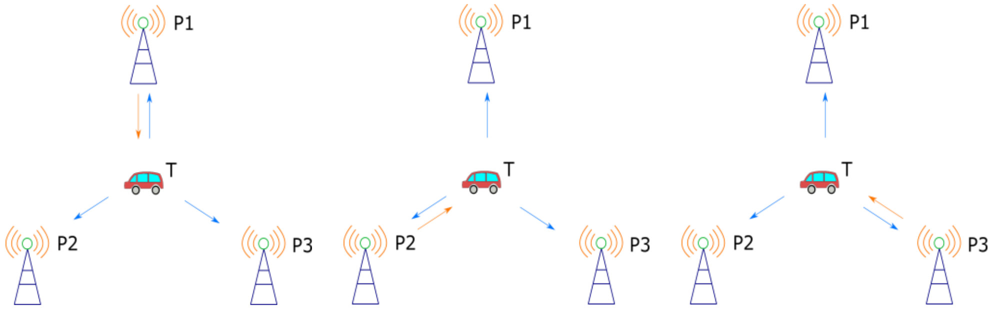
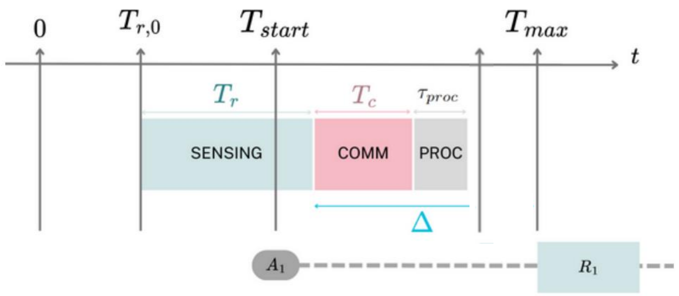
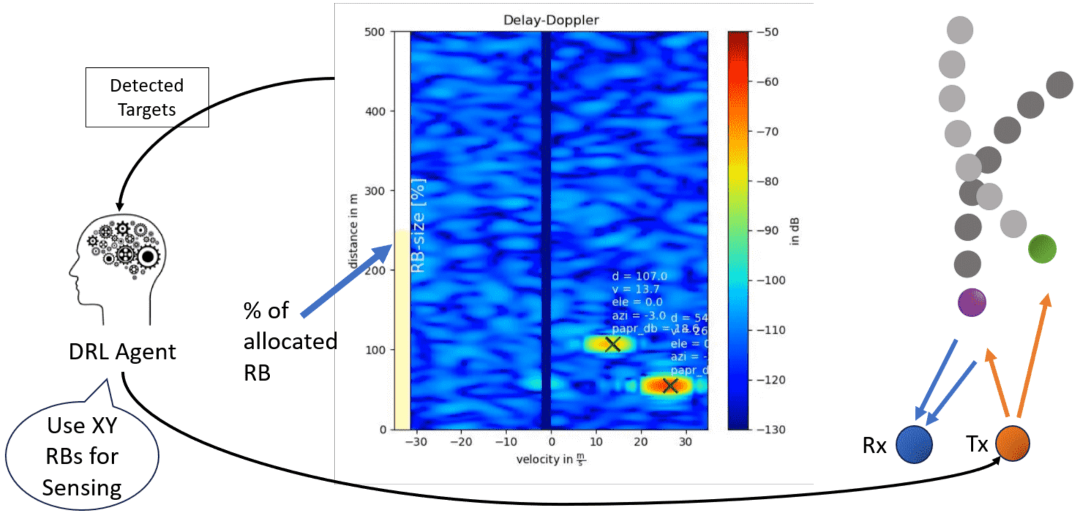


Fig. Scheduled transmissions

Protocol / QoS / Adaptivity

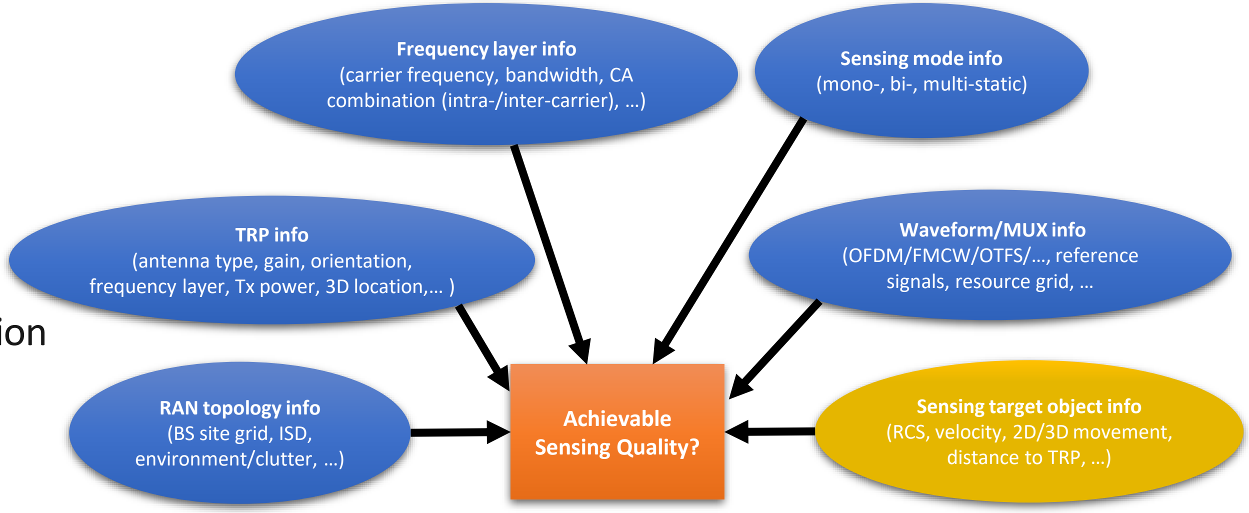
- Target adaptive sensing resource allocation
  – Bandwidth adapted by DRL to changing target separation.
- Age of Information based sensing scheduling.





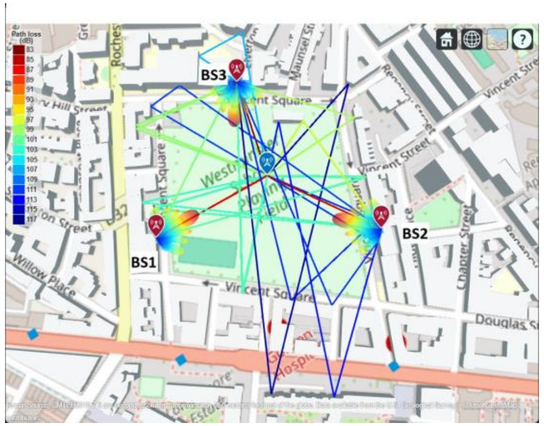
- Sensing as a Service offer by CSPs requires QoS fulfillment.
  – QoS framework based on use case specific SQI (Sensing Quality Indicator) to be introduced similar to 5QI.
  – SQIs assigned by SeMF to sensing services triggered by application functions and transferred to RAN nodes for RRM.
  – Training/calibration SQoS in real deployments, SQoS maps.

Parameters impacting the sensing quality

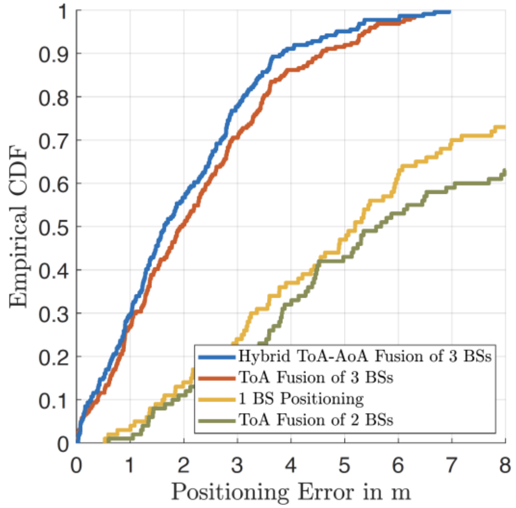


Distributed sensing and fusion approaches

Multi-monostatic sensing



Snapshot of the MATLAB's ray tracing with three BSs and one target at Vincent Square, London

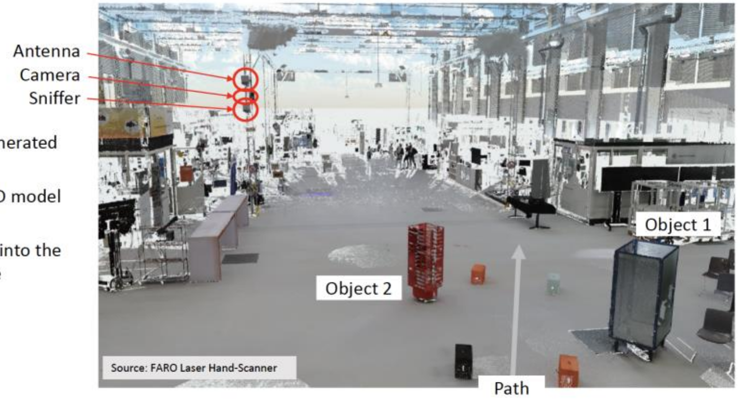


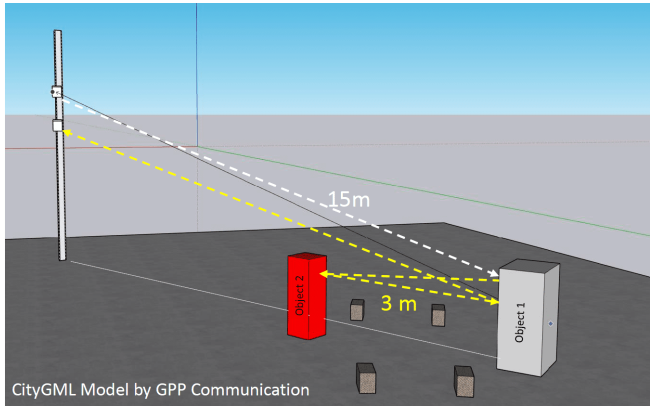
Cumulative density function of the positioning error when different fusion schemes are considered. **Multi–site fusion of estimates decreases the position error significantly**

Geo-map fusion

Improves object- identification, -classification and -localization by fusing sensing data with a 3D Geo-Model

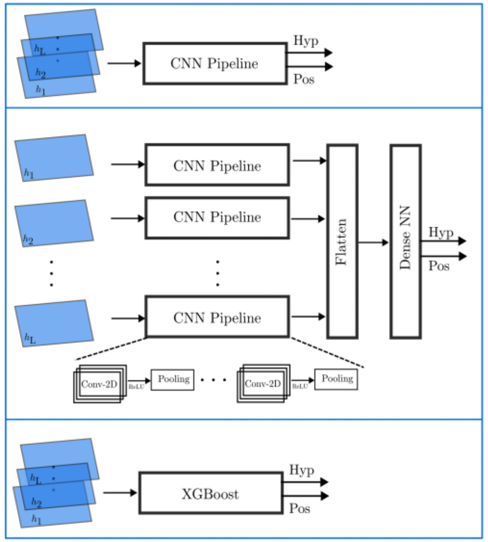
- Point Cloud Model generated by FARO Laser Scan
- 4 Scan positions for 3D model fully illuminated
- Point Cloud imported into the CityGML-Model of the Arena2036

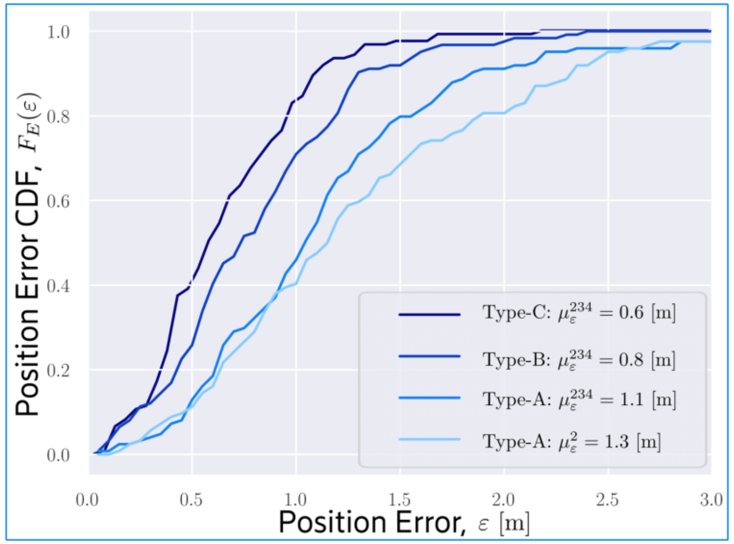




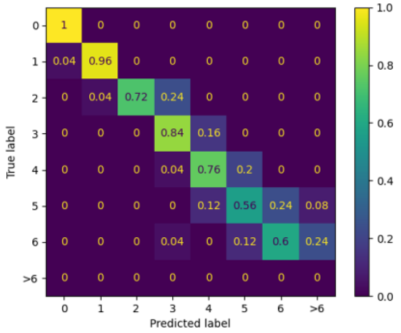
AI based approaches to parameter estimation and object detection

ML-based target detection and localization using CNNs

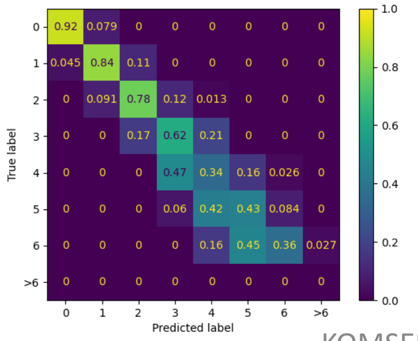




ML-based multi-target detection

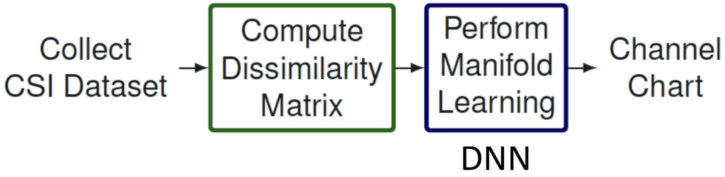


CA-CFAR

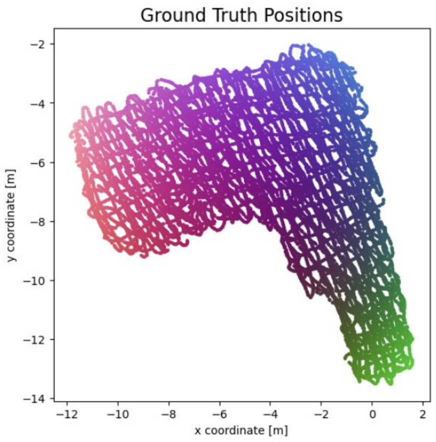


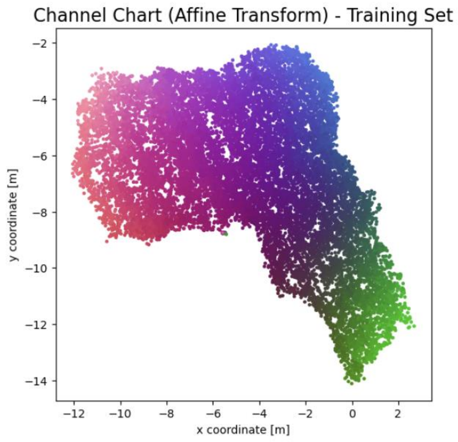
CNN

Channel charting



- Can be used for localizing a user moving in an indoor environment
- Channel Charting can also be useful for several RRM tasks such as SNR prediction, beam management, and others

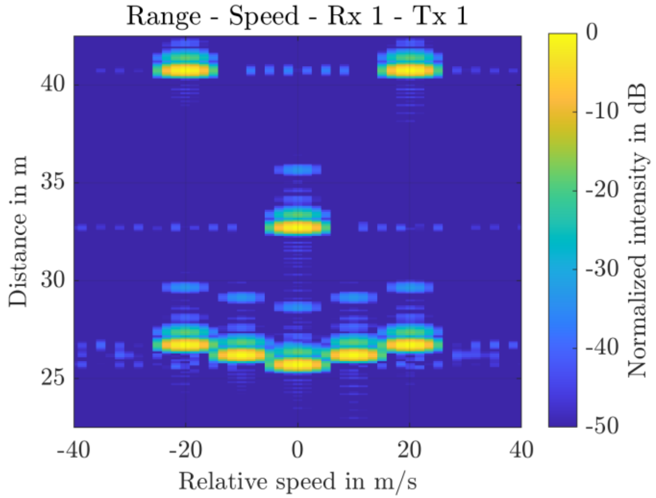




Demonstrators / Contributions

- **DICHASUS: Massive MIMO Sensing** (University of Stuttgart)
- **ISAC UAV Dataset** (Technische Universität Ilmenau)
- **GeoMap Fusion, System Modelling** (GPP)
- **Base station (gNB) based sensing setup** (Arena 2036, Bosch/Nokia/GPP)
- **Broadband Massive MIMO Testbed** (Karlsruhe Institute of Technology)
- **Sub-THz Lens Array and RF Frontend** (IMST)
- **M³PA Aperture Antenna Array** (Leibniz University Hannover)
- **Antenna evaluation and Test Platform development** (Barkhausen Institut)
- **Self-interference Cancellation** (Nokia)

KIT Live Demo with R&S at Open6GHub



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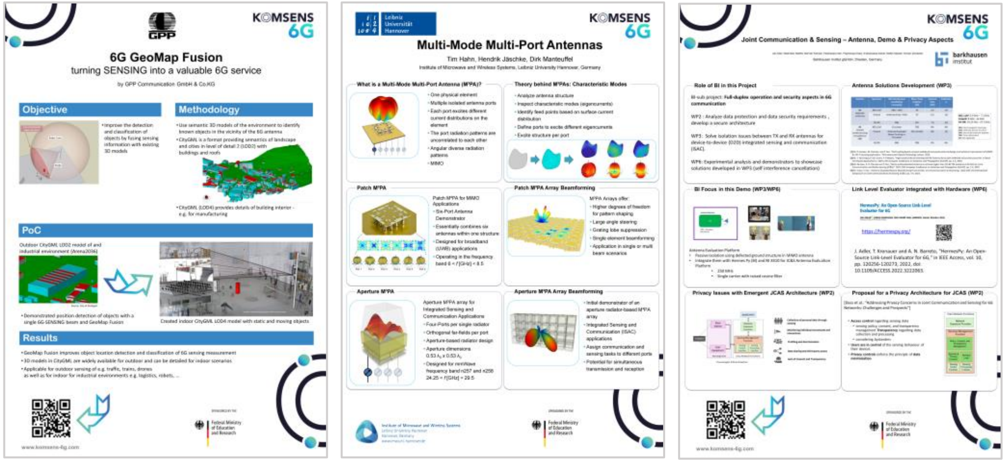
13B/C (across the catering area) for

- **Demonstrators, exhibits**
- **Digital posters**
- **Further details**

Posters



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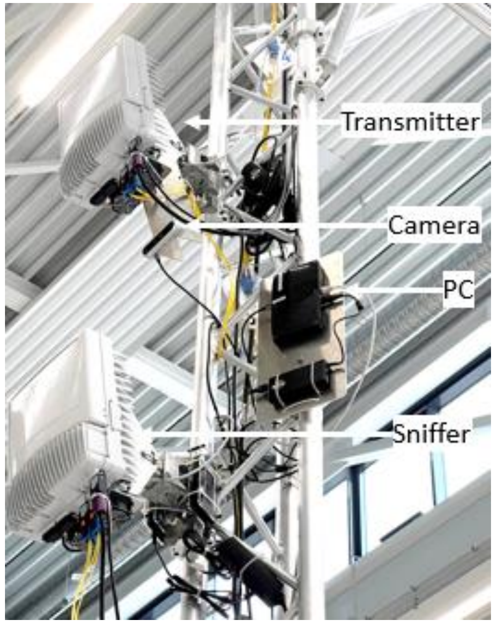
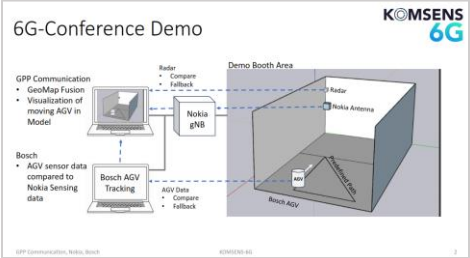
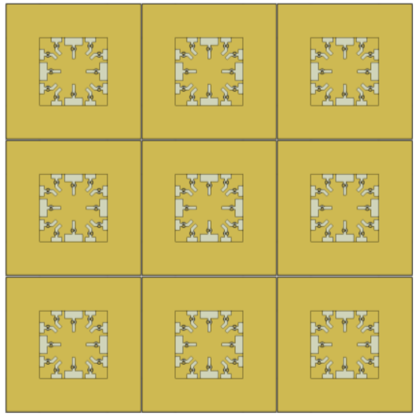


Infos



Live AGV Sensing

Multi-Mode Multi-Port Antenna Prototype



Antenna Evaluation Live Demo

Conclusion

- The real challenge of ISAC is not sensing, but doing sensing with communication hardware, standards and implementation architecture.
- TX-RX antenna isolation is key; array sub-division and separation is required.
- BS-BS interference is a serious challenge, appears to be manageable by using sensing signals that appear to victim BS like yet another radar target.
- Clutter suppression is a challenge in particular for detecting close to zero Doppler targets.
- Sensing as a Service offer by CSPs requires a Sensing QoS framework.
- KOMSENS-6G is on track with developing solutions for these challenges.