

# REINDEER

## RESILIENT INTERACTIVE APPLICATIONS

THROUGH HYPER DIVERSITY IN  
ENERGY EFFICIENT RADIOWEAVES  
TECHNOLOGY

### Message from the Technology Lead, Liesbet Van der Perre (KU Leuven)

I am very excited about the REINDEER project as we are advancing technology for beyond 5G networks. The questions of what 6G should offer have received a lot of attention recently. The interactive applications we focus on require support for novel functionalities, including positioning information and interaction with energy-neutral devices. The RadioWeaves technology we are developing is very well suited to provide these features. One key aspect we aimed for is the reduction of energy consumption in the network for the same data transmission volumes. The REINDEER project promises a big leap in this aspect based on the way we conceptually develop the network. A further question raised for 6G is that networks will not be cell based as hard as they are today. We are anticipating and developing cell-free networks that are much more fluent and can adapt much better to the traffic that is at a certain place and time. The results achieved in the first 18 months of the project confirm the great potential of the new concepts being developed in REINDEER to offer better service levels, including higher reliability, at significant better energy efficiency. The project partners have been very active in the dissemination of the results via papers, presentations, and workshop contributions.



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[reindeer-project.eu](https://reindeer-project.eu)



@H2020Reindeer



[reindeer-h2020](https://reindeer-h2020.com)

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### Budget

€ 4.7 Million

100% EU-funded



### Consortium

9 Partners

4 countries



### Duration

42 Months

01/2021 - 06/2024

## WP2

### RadioWeaves platform: Models, architectures, and typologies

WP lead: Ove Edfors (ULUND)

The REINDEER teams under the lead of ULUND in cooperation with TEC, KU Leuven, LIU, ULUND, EAB and TU Graz assessed the RadioWeaves infrastructure. Based on the use cases and KPIs defined in D1.1 “Use case-driven specifications and technical requirements and initial channel model” the team established a first version of the building blocks of the infrastructure together with new terminology. Architecture and topology were introduced together with a quantitative and qualitative analysis of high-level requirements on a RadioWeaves infrastructure, setting the scope for more detailed investigations and design. Initial studies of local and

centralized processing alternatives for uplink and downlink RadioWeaves architecture that reduce fronthaul traffic and processing.

The ambition regarding energy efficiency was elaborated. Discussions to consider the requirements of zero-energy devices and localization algorithms took place between partners. Furthermore, partners worked on analysing performance evaluations, implementation of a simulation environment, simulations and specifications on BLE backscattering and Wifi.

## WP3

### Scalable Protocols and algorithms for robust cell-free operation

WP lead: Erik G. Larsson (LIU)

The focus of the project team led by LIU in cooperation with ULUND, TU GRAZ, KU Leuven, EAB and TEC has been on physical-layer performance evaluation of RadioWeaves. Specifically, an effective-SINR abstraction model was developed and shown to be accurate and highly efficient in terms of computational complexity. Furthermore, an evaluation of the complexity of existing algorithms in terms of computational load and front-haul signalling for different cell-free topologies considered in the literature took place. The team also developed and proposed efficient algorithms for distributed MIMO processing of RadioWeaves with centralized and decentrali-

zed approaches. In the process they recognised issues which can cause scalability issues, listed possible solutions for the distributed architecture and formulated a computationally efficient performance evaluation framework. The work package is progressing well. Specifically, progress has been made in the direction of energy efficiency and operation in unlicensed bands, on federation-based orchestration, and on method development for initial access and phase alignment/calibration. Additionally, investigations on interference cancellation for out-of-system interference are underway.

## WP4

### Processing and Signalling for Energy-Neutral Devices

WP lead: Klaus Witsrisal (TU Graz)

The team of WP4, led by TU Graz in cooperation with NXP, KU Leuven, LIU, and ULUND, has started two new tasks in the last period, concerned with signal processing and signalling schemes, respectively. Work commenced on common definitions of scenarios, devices and related specifications. A simulation environment has been prepared to investigate specific geometric settings and to analyse the link budgets and architecture requirements for energy neutral devices in such realistic scenarios. The simulation environment is also used to develop and evaluate signal processing algorithms for interacting with energy-neutral devices. Specifically, in

an initial paper presented ICC 2022, the initial access problem has been studied, i.e. the problem how to power up a purely passive device while no information is available yet on its channel state information, hence no array gain can be leveraged yet. The proposed solution makes use of a site-specific model of the propagation environment to realize robust beam sweeping towards potential device locations.

In the next period, the first report is due to be completed presenting a system design study for energy-neutral devices interacting with the RadioWeaves infrastructure bringing many of the above named tasks to a completion.

## Podcasts

Members of the REINDEER project have delivered and participated in a number of podcast discussing the REINDEER project and themes related to the project. All podcasts are available from our blog section on the project web site.

The Teknikon team has recorded a podcast with the technical leader **Liesbet Van der Perre** talking about the scope and reach of the REINDEER project, RadioWeaves and a bit of use cases and challenges. **Erik G. Larsson** (Linköping University) continues the discussion how the project can help facilitate

the idea of embedded antennas by using RadioWeaves technology.

**WIRELESS FUTURE** hosted by Linköping University hosts regular podcasts and a blog where emerging technologies, promising research results and commentary of news in the broader field of wireless technology are regularly discussed. Members of the REINDEER team are discussing their upcoming research and challenges in the REINDEER project within this environment.

## ADVISORY BOARD MEETING

14 January 2022

The REINDEER project started the new year highly motivated and met on Friday, 14th January 2022 with its Advisory Board. The REINDEER Advisory Board, composed of representatives from Niko, SES-imagotag and Thomas L. Marzetta who cooperates with project partners already for some years. The consortium presented an overview of the project and results of the first year, as well as some plans for 2022. There have been very interesting discussions. This first meeting was very helpful to get an external view on the planned project outcomes and use cases and we will continue with the discussions in the upcoming months.



## IEEE ICC International Conference on Communications 2022 and visit to POSTECH

16-20 May 2022

Under the theme “Intelligent Connectivity for Smart World” the vision of the ICC2022 was to discuss important future communication issues, share ideas and information, and accelerate innovation. The event was organized as a hybrid event, and many researchers still could not be present on site. The REINDEER team was strongly represented during the conference with 5 partners (KU Leuven, TU Graz, LIU, ULUND, EAB), >5 papers on results of REINDEER and related

work, 1 co-organized workshop, and taking responsibilities in the (TPC) Technical Program Committee and session chairing. They discussed the progress on the REINDEER project in regard to wireless power transfer and MIMO processing opportunities. At this occasion, Liesbet Van der Perre visited POSTECH and presented a lecture co-authored by REINDEER partners on distributed architectures for 6G.

<b>Conference Paper</b>	Location-based Initial Access for Wireless Power Transfer with Physically Large Arrays (TU Graz, LIU) <i>By Benjamin J. B. Deutschmann, Thomas Wilding, Erik G. Larsson, Klaus Witrisal</i>
<b>Conference Paper</b>	Uplink D-MIMO with Decentralized Subset Combining (EAB) <i>by Ke Wang Helmersson, Pal Frenger, Anders Helmersson</i>
<b>Conference Paper</b>	Energy-Efficient Power Allocation for an Underlay Spectrum Sharing Cell-Free Massive MIMO Network (LIU) <i>by Zakir Hussain Shaik, Rimalapudi Sarvendranath and Erik G. Larsson</i>
<b>Workshop</b>	ULUND and KU Leuven organized a workshop on “Synergies of sensing, communication, and localization towards 6G”.



# More past Events

## One World Signal Processing Seminars

The quest for future connected environments: the potential of RadioWeaves technology  
20 October, 2021

## NYU Wireless

Erik G. Larsson participated and debated in a panel organized by. Liesbet Van der Perre was co-organizer of the event  
28 October, 2021

## 55th Asimolar Conference on Signals, Systems, and Computers 2021

"A Multi-band Solution for Interacting with Energy-Neutral Devices"  
30 October - 3 November, 2021

## WSA2021

Carrier Synchronization in Distributed RadioWeaves  
10-12 November, 2021

## Wireless Future podcast

Liesbet Van der Perre guest on the Wireless Future podcast show  
10 November, 2021

## REINDEER Technical Meeting

Lund  
10 November, 2021

## Tutorial on distributed MIMO

for students in H2020-MINTS, delivered by Erik G. Larsson in Lund  
12 November, 2021

## 5GPPP Architecture WG

Progress of REINDEER presented  
26 November, 2021

## Advisory Board Meeting

14 January, 2022

## 5G-PPP TB Workshop

Presentation KU Leuven  
18-19 January, 2022

## ICT-52 Workshop on 6G

3-4 February 2022

## COST CA20120 INTERACT 2nd MC Meeting and 1st Technical Meeting

8-11 February, 2022

## REINDEER Technical Meeting WP2 and WP4

TU Graz in Graz / Austria  
26-27 April, 2022

## Presentation KU Leuven

"5G: Where are we (going) in EU-China relations?"  
27 April, 2022

## REINDEER Task 3.2 Workshop

LiU in Linköping / Sweden  
3 May, 2022

## IEEE International Conference on Communications (ICC) 2022

16-29 May 2022

## REINDEER Task 3.3 Workshop

ULUND in Lund / Sweden  
3 May, 2022

## EUCNC 2022 (EuCNC European Conference on Networks and Communications) 6G Summit

ULUND in Lund / Sweden  
7-10 June, 2022

Liesbet Van der Perre presented REINDEER in "The 6G workshop series by Hexa-X", presented the KU Leuven testbed paper "Techtile – Open 6G R&D Testbed for Communication, Positioning, Sensing, WPT and Federated Learning" and she participated in the panel "Developments and Challenges Enabling 6G THz Radio HW".



## Upcoming Events

### IEEE VTC 2022

19-22 June, 2022

@Helsinki, Finland

### IEEE SPAWC

4-6 July, 2022

@Oulu Finland

### Prep & Review Meeting

7-9 September, 2022

@Ghent Belgium

### Asilomar 2022

30 October - 2

November, 2022

@Pacific Grove, USA

### Globecom 2022

4-8 December, 2022

@ Rio de Janeiro, Brazil



All past and upcoming events can be found on the REINDEER official webpage:

[reindeer-project.eu](https://reindeer-project.eu)

# Results

<b>Conference Paper</b>	A Multi-band Solution for Interacting with Energy-Neutral Devices by Chesney Buyle, Bert Cox, Liesbet Van der Perre, Lieven De Strycker IEEE Asilomar 2021, 03/11/2021
<b>Conference Paper</b>	BeamSync: Over-The-Air Carrier Synchronization in Distributed RadioWeaves by U. K. Ganesan, R. Sarvendranath, E. G. Larsson
<b>Academic Article</b>	Partial Interference Suppression in Massive MIMO Systems: Taxonomy and Experimental Analysis by Andrea P. Guevara, Cheng-Ming Chen, Alessandro Chiumento, Sofie Pollin IEEE Access 15/09/2021
<b>Deliverable</b>	D1.1 "Use case-driven specifications and technical requirements and initial channel model"
<b>Deliverable</b>	D2.1 "Initial assessment of architectures and hardware resources for a RadioWeaves infrastructure"
<b>Deliverable</b>	D3.1 "Analytical Performance Metrics and Physical-Layer Solutions"
<b>White Paper</b>	Beyond 5G/6G KPIs and Target Values by Nielsen, L., Gavras, A., Dieudonne, M., Mesogiti, I., Roosipuu, P., Houatra, D., Kosmatos, E. June 2022

## The REINDEER Consortium

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