MiFuture Newsletter

April 2025

Grant Agreement Number: 101119643
Project Acronym: MiFuture
Project Title: ultra-massive MIMO for future cell-free heterogeneous networks
Call: HORIZON-MSCA-2022-DN-01
Type of action: HORIZON TMA MSCA Doctoral Networks - Industrial Doctorates
Granting authority: European Research Executive Agency
Project start date: 01/01/2024

DC01: Waveform design for joint communications and sensing

Andrés Reyes Castro

DC01

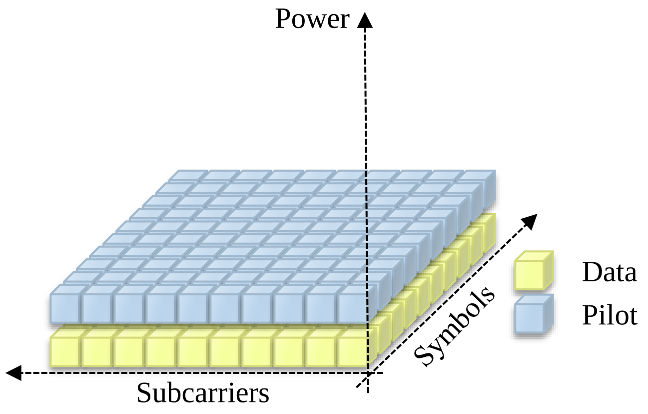
- **Title:** Waveform design for joint communications and sensing
- **DC name:** Andrés Fernando Reyes Castro
- **Institution:** *Universidad Carlos III* de Madrid & Vodafone Intelligent Solutions España
- **Secondment at:** *Instituto de Telecomunicaçoes*, Portugal
- **Project Description:** This project aims to design integrated waveforms, pilot sequences, and frame structures for joint communications and sensing. The design will optimize the trade-off between minimizing communication errors and maximizing sensing detection (with bounded false alarms), while addressing issues such as PAPR, multipath delay spread, and time variability across different frequency bands.
- **Objetive:** Design the waveform, pilot sequence and frame structure to jointly perform communications and sensing with the best possible trade-off performance of each of them.

DC01

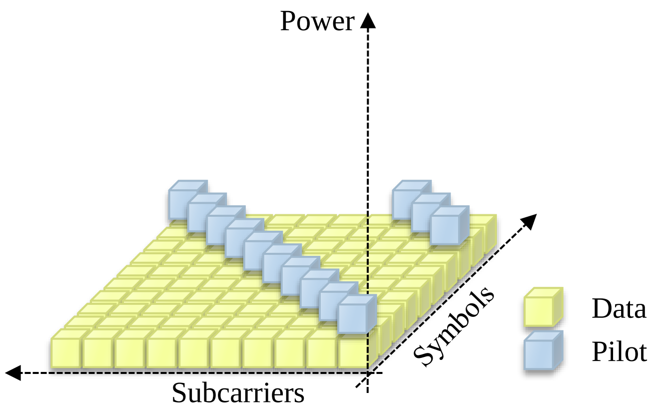
- **Activities completed so far:**
  - Literature review of Orthogonal Time Frequency Space (OTFS) modulation with Superimposed Training.
  - Literature review in ISAC (Integrated Sensing and Communications) waveform comparison.
  - Implementation of basic OTFS modulation – demodulation.
  - Comparison of OFDM, AFDM (Affine Frequency Division Multiplexing) and OTFS under time-variant cannel with perfect channel estimation.
  - Collaborator for a Journal Article about Superimposed Seascape Pattern in the Delay-Doppler Domain with OTFS for ISAC.
- **Planned activities:**
  - Journal article in ISAC waveforms comparison.
  - Design Superimposed patterns suitable for ISAC.

DC01

- **Planned activities:**
  - Journal article in ISAC waveforms comparison.
  - Design Superimposed patterns suitable for ISAC.



- ***Full grid superimposed pattern***



- ***Diagonal superimposed pattern***

MiFuture
UMMIMO FOR 6G

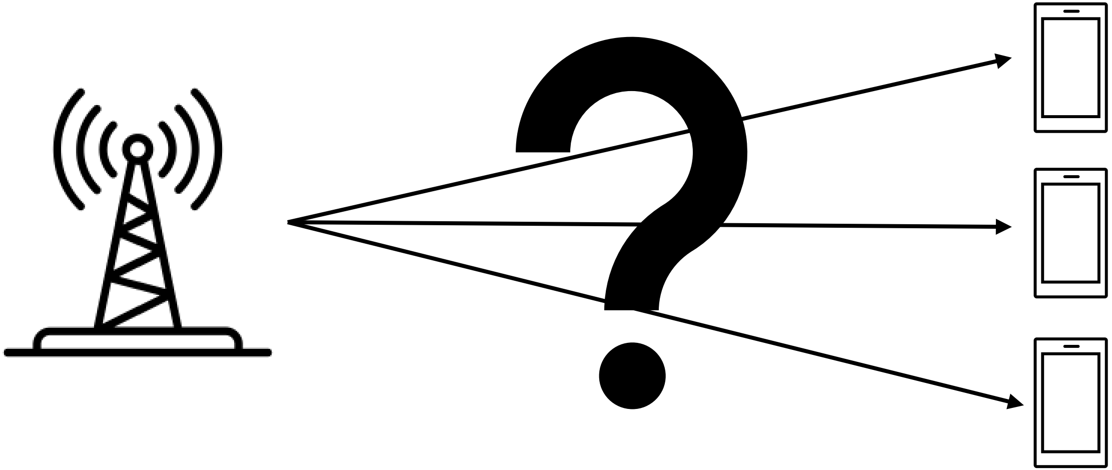
DC02: Non-coherent approaches for ultra-massive MIMO

Rubén de Miguel

uc3m

DC02 Non-coherent approaches for ultra-massive MIMO

- Rubén de Miguel Gil (UC3M)
- The project is focused on exploring transmitting and receiving schemes able to work in ultra-massive MIMO systems without channel state information in the transmitter or receiver. The project targets one of the main issues appearing with increasing numbers of antennas, which is increased pilot overhead and pilot contamination.



DC02 Non-coherent approaches for ultra-massive MIMO

- The objective of the project is to study and implement non-coherent transmission algorithms able to exploit the high data rate capabilities of ultra-Massive MIMO under conditions restrictive for coherent communications.
- The target scenarios are in the area of high mobility communications, which are known to have high channel variability, which increases the required frequency of the channel estimation process.
- So far, an extensive review of the State of the Art has been performed and some initial designs proposed with the goal of a conference article in mind.
- The project plans on exploring measurement and implementation possibilities along with the beneficiary, Keysight Technologies

DC02: Very low complexity implementations of ultra-massive MIMO

Mohd Adnan

Project Title (DC03)- Very low complexity implementations of ultra-massive MIMO

- Student Name – Mohd Adnan
- Pursuing PhD Degree – University of Aveiro, Portugal
- Secondment – Universidad Carlos III de Madrid (UC3)
- Industry Partner – Nokia Poland
- **Project Descriptions**

✓ This project develops advanced transmitter and receiver systems for distributed ultra-massive multiple-input multiple-output (UmMIMO) networks. These networks use many access points (APs), each with several antennas, covering wide areas. To efficiently serve users, the system selects specific APs based on the users' locations.

✓ Both APs and user devices use cost-effective and simple hardware, including basic amplifiers, low-resolution components, and shared hardware. Complex tasks such as separating signals from different users and correcting interference are handled centrally at the APs or a central processing unit, simplifying user equipment and reducing costs.

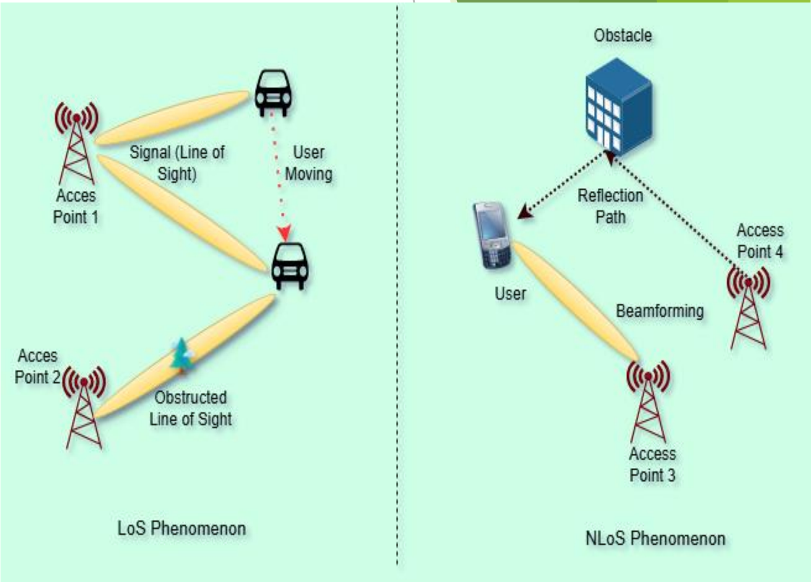


Fig: Positioning scenarios in mmWave Distributed MIMO

- **Project Objectives**
  - Develop High-Performance Transmitter and Receiver Structures
  - Optimize Access Points (AP) Selection Based on User Equipment (UE) Positioning
  - Implement Low-Complexity Hardware
  - Focus Processing at APs or Centralized Units
  - Investigate Local and Centralized Transmission/Detection
  - Develop positioning Techniques
- **Scenarios:** Currently, I am working on user positioning for beamforming in Millimeter Wave (mmWave) distributed MIMO system in Non-Line of Sight channel. I am focusing to solve the accurate positioning problem in high mobility scenario.
- **Activities completed so far:** I finished my mandatory course work at University of Aveiro and working on thesis proposal report. Also, I finished a survey paper on user positioning in mmWave MIMO system.
- **Planned Activities:** I will finish my thesis proposal report by end of the June. Also, I am planning to submit my conference paper in International Conference on Localization and GNSS 2025.

DC04: Channel Estimation and Tracking Aided by Positioning

Omid Abbassi

Channel Estimation and Tracking Aided by Positioning

Researcher: Omid Abbassi
Institution: instituto de telecomunicacoes

Brief Project Description

This project focuses on channel estimation for the links between Access Points (APs) and User Equipments (UEs), where both can employ multiple antennas. The goal is to achieve accurate channel estimates with reduced estimation overhead by utilizing precise positioning information (e.g., AoA/AoD, antenna orientation). We also explore channel tracking and prediction algorithms, leveraging positioning data to further minimize overhead in both temporal and spatial domains.

Objectives

- Develop efficient channel estimation algorithms integrating training and positioning data.
- Design channel tracking and prediction algorithms in time and space domains.
- Explore mid- to long-term channel prediction techniques.

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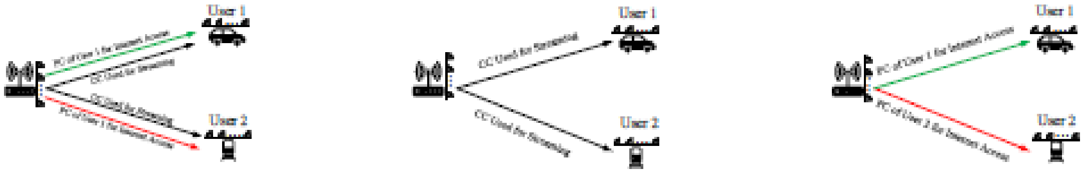
Scenario

We aim to address challenges in modern wireless communications by enhancing channel estimation and tracking for multi-antenna systems. Leveraging accurate positioning, this work optimizes performance in complex, dynamic environments.

Activities Completed So Far

• Designed a MIMO multi-user system to evaluate performance with channel estimation.

• Accepted paper at IEEE VTC 2025: Advanced Channel Decomposition Techniques in OTFS: A GSVD Approach for Multi-User Downlink



(a) First Scenario, $G \leq C \leq 2G$

(b) Second Scenario, $C \leq G$

(c) Third Scenario, $2G \leq C$

Figure 1: Schematic of different scenarios in GSVD-based channel decomposition for precoding and detection matrix design.

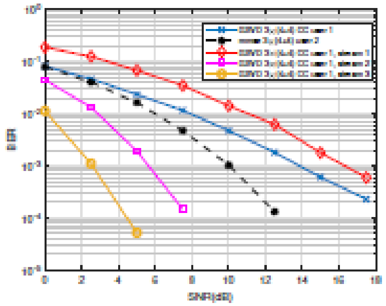


Figure 2: BER vs SNR for Scenario 2, comparing GSVD-based precoding and MMSE equalization.

- In Fig. 1, the system model of the downlink system is presented for three cases, where C represents the number of antennas at the transmitter and G represents the number of antennas at each user.
- In Fig., the simulation results of the proposed method are shown for the second scenario,compared to the minimum mean square error (MMSE) and zeroforcing (ZF) detection methods.

Planned Activities

- Extend the system design to uplink scenarios (paper nearing completion).
- Develop channel modeling and estimation techniques, incorporating tracking and prediction.

DC05: mm-Wave positioning and sensing for aerial user application

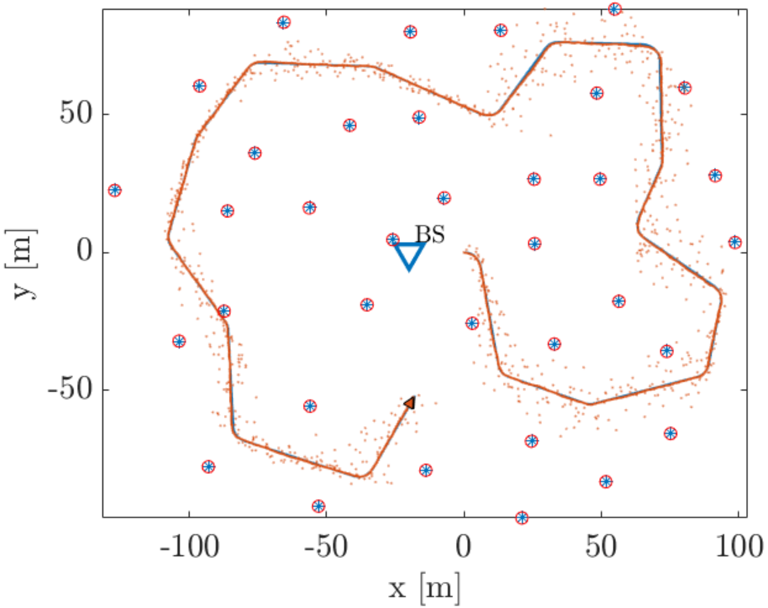
Ariele Sapienza

mm-Wave positioning and sensing for aerial user application

- **Title of the project**: mm-Wave positioning and sensing for aerial user application
- **Researcher details**: Ariele Sapienza, Tampere University and Altys Technologies
- **Objectives**: Applying bistatic radio SLAM (Simultaneous Localization And Mapping) algorithm to aerial user inside small and medium-size airports with the usage of EKF-SLAM simulator.
- **Scenario**: BS inside an airport and a UE that is moving inside it, with multiple obstacles that are also moving. The UE can also fly

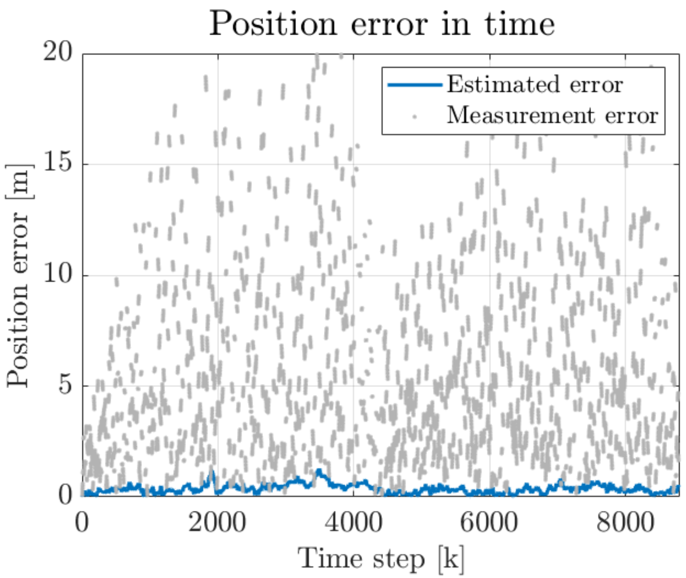
- **Activities completed so far**:
    - Literature review and learning about positioning and SLAM
    - Adaptation of a SLAM simulator in monostatic scenario with lidar sensor to my bistatic radio
    - Following PhD courses
- **Planned activities:**
    - Applying motion to the obstacle and elevation to the UE
    - Use real data based on measurement
    - Write conference papers

Trajectory estimation in the SLAM simulator

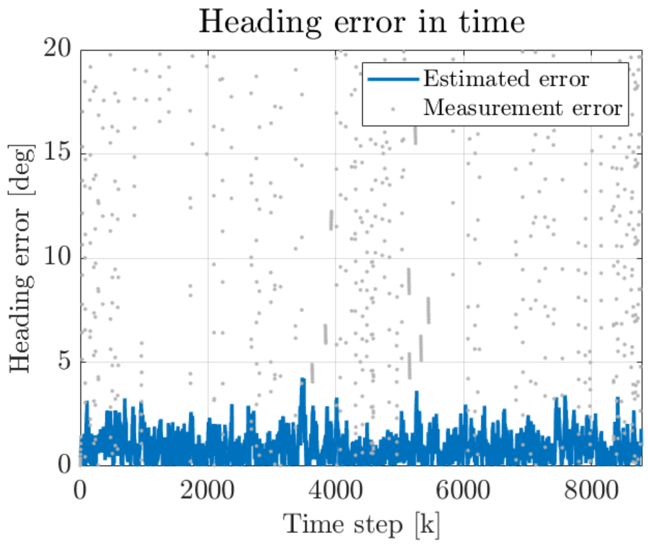


The EKF SLAM filter is approximating well both the trajectory of the UE and also the environment

Performance in position and heading



Measurement-RMSEs = 7.70 m
EKF-RMSE = 0.42 m



Measurement-RMSEs = 7.24 degrees
EKF-RMSE = 1.14 degrees.

DC06: Clutter Characterization and Cancelation in MIMO Sensing via Backscattered Signals

Mehmet Ertug Pihtili

Name: Mehmet Ertug Pihtili

Institution: Tampere University (first 18 months) and Ericsson Finland (last 18 months)

Project Title: DC6: Clutter Characterication and Cancelation in MIMO Sensing via Backscattered Signals

Activities completed so far: *5G Mobile Communications* course has taken.

Planned activities: Attending courses and seminars related to the focus.

Objectives:

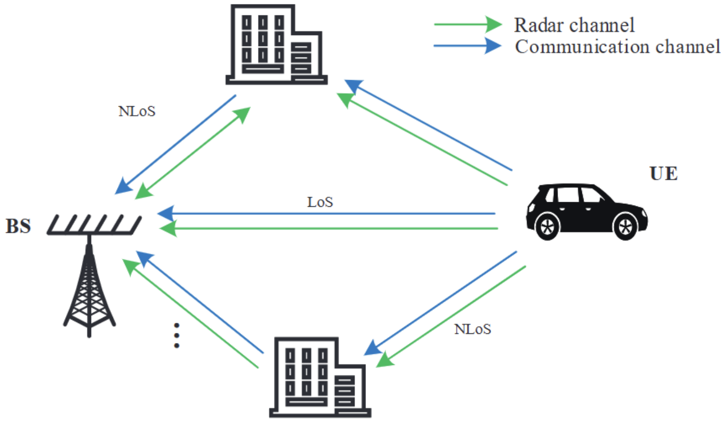
1. To investigate the statistical models, topologies, and scenarios of clutter backscattered signals (NLOS propagation) in sensing applications.

2. To propose clutter mitigation and cancellation methods and compare performance under un-mitigated and mitigated clutters.

3. To study the use of cluster characteristics for channel estimation purposes.

Project Description

Mobile communication networks were originally designed for ubiquitous wireless communication but are now expected to integrate radio sensing capabilities. The fusion of communication and sensing is set to be a core technology in the sixth generation (6G) era, enabling sensing-assisted communications to enhance network performance. However, most research has focused on scenarios with minimal clutter, overlooking complex indoor environments such as industrial settings, where propagation channels exhibit high clutter density. This project aims to develop novel ISAC system designs for cluttered environments, assess performance under clutter effects, and propose clutter cancellation techniques.



DC08: Joint positioning and spatial resource allocation for cell free systems

Prabhat Gupta

Title : Joint positioning and spatial resource allocation for cell free systems
Name: Prabhat Gupta
Supervisor: Prof. Marco Gomes, Dr. Akshay Jain
Institute: Instituto de Telecomunicações (University of Coimbra)

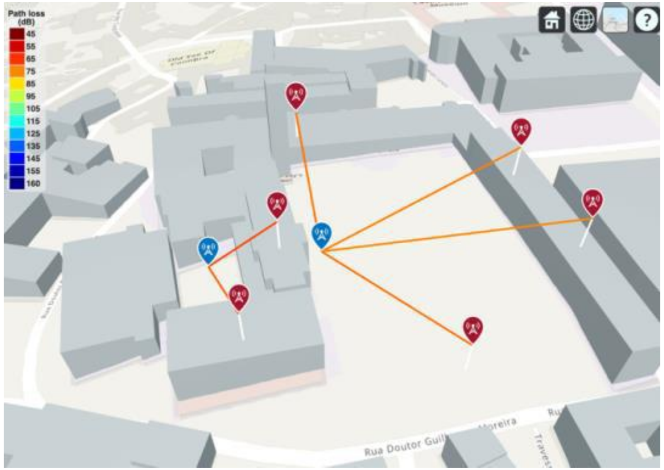
Project Description: The Cell-Free Architecture comes at a cost of increased fronthaul signalling and higher power consumption. To make the network scalable and ubiquitous a key challenge is to optimize this network to reduce the signalling requirments and power consumption while increasing the spectral efficiency to serve the Quality of Service (QoS) requested by the user. To address this challenge of optimization positioning and tracking of the user can play a crucial part. Resource allocation can be carried out leveraging the user-position and assigning the best possible Access Points to the users based on the channel conditions and the load on the Access Points. This ensures that the buffer time for each is reduced and the power is optimize.

Objective :

- To optimally allocate the resources to the users keeping in mind the overall sum rate, fairness scheme and latency along with power consumption.
- *To have adaptive algorithms based on eigen vectors and eigen values that can effectively save power and utilize only the APs and the resources that are required*
- To have the network work as a sensor that predicts user location and *refines resource allocation with the help of that location*.

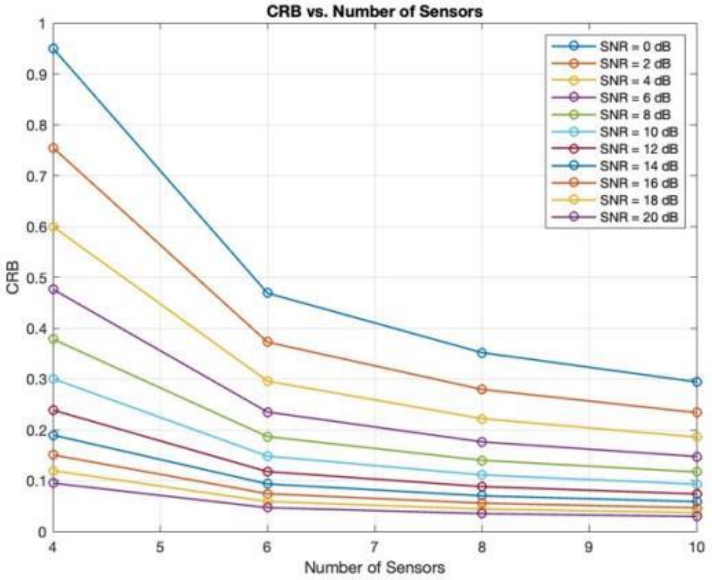
Scenario :

The current sceanrio is to have Access Points and UEs connected with a CPU. The Access Points coordinate to provide resources to the UE according to different parameters. The ray tracing channel model considers various geometrical ascepts of the sceanrio and we can obtain the channel conditions from it. These channels conditions are then utlizied to have algorithms which can serve the user based on the throughput required while reducing the blockage rate.



Plans for Optimization : Since the optimization problem is a non-convex problem, and we are in a multi-dimensional space the idea is to use eigen vectors and eigen values which would represent received power in the downlink and the uplink. If the eigen vector changes, it would imply that the user has to be assigned new resources and the optimization will be carried out accordignly. Further from the evolution of the eigen vectors, the prdicition of the user movement can be carried out and the resources can be assigned before-hand to that user which would reduces the signalling requirments to a great extend while incresing the Spectral Efficiency.

Activites Completed : For the prilimary study, we simulated a beamforming scene where the low-power sensors send a common signal to the Drone. Then we tested the minimum number of sensors which would be required to send the signal with a minimum SNR to ensure the message is received correctly. The Cramer-Rao Lower Bound was utilised to know the performace accuracy for number of sensors required for different SNR values. CRB was calculated on the esitmate of the phase change of the signal when the position of the sensors is not perfectly known.

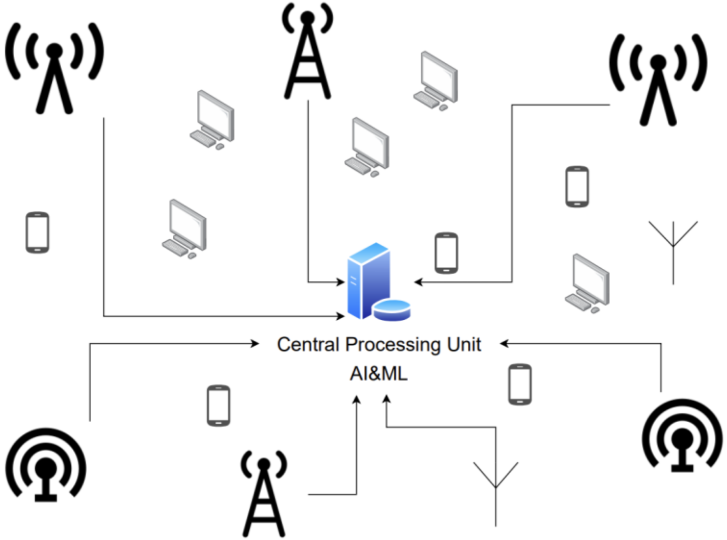


DC09: Machine Learning Algorithms for Cell-Free systems in 6G networks

Mehmet Fatih

Tampere University

- Title of the project: Machine Learning Algorithms for Cell-Free systems in 6G networks
- Researcher: Fatih Ayten – Tampere University
- Project Description:
  i. Novel analysis of MAC/RRM methods and ML algorithms, focusing on the complexity and deployment.
  i. New MAC/RRM procedures for cell-free distributed Massive MIMO in 6G networks.



Cell-free distributed heterogenous UmMIMO network

- Objectives:
  1. To develop novel ML algorithms for evolving UmMIMO scenario in the context of distributed/cell-free MIMO.
  2. To analyze the challenge of multiple service types, ultra-dense scenarios, super high density of UEs as well as heterogeneous RAT types.
  3. To analyze also the computational complexity and deployment capabilities of the developed algorithms.
- Scenario: Cell-free/distributed ultra-dense UmMIMO deployments.
- Activities completed so far:
  - Course work of 15 ECTS credits.
  - Paper publication in 5th IEEE International Symposium on Joint Communications & Sensing.
  - Paper submission to IEEE International Symposium on Personal, Indoor and Mobile Radio Communications.
- Planned activities:
  - Extending the submitted paper to a journal paper.
  - Completing the remaining ECTS credits.

DC10: Positioning and tracking of non-connected objects for vehicular safety with mmWave frequencies

Radovan Juran

Title of the Project:

Positioning and tracking of non-connected objects for vehicular safety with mmWave frequencies

Researcher's Name and Institution:

Radovan Juran

Tampere University (academic part)

Ericson Finland (industrial part)

Universitat Autonoma de Barcelona (academic secondment)

Brno University of Technology (joint double-degree)

Brief Project Description:

The project aims to develop methods for utilizing mmWave signals within concepts of ISAC (Integrated Sensing and Communication) to enhance Simultaneous Localization and Mapping (SLAM) capabilities in Ultra-Massive Multiple-Input Multiple-Output (UmMIMO) systems. The aim is to enrich general vehicular scenarios with capabilities of sensing, obstacle detection and collision prevention.

Objectives

1. To propose sensing-based positioning enhancements (ISAC) of non-connected vehicles when sensing is done by the cellular network, based on UmMIMIO and back-scattered millimeter wave signals (bistatic radar).
2. To study the impact on the performance metrics when positioning is done either at the vehicle side, or at the network side, or both (collaborative localization).
3. To perform parameter estimation and tracking of those (Doppler, angle, etc.) in order to support and enhance the positioning performance in vehicular scenarios (SLAM).
4. To develop collision detection and prevention metrics based on mmWave sensing.

Scenario

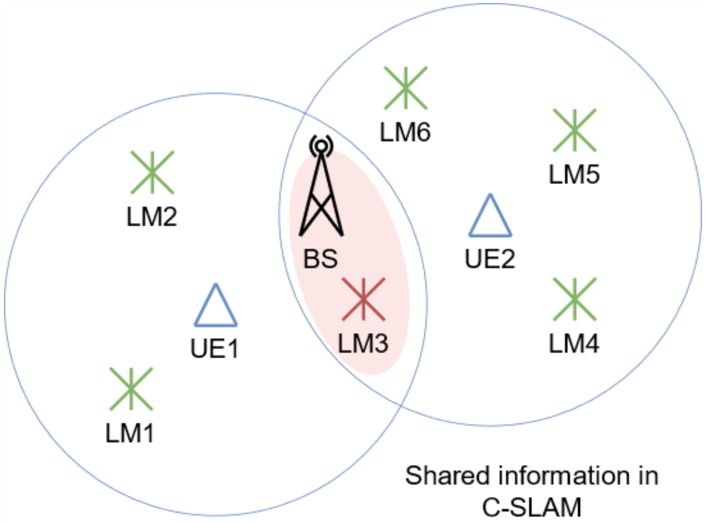


Figure 1: Collaborative SLAM based on shared information between user equipment (UE) – here Land Mark 3 (LM) is visible by both UE1 and UE2, while UE1 also knows about LM1, LM2 and UE2 about LM4, LM5, LM6 and can share this knowledge.

Figure 2: Legacy car (green) visible to a modern, sensing-capable car (white); ChatGPT generated.

My topic aims on vehicular scenarios in general, especially focusing on collision detection and prevention. Nowadays cars are equipped with various sensors, however there are still legacy cars on the roads as well as cyclists, pedestrians and other road traffic participants. On top of that environment can be dynamic and obstacles might appear in the car's way quite quickly out of xnowhere. Thus, the ultimate goal is to utilize methods ISAC for radio-based SLAM enhanced also by sharing information among the users. This will create the Radio Collaborative SLAM (Radio C-SLAM), based on utilizing mmWave frequency signals, which includes:

- Advanced sensing-based models for accurate positioning and tracking of vehicles.
- Novel parameter estimation algorithms.
- Collision detection and prevention based on sensing the vehicle's environment.

Activities completed so far

Theoretical background of the given problematics is broad, thus it requires courses and learning as well as reading papers and performing critical analysis of published results. This is valuable, as it brings a summary of new perspective to the topic and preparing inseparable meaningful theoretical foundations for upcoming simulations and evaluation of the given methods – paper in progress.

On-line course on edX “Sensor Fusion and Non-linear Filtering for Automotive Systems”.

Planned activities

- Finishing courses at the Tampere University.
- Preparing own papers and publishing the first results.
- Finalizing the university part of the PhD and preparing for the secondment at Universitat Autonoma de Barcelona, Spain. This secondment shall include data acquisition, consultations and valuable networking.
- In the meantime, it’d worthwhile to attend conferences to further enhance networking by meeting experts from the field.
- Then, the industrial part with Ericson will begin. There, a wider application of the theory shall be implemented as simulations or real-data processing algorithms.

DC11: Measurement and Calibration of Ultra-Massive MIMO Technologies for 6G Communications

Joao Pedro Ferreira

Researcher's Name and Institutions:

- Joao Pedro Ferreira, Keysight Technologies (joao.ferreira@keysight.com) and KU Leuven (joaopedro.secoramosvieiraferreira@kuleuven.be), Belgium, Leuven.

Project Description:

- As 6G technology emerges as the next frontier in mobile communications, ultra-massive MIMO (umMIMO) systems and Reconfigurable Intelligent Surfaces (RIS) are key innovations to enhance network capacity, spectral efficiency, and energy efficiency. This project focuses on developing advanced calibration and measurement methodologies to ensure accurate amplitude and phase alignment in umMIMO and RIS systems. By addressing critical calibration and performance verification challenges, the project aims to enable precise beamforming and reliable operation in future 6G networks.

Objectives:

1. Develop robust calibration techniques for umMIMO arrays and RIS.
2. Design measurement methodologies to verify beamforming accuracy and system performance.
3. Optimize testing environments for large-scale umMIMO and RIS in 6G communications.

Scenario:

- In future 6G networks, ultra-massive MIMO arrays with thousands of antenna elements and RIS panels will dynamically shape and optimize wireless environments. Accurate calibration and measurement of these technologies are essential to ensure efficient beamforming, minimize interference, and achieve reliable, high-capacity communications across diverse operational conditions.

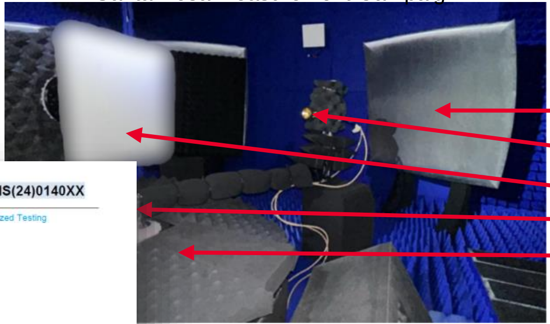
Completed and Ongoing Activities:

- Development of intellectual property rights (IPR): *04/2024.*
- NWI proposal for ETSI: *09/2024.*
- Teaching assistant duties: *09/2024 – 01/2025.*
- Master Thesis orientation: *09/2024 – Ongoing.*
- Group Specification for ETSI ISG RIS: *10/2024 – Ongoing.*
- MiFuture deliverables: *12/2024.*
- Santa Rosa characterization measurement campaign: *01/2025.*
- Malaga live mmWave network trial for passive reflectors: *02/202*
- MiFuture workshops: *03/2025.*

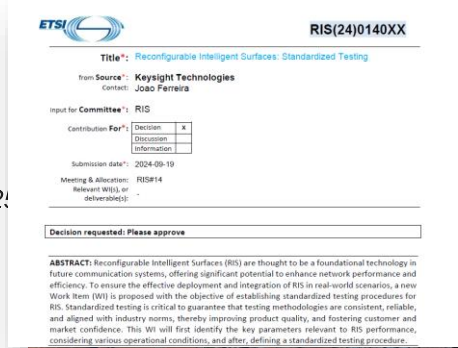
Planned Activities:

- Malaga live mmWave network trial for RIS: *05/2025.*
- Athens live mmWave network trial RIS: *07/2025.*
- Calibration procedure testing: *2025.*

Santa Rosa Measurement Campaign



GS for ETSI ISG



ETSI **RIS(24)0140XX**

Title*: Reconfigurable Intelligent Surfaces: Standardized Testing

from **Source*:** **Keysight Technologies**
Contact: Joao Ferreira

Input for **Committee*:** RIS

Contribution **For*:**

Decision	X
Discussion	
Information	

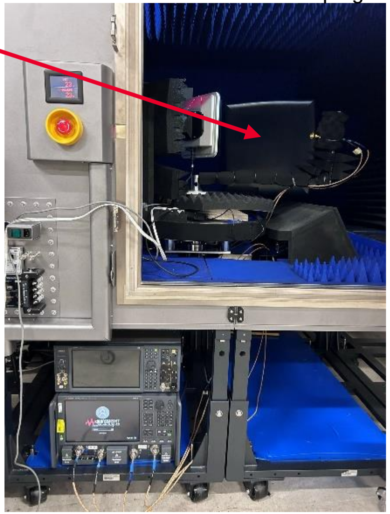
Submission date*: 2024-09-19

Meeting & Allocation: RIS#14
Relevant WI(s), or deliverable(s): -

Decision requested: Please approve

ABSTRACT: Reconfigurable Intelligent Surfaces (RIS) are thought to be a foundational technology in future communication systems, offering significant potential to enhance network performance and efficiency. To ensure the effective deployment and integration of RIS in real-world scenarios, a new Work Item (WI) is proposed with the objective of establishing standardized testing procedures for RIS. Standardized testing is critical to guarantee that testing methodologies are consistent, reliable, and aligned with industry norms, thereby improving product quality, and fostering customer and market confidence. This WI will first identify the key parameters relevant to RIS performance, considering various operational conditions, and after, defining a standardized testing procedure.

Santa Rosa Measurement Campaign



Malaga live mmWave network trial

KEYSIGHT

DC13: Mid-band channel characterization for joint communication and sensing

Aleksandar Birmancevic

Mid-band channel characterization for joint communication and sensing

ALEKSANDAR BIRMANCEVIC, LUND UNIVERSITY

Aleksandar will work on 6G and especially distributed MIMO deployments. A multi-link system will be used for joint communication and sensing. The subject area includes next generation cellular communication systems, channel characterization, channel modeling, combined communication and mono- and bi-static sensing, with associated signal processing.

Distributed MIMO deployments will be investigated in both indoor and outdoor (urban) environments.

Objectives:

- Dynamic channel characterization for joint communication and sensing;
- Mid-band channel modelling for joint communication and sensing;
- Positioning and sensing algorithms for high resolution environmental awareness.

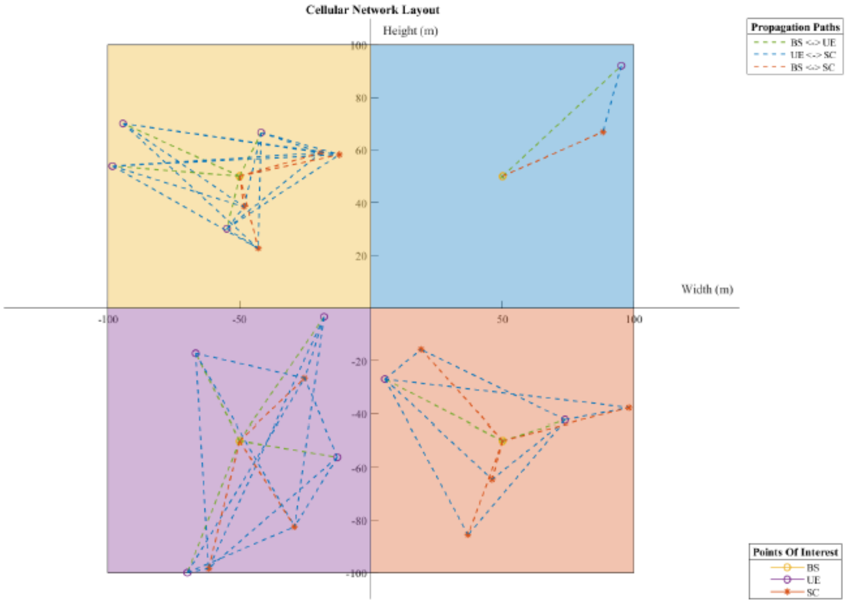
Completed and ongoing activities:

- A systematic literature review of distributed MIMO and smart repeaters;
- A PHY-level simulator based on positions of interacting points and distances.

Upcoming activities include to extend the simulator capabilities to progress towards the objectives and to conduct an indoor measurement campaign.

Ongoing activities

Current focus is on smart repeaters for Massive MIMO.
Simple simulation model where everything is based on positions and distances is built before proceeding to a more advanced system simulator. In the simple simulation model, repeaters will be also integrated.



BS represents a Base Station located in the middle of a rectangular cell.
UE describes User Equipment. Depending on a cell, different numbers of UEs are randomly positioned across the cell.
Scatterer is marked with *SC* and similarly to UEs, they are also randomly distributed between cells.

Based on insights from the simulations, a measurement plan should be done taking real constraints of actual measurement capabilities with the distributed channel sounder.
Special consideration will be put to the Base Station - Repeater - User Equipment link and Repeater - Repeater links.

LUND UNIVERSITY

DC15: UE aspects of ultra-massive MIMO

Josep fernández

All about me

Josep R. Fernández Rull

26 yo (9th of October 1998)

Telecommunications engineer

Beneficiaries

ERICSSON

LUNDS UNIVERSITET

LTH
LUNDS TEKNISKA HÖGSKOLA

UE aspects of ultra-massive MIMO

Project overview

- Analyze multi-antenna solutions for UmMIMO within wireless devices (UE)
- Evaluations of antenna configurations and signal processing requirements for different device form factors.
- Both communication and sensing use cases will be studied.

Main Goals

- Understand and quantify the potential benefits of using multiple antennas in an UmMIMO UE operating at carrier frequencies up to the mmW range.
- Develop efficient signaling and signal processing methods with a minimum of power consumption and signaling overhead.

Expected results

- Characterize benefits of multiple antennas in terms of increased performance for mobility and relaxed requirements on network frequency synchronization.
- Development of the required signaling, signal processing methods, and antenna configurations.

MiFuture
UMMIMO FOR 6G

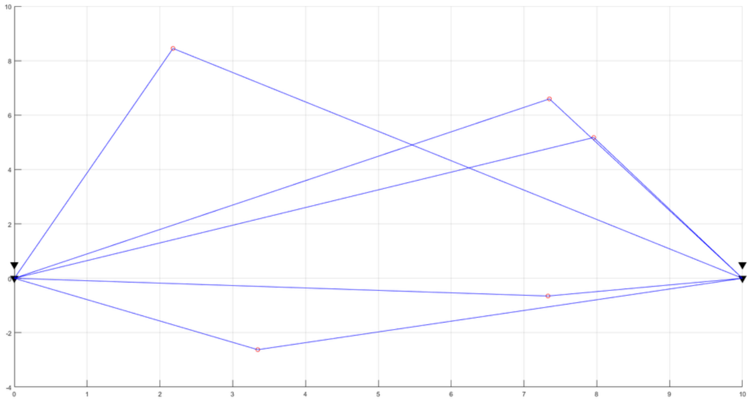
1st topic

Multi-antenna UE beamforming for high-mobility

Objectives

Beamforming algorithms that can dinamically adapt to rapidly changing environment in the UE side.

Minimize energy consumption



Next steps

1. Introducing movement in the UE
2. More scatters
3. Different antenna configurations