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) Contact**
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/**
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 (TID), Teleónica (TSA)**

Contributors in this Newsletter: Researchers in the consortium

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Overview

The INSTINCT project is aimed to enable globally sustainable, interactive, immersive, and intelligent 'beyond communications' 6G connectivity by developing three complementary but critical breakthrough technology pillars:

PILLAR I – "Sense-to-communicate": to improve radio spectrum usage by leveraging sensing information for supporting of 'beyond communications' use cases.

PILLAR II – "Communicate-to-sense": to transform the wireless network into a smart 'sense the world' platform, capable of providing JCAS (Joint Communication and Sensing) -as-a-service functionalities towards a wireless radio 'beyond transmitting bits', capable of sensing, detecting, mapping, and 'understanding' semantics.

PILLAR III – Multi-functional JCAS Network Intelligence: to optimise the architecture, resources, propagation and waveforms aided by AI for wireless JCAS systems.
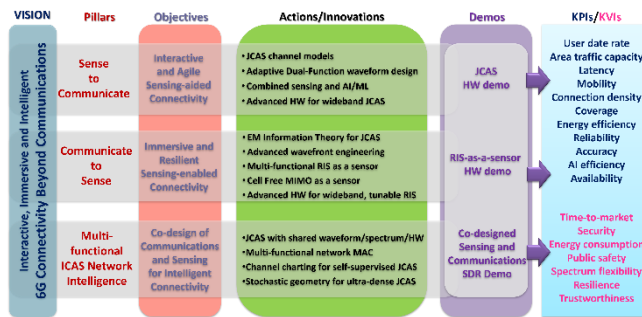
Summary of INSTINCT pillars, objectives, innovations, demos and KPIs.

Concept/Architecture/Technologies

INSTINCT aspires to deliver the theoretical framework and relevant Key Performance Indicators (KPIs), waveforms, protocols and hardware (HW) design of an innovative beyond communications 6G architecture, which combines the benefits of Sensing-assisted Communications, Communications-assisted Sensing and the Co-design of Sensing and Communications, leveraging Intelligent Surfaces and AI/ ML (machine learning).

INSTINCT, by means of its 3 pillars, will establish the foundations, invent the enablers and devise new architectures and, thus, offer the cornerstones of a new ICST (Information Communications and Sensing Technologies) era, where IoT meets ICT.

Innovation (1200 characters max without image)

INSTINCT develops sensing-assisted communication technologies thus allowing localization, tracking, mapping, monitoring, imaging, incident detection and semantics become integral parts of connectivity services. (Pillar I)

INSTINCT leverages the capabilities of intelligent surfaces, holographic radios and cell free systems, which offer wavefront engineering functionalities, tunability and programmability of the wireless environment and can act as reconfigurable and intelligent sensors. (Pillar II)

INSTINCT employs Machine Learning (ML) techniques and structured optimisation to incorporate the co-design of Sensing and Communications as main ingredient of multi-functional 6G network intelligence. (Pillar III)

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INSTINCT interdisciplinary approach comprises 3-phase methodology (theoretical studies, ecosystem development, demonstration and KPI evaluation) and will provide 2 HW and 1 software (SW) demo for interactive, immersive and intelligent connectivity in three 6G usage scenarios.

The timeliness and pertinence of INSTINCT impact originates from its relevance to 6G technologies and to recent developments in regulation and standardisation, specially to address the gaps, especially in recent EC funded research (under the SNS JU call 1 framework).

Work Package 1 Updates

The use cases in INSTINCT (work package 1) are classified in three general categories, namely sensing-aided connectivity, sensing-able connectivity and multifunctional JCAS intelligence. To allow their simulative evaluation, available deterministic and statistical channel models will be upgraded, focusing on the integration of reconfigurable intelligent surface (RIS) models and JCAS performance metrics. The outcomes will allow to quantify the achievable performance of JCAS wireless networks and to benchmark the final demonstrations.
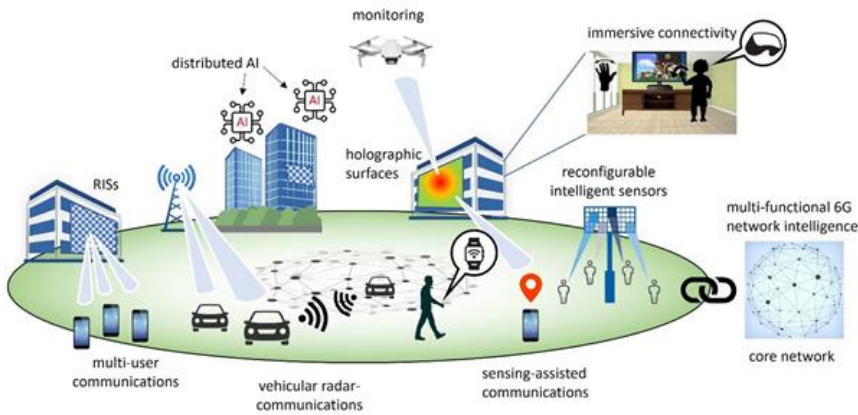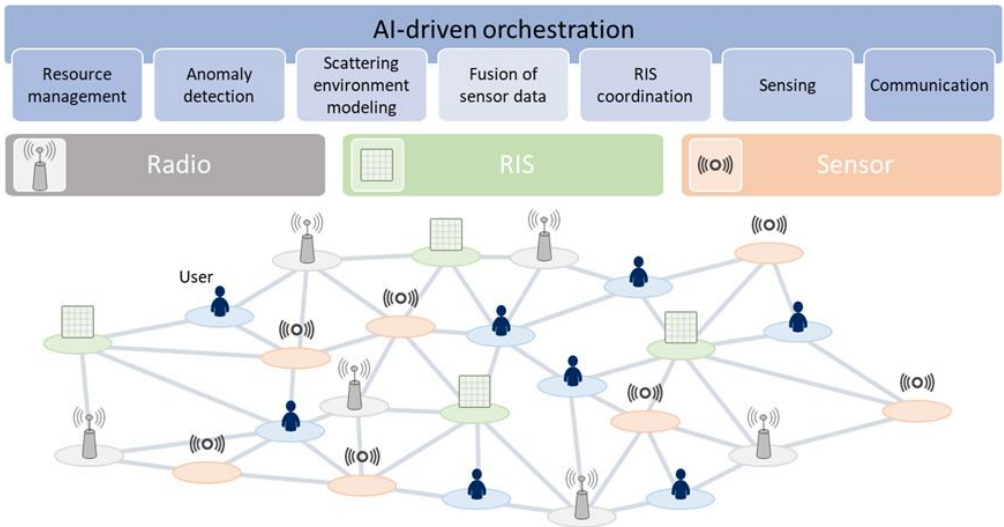

Work Package 2 Updates

During the first year of the project, the work in Work Package 2 (WP2) Joint Communications and Sensing Technology Enablers has resulted in the first results in waveform development for vehicles for detecting their surroundings and communicating with other vehicles, multi-carrier waveforms for JCAS systems, improved positioning by combining data from more than one positioning system, near-field localization utilizing a reconfigurable intelligent surface (RIS) and understanding of limits for communications and sensing in cellular and cell-free systems. Furthermore, a design for RIS prototype has been developed and conformal RIS layout design as well as the development of autonomously reconfiguring RISs have been considered. The mitigation of hardware impairment in both JCAS transmitters and receivers has also been studied. The work on these topics will continue during the rest of the WP2 duration.

Work Package 3 Updates

Work package 3 focuses on developing a network architecture that fully supports JCAS operations. Its primary goals include designing efficient resource allocation strategies, managing coordination among multiple sensors and RISs, implementing an AI-driven orchestration layer, and crafting a flexible management system to address diverse service requirements. The outcomes of the work package will encompass architectures, protocols, and software solutions.

Work Package 4 Updates
Work package 4 includes plans for indoor and outdoor scenarios, such as industrial manufacturing and large campus logistics, to demonstrate the project's outcomes. This will involve evaluating relevant KPIs including object detection probability, localization accuracy, range and angular resolution, service latency, maximum guaranteed data rate, etc. The demonstrations will showcase the benefits of the project by combining different techniques such as JCAS, RIS, GNSS, etc.

Major Events

The SNS INSTINCT 6G project held a plenary meeting in Barcelona, hosted by the i2CAT Foundation. The meeting brought together consortium members for a three-day series of discussions focused on the project's recent technical progress, results, and forthcoming key performance indicators (KPIs). It enabled the team to make significant progress in shaping the future of 6G technology, underlining the project's commitment to innovation and collaboration within the field.
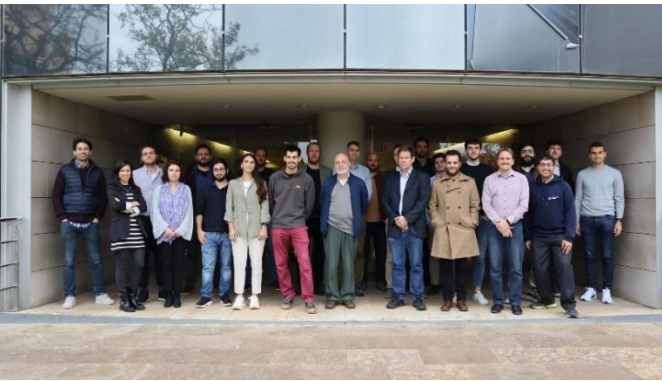
The **SNS INSTINCT 6G** project organized a workshop in the 5th IEEE Symposium on Joint Communications & Sensing (**https://lnkd.in/esdKwGR9**) on January 28. The symposium is held in Oulu, Finland, and hosted by the **University of Oulu**, one of the **#INSTINCT** partners. The INSTINCT workshop consisted of talks by **Padmanava Sen** (**Barkhausen Institut**e), **Angeliki ALEXIOU** (**University of Piraeus**), **Nhan Nguyen** (**University of Oulu**) and **Simon Martin Schütze** (**Fraunhofer Heinrich Hertz Institute HHI**).

List of Publications (2024)

Andra Blaga, Federico Campolo, Maurizio Rea, Xavier Costa-Pérez, "3DSAR+: A Single-Drone 3D Cellular Search and Rescue Solution Leveraging 5G-NR," in *IEEE Open Journal of the Communications Society,* vol. 5, pp. 4808-4822, 2024

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Antonio Albanese, Francesco Devoti, Vincenzo Sciancalepore, Marco Di Renzo, Albert Banchs, Xavier Costa-Pérez, "ARES: Autonomous RIS Solution With Energy Harvesting and Self-Configuration Towards 6G," in *IEEE Transactions on Mobile Computing*, vol. 23, no. 12, pp. 12006-12019, Dec. 2024

Hongyu Li, Shanpu Shen, Matteo Nerini, Marco Di Renzo, Bruno Clerckx, "Beyond Diagonal Reconfigurable Intelligent Surfaces With Mutual Coupling: Modeling and Optimization," in *IEEE Communications Letters*, vol. 28, no. 4, pp. 937-941, April 2024

Naveed Ul Hassan, Jiancheng An, Marco Di Renzo, Mérouane Debbah, Chau Yuen, "Efficient Beamforming and Radiation Pattern Control Using Stacked Intelligent Metasurfaces," in *IEEE Open Journal of the Communications Society*, vol. 5, pp. 599-611, 2024

Gerard Calvo Bartra, Filip Lemic, Guillem Pascual, Aina Pérez Rodas, Jakob Struye, Carmen Delgado, Xavier Costa Pérez, "Graph Neural Networks as an Enabler of Terahertz-Based Flow-Guided Nanoscale Localization Over Highly Erroneous Raw Data," in *IEEE Journal on Selected Areas in Communications,* vol. 42, no. 8, pp. 1992-2008, Aug. 2024

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Aritra Basu, Soumya P. Dash, Aryan Kaushik, Debasish Ghose, Marco Di Renzo, Yonina C. Eldar, "Performance Analysis of RIS-Aided Index Modulation With Greedy Detection Over Rician Fading Channels," in *IEEE Transactions on Wireless Communications*, vol. 23, no. 8, pp. 8465-8479, Aug. 2024

Yun Wen, Gaojie Chen, Sisai Fang, Miaowen Wen, Stefano Tomasin, Marco Di Renzo, "RIS-Assisted UAV Secure Communications With Artificial Noise-Aware Trajectory Design Against Multiple Colluding Curious Users," in *IEEE Transactions on Information Forensics and Security,* vol. 19, pp. 3064-3076, 2024

Sotiris Droulias, Giorgos Stratidakis, Emil Björnson, Angeliki Alexiou, "Reconfigurable Intelligent Surfaces as Spatial Filters," in *IEEE Transactions on Wireless Communications,* vol. 23, no. 11, pp. 16922-16934, Nov. 2024

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Jakob Struye, Filip Lemic, Jeroen Famaey, "Multi-Gigabit Interactive Extended Reality over Millimeter-Wave: An End-to-End System Approach," *2024 IEEE 35th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC),* Valencia, Spain, 2024, pp. 1-7

Yamil Vindas, Maxime Guillaud, "Multi-Site Wireless Channel Charting Through Latent Space Alignment," *2024 IEEE 25th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC),* Lucca, Italy, 2024, pp. 826-830

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Vesa Saarinen, Robin Rajamäki, Visa Koivunen, "Generative Deep Synthesis of MIMO Sensing Waveforms with Desired Transmit Beampattern," *2024 58th Asilomar Conference on Signals, Systems, and Computers,* Pacific Grove, CA, USA, 2024, pp. 1194-1198

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