Project Overview

Project name, short and extensive	**INSTINCT (Joint Sensing and Communications for Future Interactive, Immersive, and Intelligent Connectivity Beyond Communications)**
Name of Coordinator, Company of coordinator	**Padmanava Sen (Barkhausen Institut gGmbH)**
Technical Manager	**Angeliki Alexiou (University of Piraeus - Research Center)**
Start date-End date of the project	**January 2024 – December 2026**
Website	http://instinct-6g.eu/
LinkedIn account	https://www.linkedin.com/company/eu-instinct/
YouTube account	https://www.youtube.com/channel/UCJTnxxFO1QQFr9MEPVyWOIg
Verticals concerned (see list below)	Wireless Communication Technologies and Signal Processing, Joint communication and sensing
List of partners	Barkhausen Institut, University of Piraeus - Research Center, Bosch, Aalto University, Fraunhofer HHI, Greenerwave, NEC Laboratories Europe, Institut National de Recherche en Informatique et Automatique, Institut National des Sciences Appliquées de Lyon, i2CAT Foundation, Oulu University, Centralesupelec, Telefónica Innovación Digital (TID), Telefónica (TSA)

Contributors in this Newsletter: Researchers in the consortium

E-mail: instinct-info@barkhauseninstitut.org

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Co-funded by the European Union

Papers and Results in July – December 2025

1. G. Stratidakis, S. Droulias and A. Alexiou, "Beam-focusing Based Hierarchical Localization and Tracking in Angle and Range," *2025 IEEE International Conference on Communications Workshops (ICC Workshops)*, Montreal, QC, Canada, 2025, pp. 317-323, doi: 10.1109/ICCWorkshops67674.2025.11162337.

In this paper, a hierarchical localization algorithm was presented for tracking mobile users. The algorithm takes advantage of beam-forming and beam-focusing techniques to estimate the direction and distance of the user in relation to the TX. To this end, a novel ranging method was presented exploiting the beam-focusing capability to concentrate the power of a beam within a desired (focal) area. The performance of the algorithm was evaluated by means of probability of success, average localization error, and the CDF of the localization error for different number of timeslots. The results show that, with sufficient number of timeslots, the algorithm can achieve 99.6% probability of success, with an average localization error of 2 cm, and 99% of the localization errors below 4 cm.

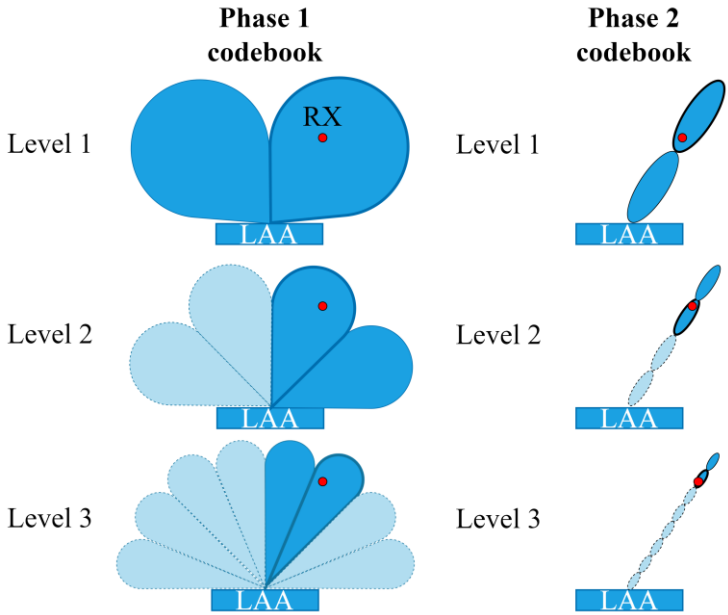
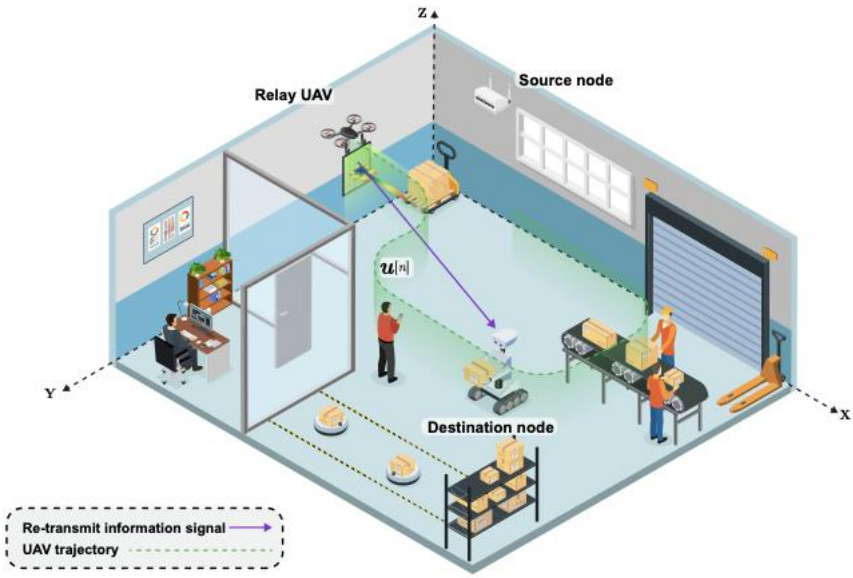


Figure 1: Concept of the proposed localization algorithm.

In Phase 1 the algorithm estimates the direction of the RX with beam-forming, and in Phase 2 the distance with beam-focusing. (The dark-toned beams, and focal areas are the ones used (for this RX location) by the algorithm, while the light-toned beams and focal areas represent the rest of the beams and focal areas that can be generated by the codebooks. The dark outline marks the beams and focal areas where the user was found.)

2. Miniature UAV-Aided Cooperative THz Networks with Reconfigurable Energy Harvesting Holographic Surfaces

Song, Y., Jalali, J., Qin, Y., Darabi, M., Lemic, F., Famaey, J., & Devroye, N. (2025). Miniature UAV-Aided Cooperative THz Networks with Reconfigurable Energy Harvesting Holographic Surfaces. IEEE Internet of Things Journal.



This paper demonstrates how constrained miniature UAVs can be elevated from simple relays to energy-aware THz network nodes by leveraging reconfigurable energy-harvesting holographic surfaces (RHS) and joint optimization across communication and mobility. Concretely, it formulates and solves an energy-efficiency maximization problem that jointly optimizes the UAV's 3D trajectory and NOMA power allocation (with RHS-assisted links), showing consistent gains over benchmark strategies and providing practical design insights on how factors such as mission time, surface size (number of elements), and molecular

absorption impact performance. Overall, the work supports INSTINCT's vision of UAVs as mobile extensions of future wireless infrastructure, capable of operating under strict energy constraints while enabling forward-looking THz connectivity and adaptive network operation.

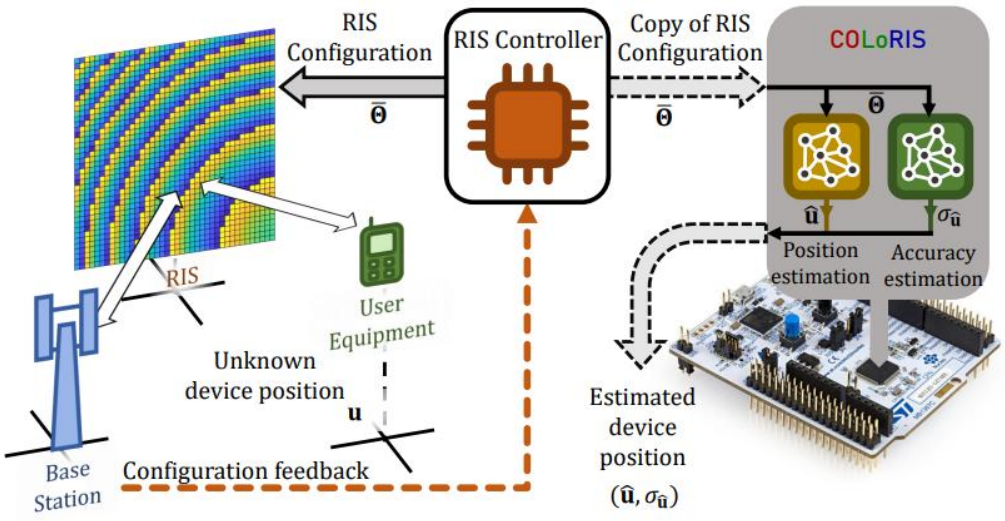
3. Experimental Assessment of Neural 3D Reconstruction for Small UAV-Based Applications

Castillo Gómez-Raya, G., Veres-Vitályos, Á., Lemic, F., Royo, P., Montagud, M., Fernández, S., Abadal, S., & Costa-Pérez, X. (2025). Experimental Assessment of Neural 3D Reconstruction for Small UAV-Based Applications. Proceedings of the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC).

This paper shows the feasibility of using sub-100 g nano-UAVs (Crazyflie 2.1) to perform advanced sensing tasks through neural 3D reconstruction (N3DR), benchmarking state-of-the-art methods (e.g., Instant-ngp, Nerfacto, Splatfacto) against classical SfM under highly constrained data acquisition conditions. Beyond demonstrating improved reconstruction fidelity in representative small-scale scenarios, it highlights that standard evaluation metrics can be insufficiently sensitive for fine-grained targets and motivates more appropriate assessment methodologies. Importantly, the reconstructed models enable downstream capabilities such as anomaly detection/localization by comparing reconstructions against a reference and visualizing/quantifying geometric deviations, aligning directly with INSTINCT's forward-looking role of UAVs as mobile carriers of sensors for inspection, digital-twin generation, and situational awareness in challenging environments.

4. Coloris

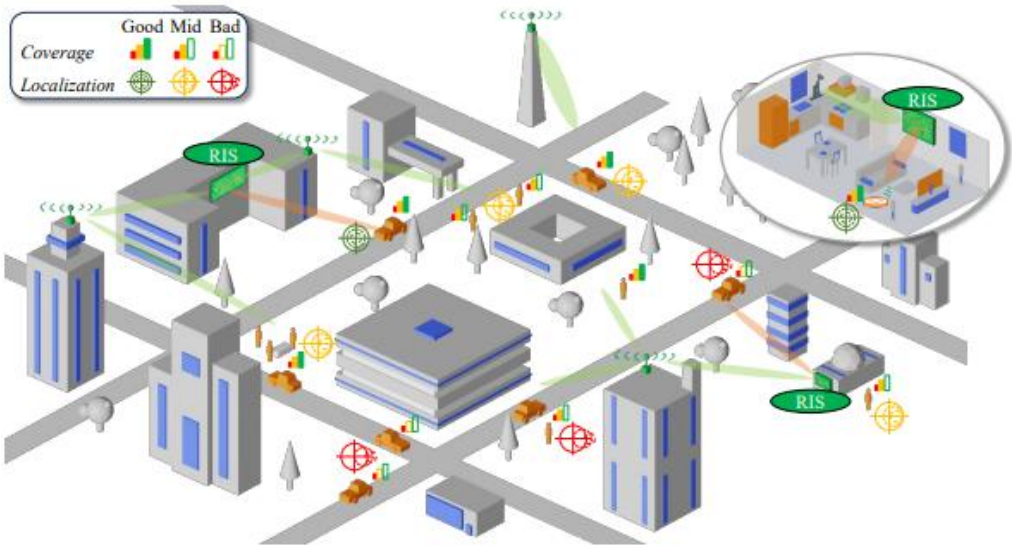
G. Encinas-Lago, F. Devoti, M. Rossanese, V. Sciancalepore, M. D. Renzo and X. Costa-Pérez, "COLoRIS: Localization-Agnostic Smart Surfaces Enabling Opportunistic ISAC in 6G Networks," in IEEE Transactions on Mobile Computing



This paper, resulting from a collaboration between i2CAT and NEC, proposes COLoRIS, an opportunistic RIS-based localization approach: instead of dedicating special time/configurations for positioning, it reuses the RIS configurations already chosen for communications to infer the UE position. The core idea is to train a DNN that maps the RIS configuration patterns to UE coordinates, so the localization runs "in parallel" without disrupting the comms optimization loop. It also includes an accuracy (error) prediction element, motivated by Fisher-Information/CRB arguments (i.e., how "sensitive" configurations are around the estimated position). The paper reports experimental + simulation validation, with positioning errors reported as a percentage of the field size, and also a low-complexity embedded version with small additional energy cost. Overall, this work advances INSTINCT's vision of sustainable, multi-functional 6G by demonstrating how intelligent surfaces can serve as dual-purpose infrastructure, providing high-performance connectivity and high-precision sensing simultaneously with minimal energy and complexity overhead.

5. Riloco

G. Encinas-Lago, V. Sciancalepore, H. Wymeersch, M. Di Renzo and X. Costa-Pérez, "RiLoCo: An ISAC-Oriented AI Solution to Build RIS-Empowered Networks," in IEEE Transactions on Wireless Communications

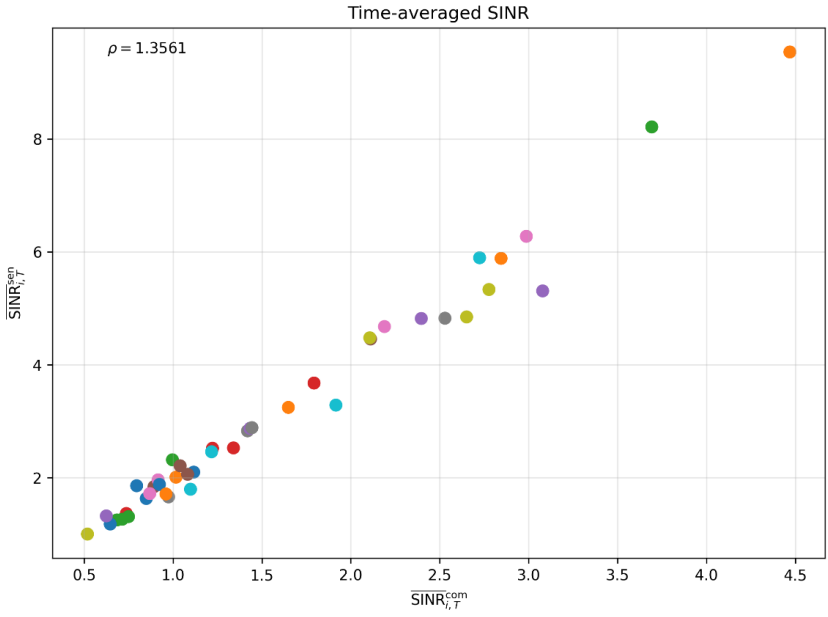


RiLoCo tackles the deployment problem: where to place infrastructure elements, including RISs so the network performs well for both communications coverage and localization (ISAC-oriented deployment). The key contribution is a joint metric that combines sensing/localization and communications performance, built around Fisher information derived from consolidated spatial PDFs of user location estimates. On top of this metric, RiLoCo uses a reinforcement learning (Q-learning) framework to efficiently search the space of plausible deployments (including blockages/shadowing and heterogeneous devices like BSs and RISs). The reported outcome is a deployment approach that can balance the two objectives, aiming to get close to "good comms" and "good localization" simultaneously rather than optimizing only one. Importantly, this aligns with INSTINCT's pillar of AI-native network co-design, providing a scalable methodology to balance competing ISAC objectives and ensuring that the next generation of wireless infrastructure is "sensing-ready" from day one.

6. Results – JCAS Performance Metrics

In this work, stochastic geometry (SG) is used to define performance metrics for Joint Communication and Sensing (JCAS). Within this framework, base stations (BSs), user equipments (UEs), and sensing objects (SOs) are modelled as spatial point processes. Communication and sensing performance is then captured through metrics such as Signal-to-interference-plus-noise ratio (SINR) and Shannon rate. By explicitly accounting for network-wide interference, spatial randomness, and mobility, these metrics reveal the intrinsic coupling between communication and sensing and provide a rigorous analytical foundation for evaluating JCAS performance in large-scale 6G networks.

To validate these metrics under realistic operating conditions, a dedicated software-based simulator has been developed. Its architecture and parameterisation are carefully aligned with the assumptions of the SG analysis, enabling the behaviour of the metrics to be observed in controlled yet flexible scenarios. The simulator supports large deployments of BSs, UEs, and SOs, implements joint radar-communication waveforms, and incorporates queue dynamics and Kalman-filter-based estimation. This allows steady-state quantities—such as queue lengths or estimation errors—to be directly compared with their SG-based theoretical counterparts. The simulator operates in JCAS, communication-only, and detection-only modes, and reports both per-BS and network-level results.



6GSNS Co-funded by the European Union

List of Publications (2025 July - December)

1. S. Beyraghi, J. Shabanpour, G. Geraci, P. Almasan and A. Lozano, "Data-Driven Deployment of Reconfigurable Intelligent Surfaces in Cellular Networks", IEEE Journal on Selected Areas in Communications, Dec. 2025.

2. M. E. M. Makhlouf, Y. Vindas, A. Kumar, M. Guillaud and M. Di Renzo, "Charting Channels in the Presence of RIS", Asilomar Conference on Signals, Systems, and Computers (Asilomar), Pacific Grove, CA, Dec. 2025.

3. A. Kumar, Y. Vindas and M. Guillaud, "Doppler-Supervised Channel Charting", Dec. 2025. doi: 10.5281/zenodo.17800204.S. Droulias and A. Alexiou, "Orthogonal Beam-Focusing With Planar Arrays for Multiple Access in Near-Field Communications", Aug. 2025.

4. S. Beyraghi, J. Shabanpour, G. Geraci, P. Almasan and A. Lozano, "Site-Specific RIS Deployment in Cellular Networks via Calibrated Ray Tracing", Nov. 2025.

5. Y. Song, J. Jalali, Y. Qin, F. Lemic, J. Famaey and N. Devroye, "Miniature UAV-Aided Cooperative THz Networks with Reconfigurable Energy Harvesting Holographic Surfaces", IEEE Internet of Things Journal, Nov. 2025.

6. J. Martínez Canals, F. Devoti, V. Sciancalepore, M. Di Renzo and X. Costa-Pérez, "Curved Apertures for Customized Wave Trajectories: Beyond Flat Aperture Limitations", Jul. 2025.

7. G. Castillo Gómez-Raya, Á. Veres-Vitályos, F. Lemic, P. Royo, M. Montagud, S. Fernández, S. Abadal and X. Costa-Pérez, "Experimental Assessment of Neural 3D Reconstruction for Small UAV-based Applications", IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Istanbul, Turkey, Sep. 2025.

8. S. Beyraghi, G. Interdonato, G. Geraci, S. Buzzi and A. Lozano, "Evaluating the Performance of Reconfigurable Intelligent Base Stations through Ray Tracing", 2025 IEEE 26th International Workshop on Signal Processing and Artificial Intelligence for Wireless Communications (SPAWC), Surrey, UK, Jul. 2025.

INSTINCT Dissemination Snapshot

📢 At a Glance

A strong series of invited talks, keynotes, workshops, and tutorials highlighted INSTINCT's leadership in ISAC, RF systems, and 6G research—reaching top universities, major conferences, and key industry players.

🎓 Academic Outreach

- University of Southern California (INRIA/INSAL)

Advances in Wireless Channel Charting

- KTH Royal Institute of Technology, Sweden (AAL)
- Lund University, Sweden (AAL)

  Resource-efficient NextG ISAC – Bridging Sparse Arrays, Spatial Modulation and Subspace Codes

🎤 **High-Profile Keynote**

- UbiComp / ISWC 2025 (AAL)

  Integrated Radar Sensing and Communications: Convergence, Co-design and Learning

🏭 **Industry Engagement**

- Invited talk at Rohde & Schwarz, Munich (Bosch)

  Integrated Sensing and Communication for Automotive and Industrial Manufacturing

🌐 **Major Conference Contributions**

- European Microwave Week 2025 (BI)

  Workshop talk:

  Reconfigurable Frontends for Deployable Privacy-preserving ISAC/JCAS (Workshop: The Path to 2030: JCAS in the 6G Internet-of-Everything Era) IEEE ICECS 2025 (BI)

  Tutorial:

  Key Hardware Enablers for Next-Generation Reconfigurable and Energy-efficient RF Systems

✨ **Impact**

INSTINCT partners **reached research communities, industry,** and **business stakeholders**, reinforcing the project's visibility and influence across the global ISAC and RF technology landscape.

Selected Events in July – December 2025

1. Venue: 6G Expert Days 2025

Link: https://www.rohde-schwarz.com/de/loesungen/wireless-communications-testing/events/6g-expert-days_254785.html

Topic: INTEGRATED SENSING AND COMMUNICATION FOR AUTOMOTIVE AND INDUSTRIAL MANUFACTURING

Abstract:

Integrated Sensing and Communication (ISAC) holds immense potential for transformative applications in automotive and industrial manufacturing, promising unparalleled new sensing prospective. However, a significant challenge lies in the insufficient definition of specific requirements from these diverse sectors, hindering targeted ISAC development. This lack of clarity contributes to the current fragmented progress in ISAC research and implementation, leading to questions about whether initial hype is giving way to a more pragmatic, yet slower, evolutionary phase. To unlock ISAC's full capabilities, a concerted effort is needed to establish precise, application-driven requirements from industry stakeholders, guiding future innovation effectively.

Data-Driven Deployment of Reconfigurable

Intelligent Surfaces in Cellular Networks

Summary:

Dense urban cellular networks suffer from persistent coverage holes, especially at higher frequencies, due to blockage by buildings, limited diffraction, and complex propagation effects that leave a non-negligible fraction of outdoor users in outage. This problem is particularly critical in urban environments, where operators aim to reuse existing base-station sites while rolling out new spectrum (e.g., 5G and beyond) without costly densification, making coverage enhancement both a technical and an economic challenge. To address this challenge, TID worked on a fully automated, data-driven framework for Reconfigurable Intelligent Surface (RIS) deployment, leveraging site-specific, physically consistent ray tracing and real measurement data from a commercial urban network. The methodology clusters outage users, identifies candidate RIS locations using reflection- and scattering-based ray heuristics, and jointly optimizes RIS placement, orientation, configuration, and base-station beamforming across multiple frequency bands (2, 3.5, and 10 GHz). The outcomes of this work have led to two peer-reviewed publications accepted at IEEE Journal on Selected Areas in Communications (JSAC) and IEEE GLOBECOM 3rd Workshop on Data Driven and AI-Enabled Digital Twin Networks and Applications (TwinNetApp).

IEEE Globecom conference presentation:

2. Venue: RADAR CONFERENCE 2025

Link: https://radarconf2025.org/

Contribution – Padmanava Sen (Barkhausen Institut) is one of the panellists in the INTEGRATED SENSING AND COMMUNICATION Panel (Special Session), moderated by Bhavani Shankar, U Luxembourg.

Picture Courtesy - Okyanus Oral and Radar conference 2025 Organizers