pepr-futurenetworks.fr

PEPR Networks of the Future

Overview of the French Priority Research Program and Equipments for the Networks of the Future

Dimitri Kténas

Indo-French Seminar, 6G Wireless Networks: Challenges and Opportunities, October 9-11, 2024

High level positioning of the PEPR

General Framework

FRENCH National Acceleration Strategy on 5G/6G & Future Network Technologies:

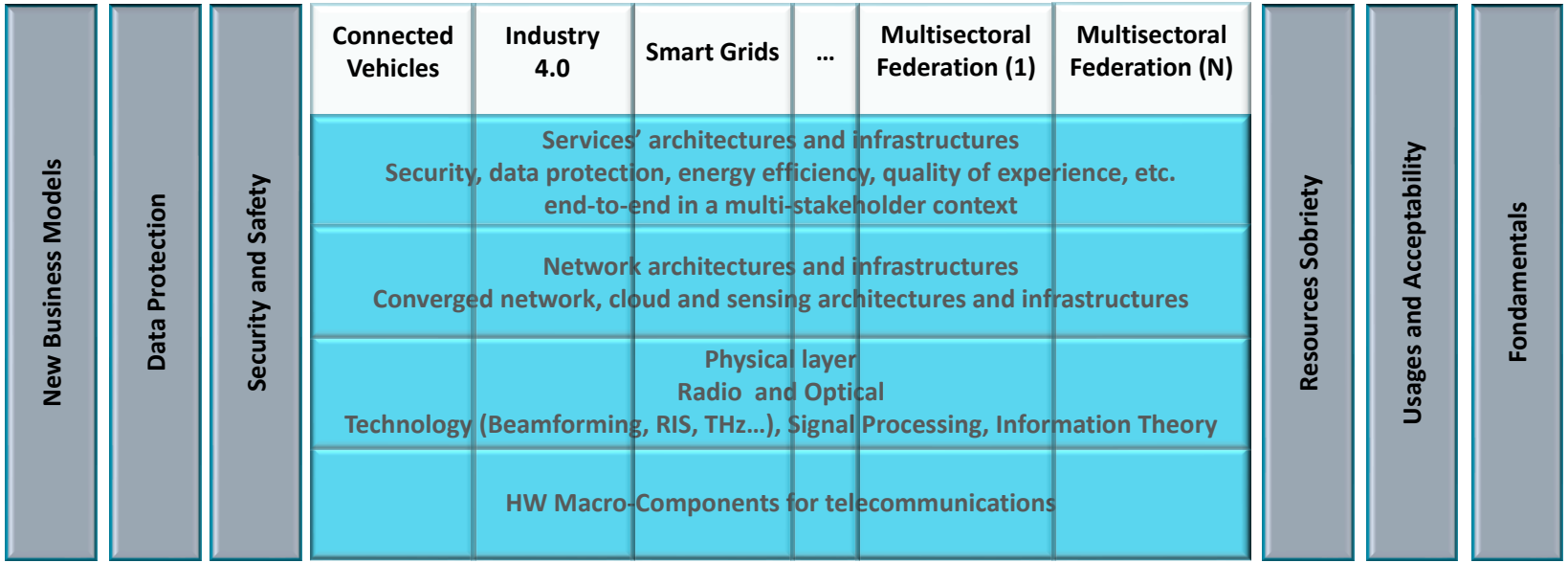
- Contribute to the competitiveness of the economy by developing 5G uses for the benefit of territories and industry - Axis 1 (**Demand component**);
- Establish a sovereign offer on telecoms networks - Axis 2 (**Offer component**);
- Support very high-level French R&D on future network - Axis 3 (**R&D component**); → Instrument: PEPR
- Strengthen the education offer on future telecom networks and attract foreign talent - Axis 4 (**Education component**).

Strategic vision – Networks of the Future

Increased capacity, Low latency, High density of connected devices - but above all strong, convergence with verticals	Industry 4.0, Transport, Energy, Health: responses to specific needs (remote industrial control, mixed reality, digital twins, distributed AI, immersive communications…)	Multi-sector services The new phase of digital transformation
From 2D to 3D Non-Terrestrial Networks	Merging with physical space: Reconfigurable Intelligent Surfaces (RIS)	Optimal use of spectrum, including towards THz
New architectural paradigms: network-cloud-sensing convergence, virtualization, slicing, orchestration of E2E AI-based control	End-to-end security and data protection, by design, in a multi-stakeholder context	Sobriety in the consumption of resources, acceptability, new use-cases, new business models

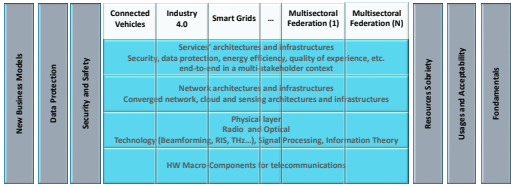
Program structuring

A set of projects with overall coherence.
Projects dealing with one or more rows and/or one or more columns.



The verticals interact technologically with the various entries of the matrix

Ongoing projects



Sept 28 2021 — Mission statements → Dec 11, 2021 — Proposal submitted → Fev 23, 2023 — Prog validation → May 1st, 2023 — T_o targeted projects

10 ongoing targeted projects, 40.5 M€
Call for projects: networks, photonics, ESS/SHS, …

Networks and services architectures

Project 1 – Archi and infra. Services
Project 2 – Archi and infra. Networks

Technology building blocks

Project 3 – « Cell free » sub 7GHz
Project 4 – MmWave
Project 5 – Towards THz

End-to-end s

Project 6 – IoT/
Project 7 – Ene
Project 8 – Sec
P
Project 9 – Fun

Experiments and Demonstrators

Integrative and open platform, accessible remotely

Coordinates and articulates the networks of high-layer platforms, IoT and high-frequency instrumentation of partners

General information

Leaders: CEA, CNRS, IMT

Partners : Inria, premium French universities and engineering schools, through common research laboratories distributed throughout the national territory.

Budget: 54 M€

PEPR activities:

- Targeted Projects
- Platforms and demonstrators
- Calls for Projects
- Pre-maturation program
- Research and innovation community structuring activities and dissemination of results
- Hiring of 104 PhDs and 67 post-docs

T0: 1st May 2023, duration 6 years - until the end of 2027 for targeted projects, April 2029 for the other activities.

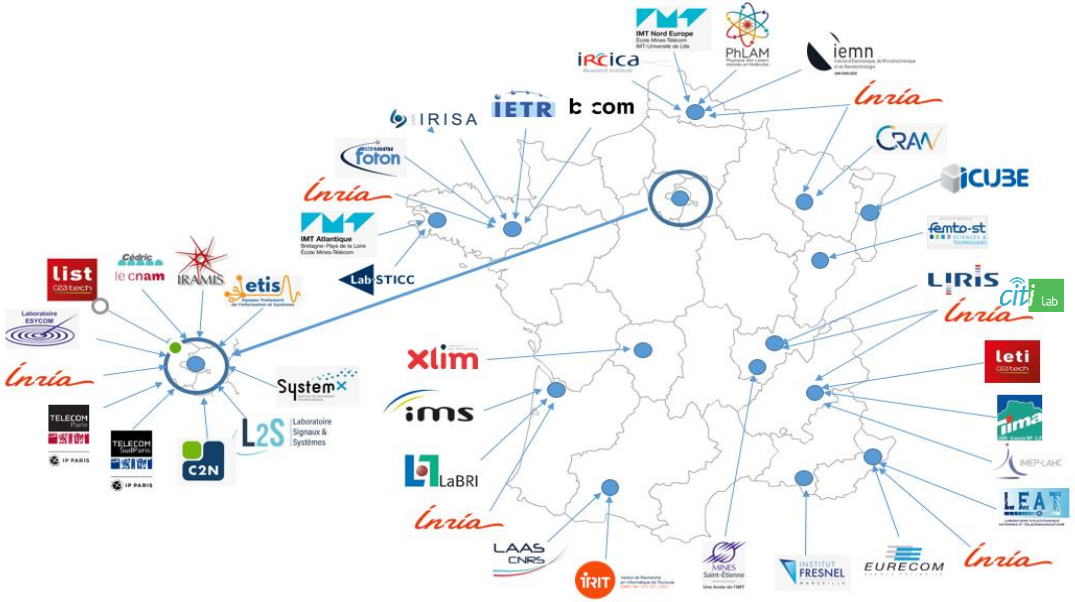
Consolidation of a network of industrial and institutional partners

500 permanent scientifics

104 doctoral students to be recruited

67 post-doctoral fellows to be recruited

34 research laboratories



Partners:

- Public French organizations
- Equipment manufacturers and operators
- European and International research centres

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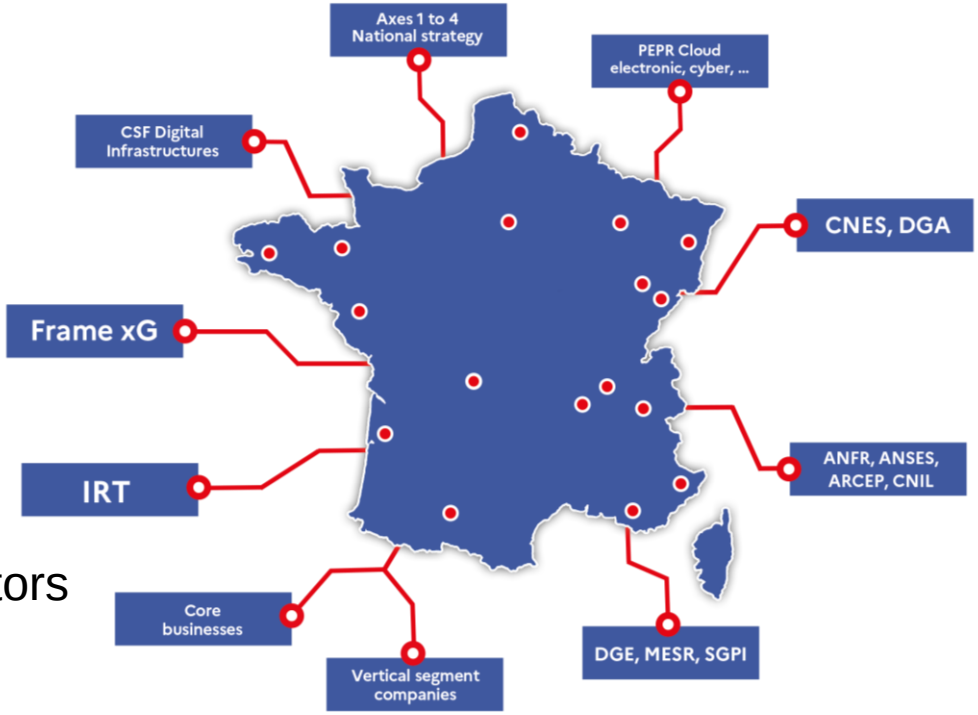


Partners:

- Public French organizations
- Equipment manufacturers and operators
- European and International research centres

Higher layer & Security

Data Protection

Security and Safety

Connected Vehicles | Industry 4.0 | Smart Grids | ... | Multisectoral Federation (1) | Multisectoral Federation (2)

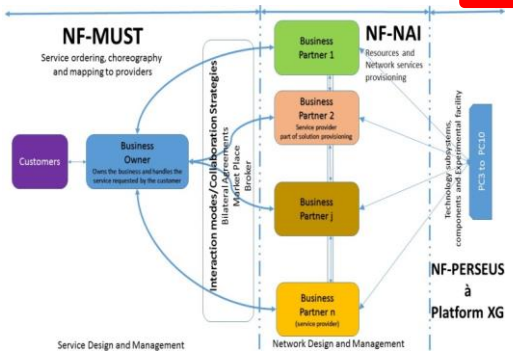
Services' architectures and infrastructures
Security, data protection, energy efficiency, quality of experience, etc.
end-to-end in a multi-stakeholder context
Network architectures and infrastructures
Converged network, cloud and sensing architectures and infrastructures

Physical layer
Radio and Optical

HW Macro-Components for telecommunications

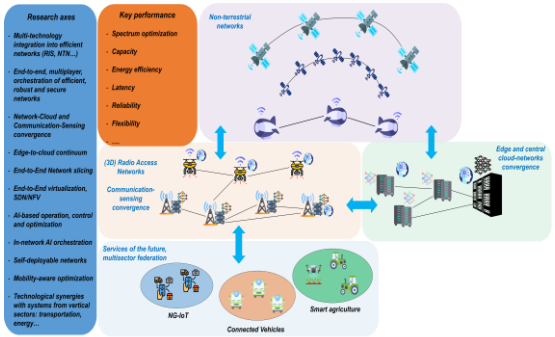
Resources Sobriety

Usages and Acceptability



NF-MUST

End-to-end 5G MUlti-domain Services managemenT architecture



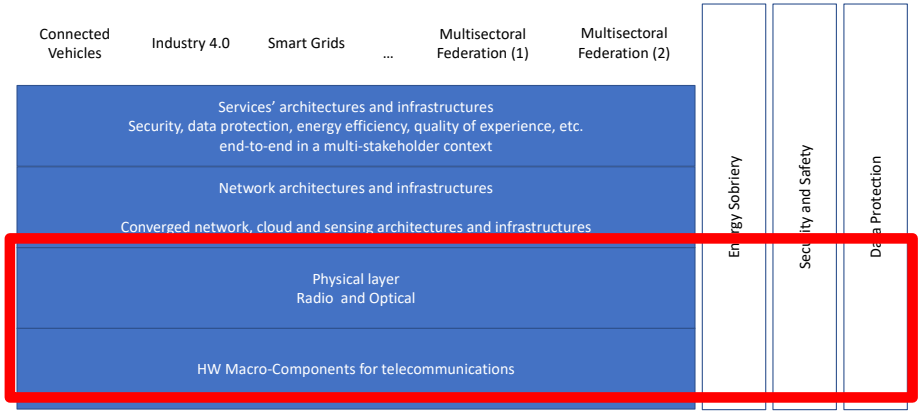
NF-NAI

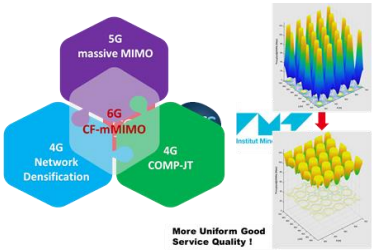
Networks Architecture & Infrastructure and Networks, Cloud and Sensing convergence

NF-HiSec

Cybersecurity for future networks

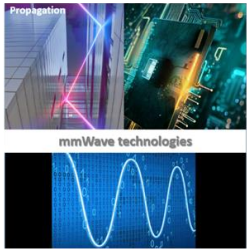
Towards ‘6G’: Technological building blocks





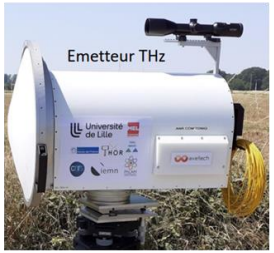
NF-PERSEUS

Efficient networks – Sub 7GHz



NF-YACARI

mm-Wave (30-90 GHz) Circuits, antennas, processing

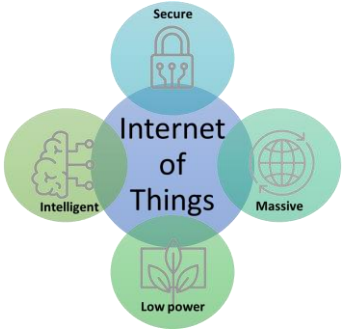


NF-SYSTERA

Beyond 90 GHz: building blocks for D & H-bands

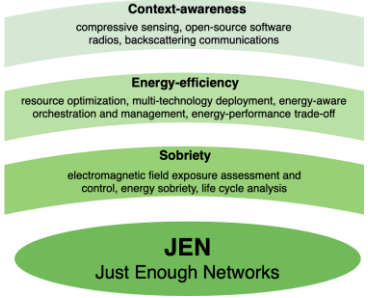
System level performance

Power consumption / Digital Process / Connectivity KPI to the limits for highly reliable information & data collection



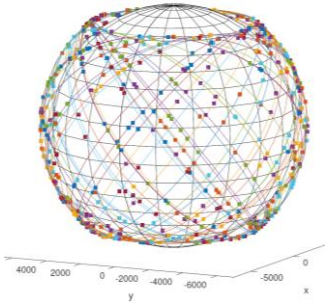
NF-FITNESS

IoT breakthroughts for massive & dense roll-out, Industry 4.0 & Mission-critical, and Connectivity in Mobility



NF-JEN

Just Enough Networks



NF-FOUNDS

Communications information process to the limits considering Mathematical Foundations

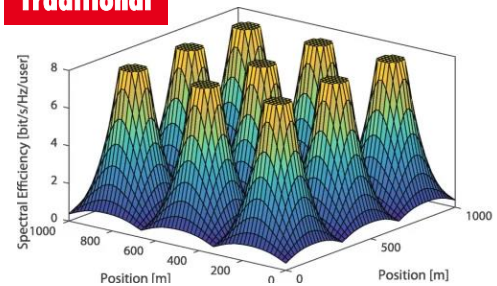
PERSEUS

Power-**E**fficient **R**adio interface
for **S**ub-7GHz distribut**E**d
massive MIMO infrastruct**U**re**S**

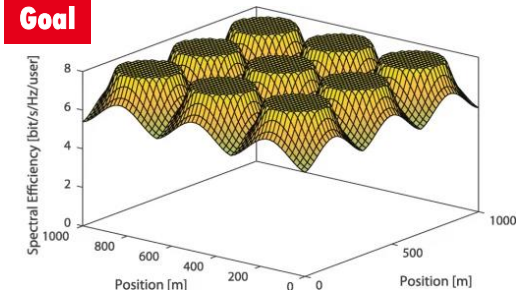
NF-PERSEUS

Power-Efficient Radio interface for Sub-7GHz distributEd massive MIMO infrastructUreS

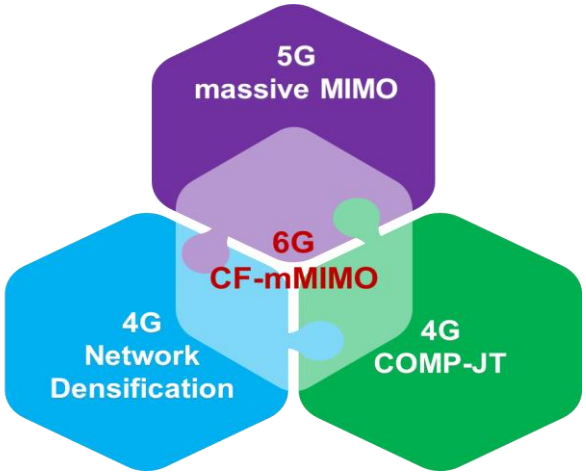
Traditional

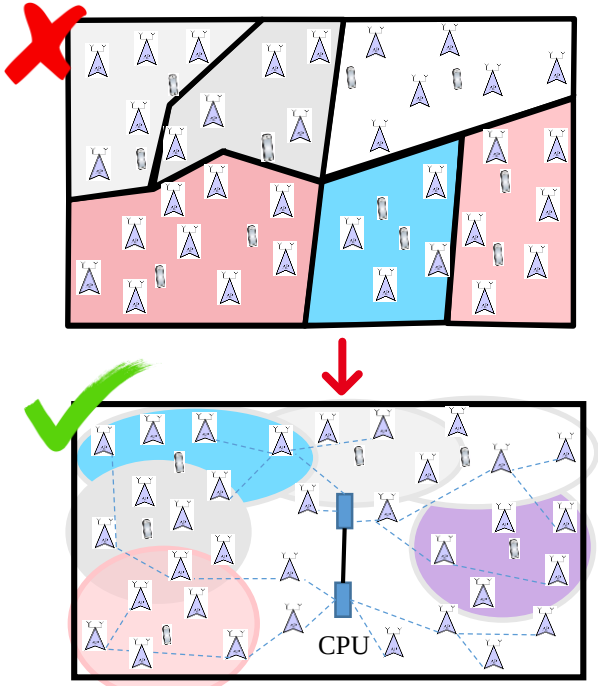


Goal



More consistent good Service Quality!





Going beyond the cellular paradigm

Scientific challenges and objectives

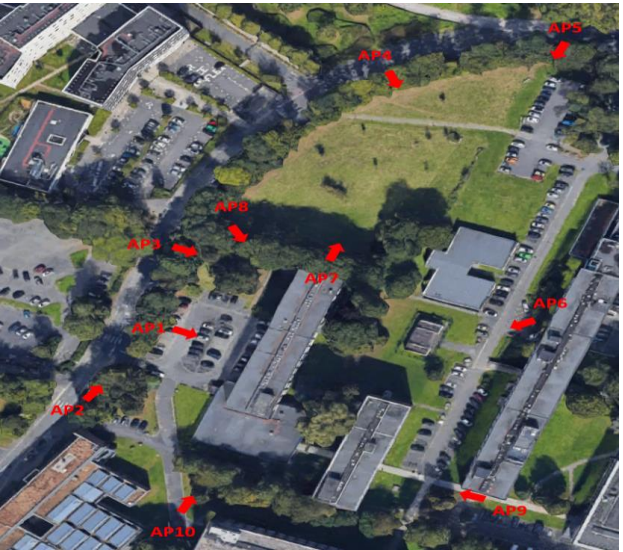
- ❑ Increasing technology maturity of **sub-7GHz Cell-free massive MIMO**
  - ✓ Evaluation of CF-mMIMO technologies with realistic scenarios (propagation channels and HW impairments)
- ❑ **Scaling up** of the CF-mMIMO solutions under energy efficiency constraints
  - ❑ *PHY and MAC* solutions for **scalable** CF-mMIMO
  - ❑ *Antennas and circuits*: low power consumption
- ❑ **RIS** and **AI**

❑ Private Networks

❑ Emergency and rescue Communications

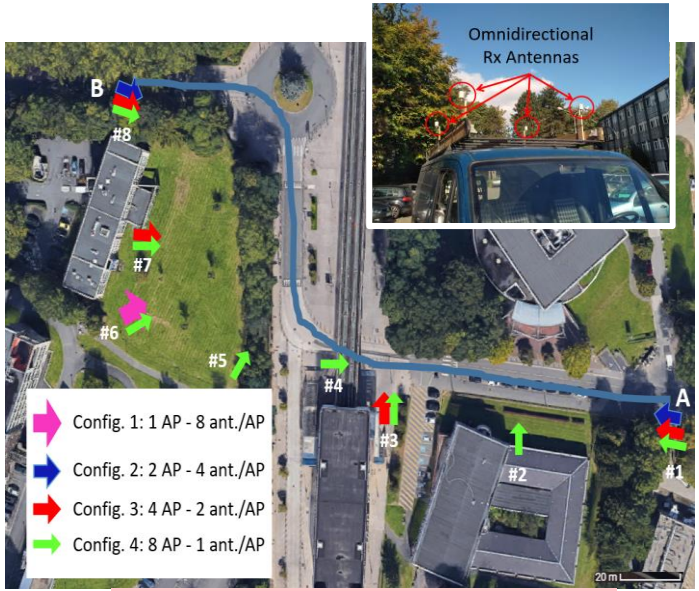
❑ Low energy consumption applications

FOCUS# Definitions of NF-PERSEUS uses-cases/scenarios

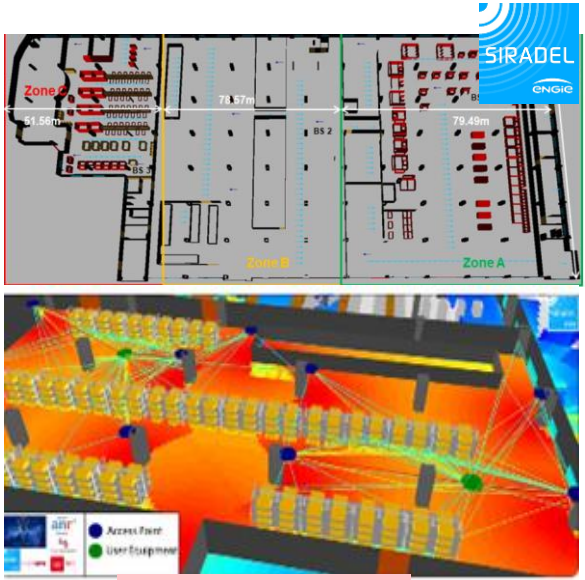


[S1] Tbps experienced data rates for ultra-dense areas

Cité Scientifique campus @ Villeneuve d'Ascq



[S3] V2I in sub-urban environment



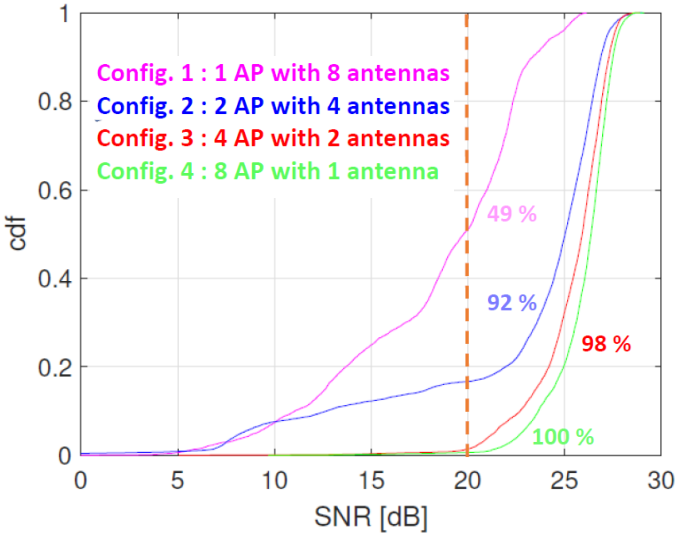
[S2] Smart factory

[D1] Deliverable D1 - Technical Report NF-PERSEUS 2023 : https://cea.hal.science/cea-04564147/

FOCUS# Measurement of Radio Channel in Cell-free Networks

V2I Channel with the Distributed MaMIMOSA Channel Sounder

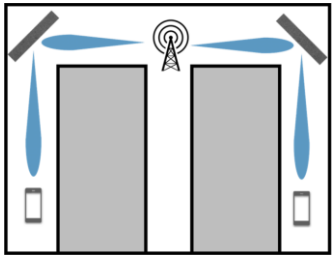
[S3] V2I in sub-urban environment



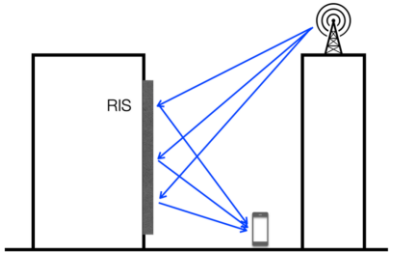
More consistent good Service Quality offered by distributed MIMO!

FOCUS# ETSI-ISG Use cases & Communication models for RIS

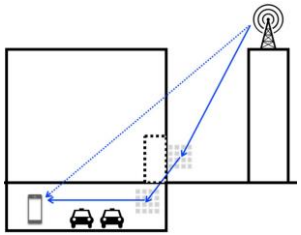
Coverage enhancement



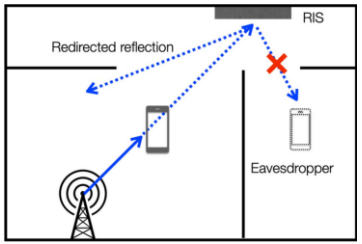
Spectral efficiency



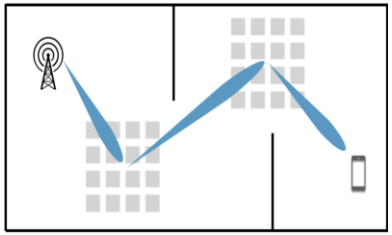
Beam management



Physical layer security

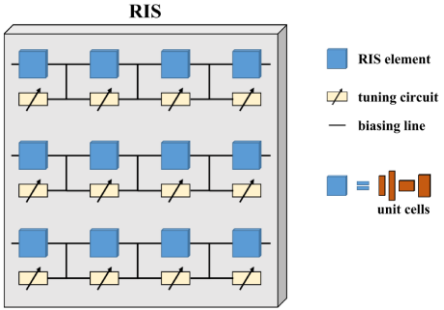


Localization and sensing

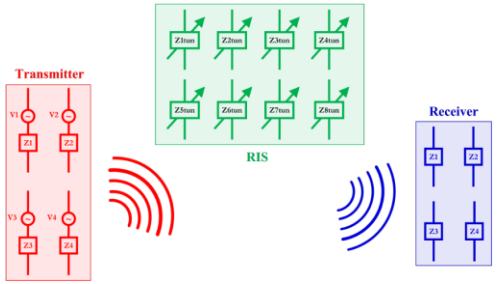


Energy efficiency

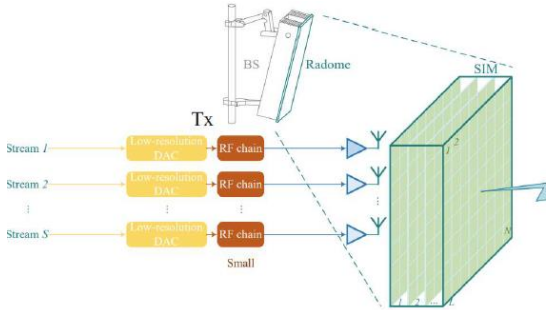
Locally Periodic Discrete Model



Multiport Network Model



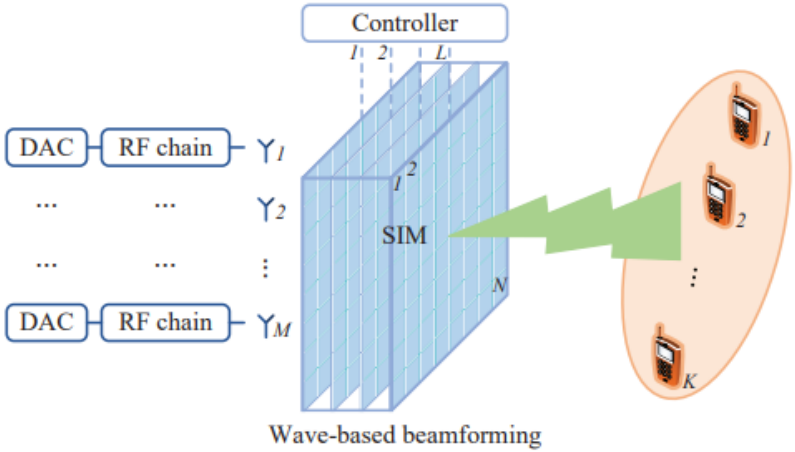
Stacked Intelligent Metasurface (SIM)

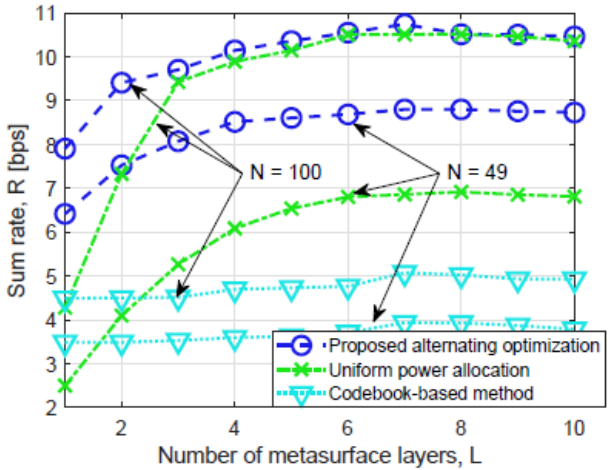


[D1] Deliverable D1 - Technical Report NF-PERSEUS 2023 : https://cea.hal.science/cea-04564147/

FOCUS# Holographic Communications

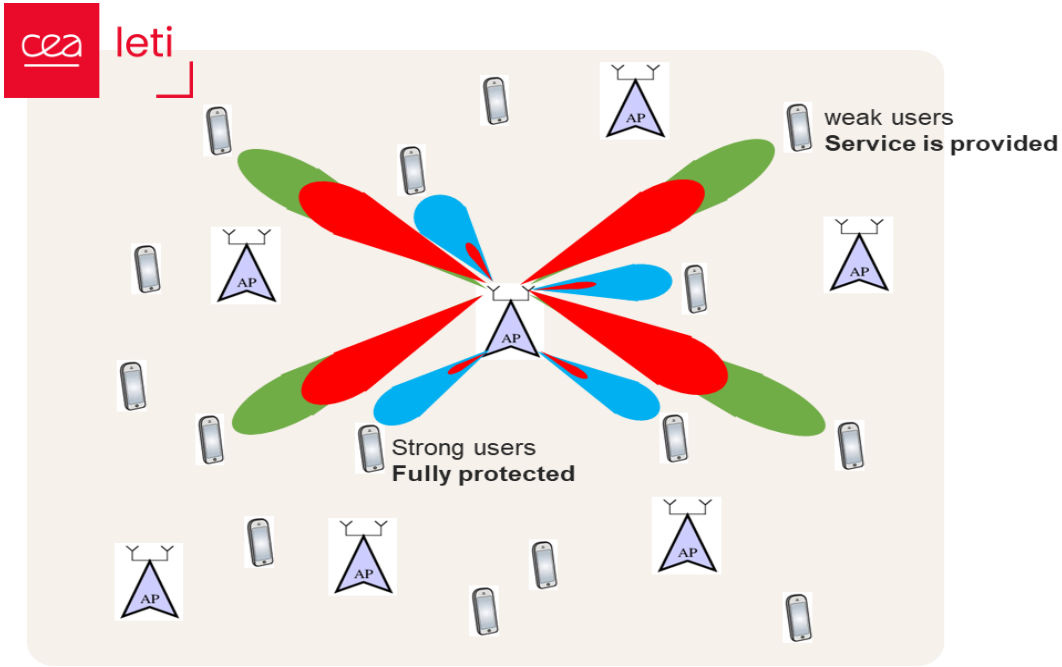
SIM-based MU beamforming in the wave-domain



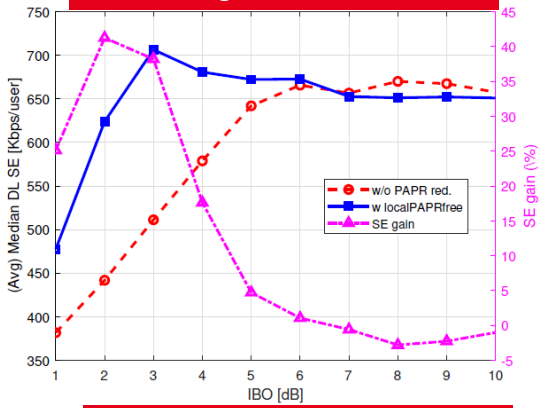


L2S Laboratoire Signaux & Systèmes

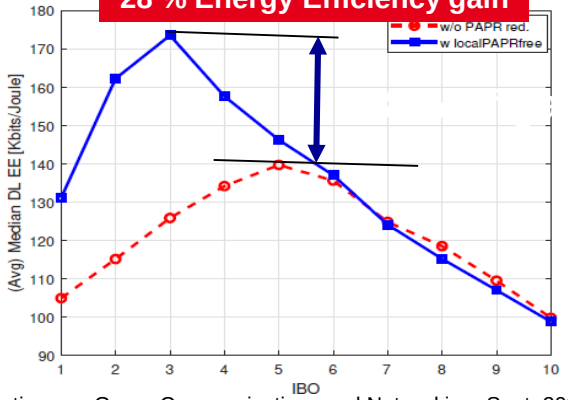
FOCUS# Hardware-aware Precoding for Cell-free massive MIMO



40 % SE gain @ IBO = 3 dB



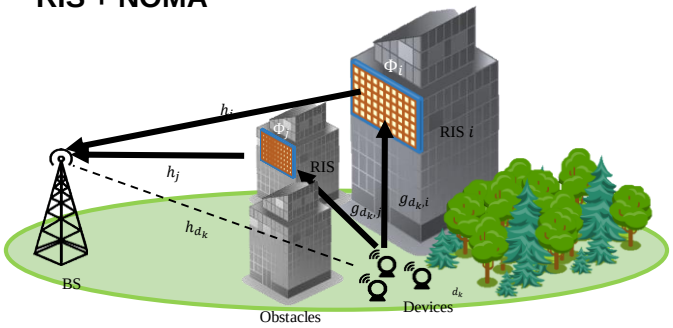
28 % Energy Efficiency gain

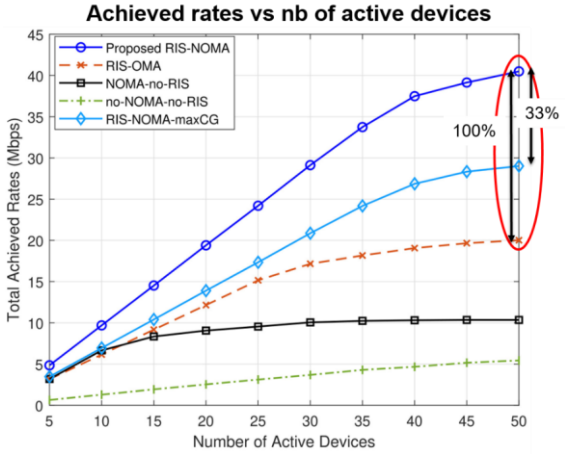


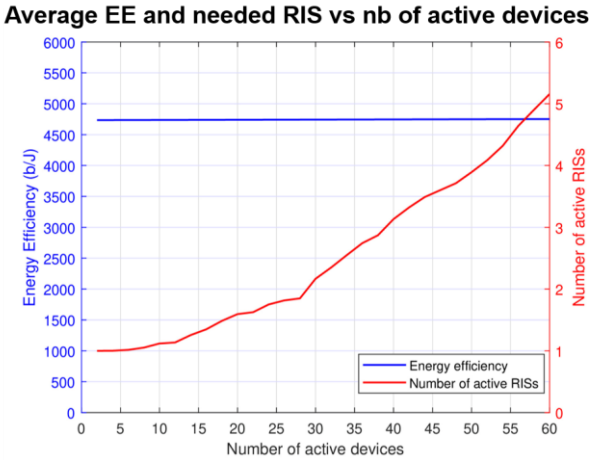
[ZAY23] R. Zayani, et al. "Local PAPR-Aware Precoding for Energy-Efficient Cell-Free Massive MIMO-OFDM Systems," in IEEE Transactions on Green Communications and Networking, Sept. 2023.

FOCUS# Distributed grant-free resource allocation for multiple access

RIS + NOMA







IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

- ~33% gain for 50 devices when compared to prior art works
- ~100% gain for 50 devices when compared to OMA method

- EE maintained at a constant level for a same requested rate for the devices
- In average for 40 devices, 3 RISs are essential for a constant EE.

YACARI

mm-Wave (30-90 GHz)

Circuits, antennas, processing

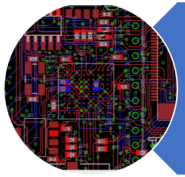
Beyond 5G : Circuits, antennas and RIS @ mmWave

Scientific challenges and objectives

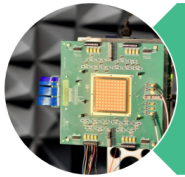
1. Maturation of technologies: RF & PA (SOI/GaN)
2. Proposal of mmW antenna systems that are efficient and integrated
3. RIS: Conception, characterization, and integration into the network
4. Exploration of Systems/Signal processing around antenna processing, JCAS and RIS

Fields of application

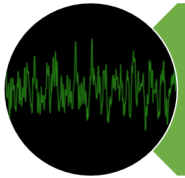
1. Mobile and gNodeB: 5G mmWave => FR3
2. Satellite communications
3. V2X



Advanced mmWave circuits and sub-systems



New active antenna & RIS concepts



Dedicated signal processing

HPA design & integration

mmWave Integrated circuits

Technological demonstrators

Phase array design

Holographic beamforming-based

RIS design & propagation model

Technological demonstrators

RIS & Radio functionalization

Beamforming

System architecture

TELECOM Paris

L2S Laboratoire Signaux & Systèmes

xlim

iemn

IETR

EURECOM Sophia Antipolis

citilab

ims Bordeaux

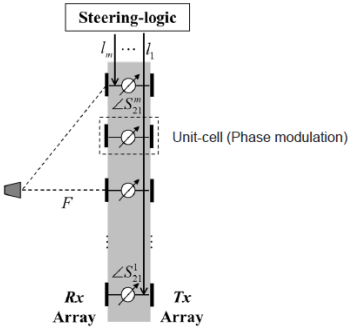
ETIS

cea

Lab-STICC

Antennas & Propagation

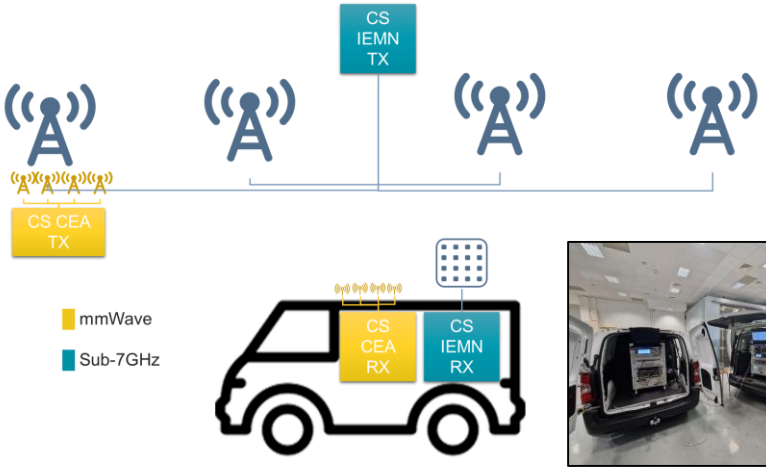
Reconfigurable Intelligent Surface (lens)



- Low-loss spatial feeding mechanism
- No feed blockage
- Low-cost planar fabrication process
- Energy-efficient electronic 2-D beam-steering using simple electronic devices
- Increased volume occupancy

→ Dual band, low-profile design, stacked lens

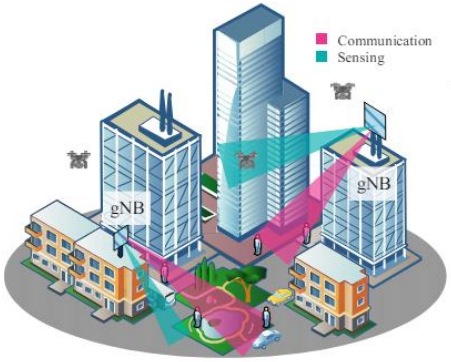
Propagation

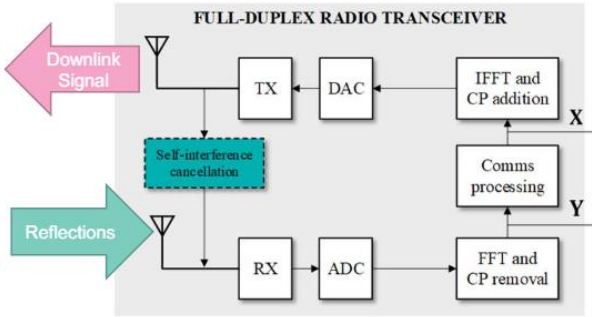


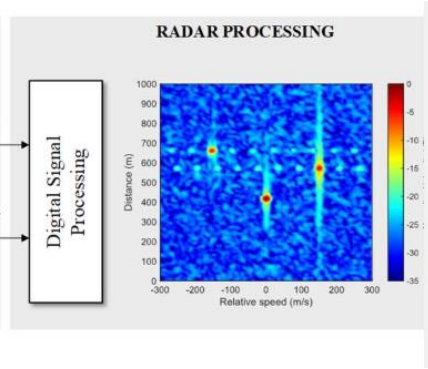
Shared multi-spectral campaign

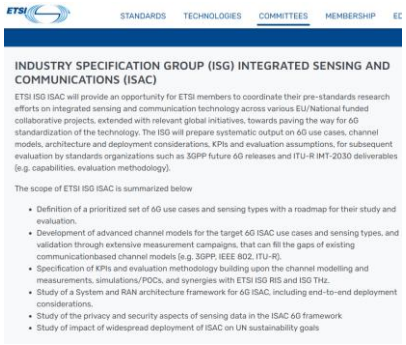
- sub-7GHz (IEMN/Université Lille)
- mmWave 26.5 GHz (CEA-Leti)

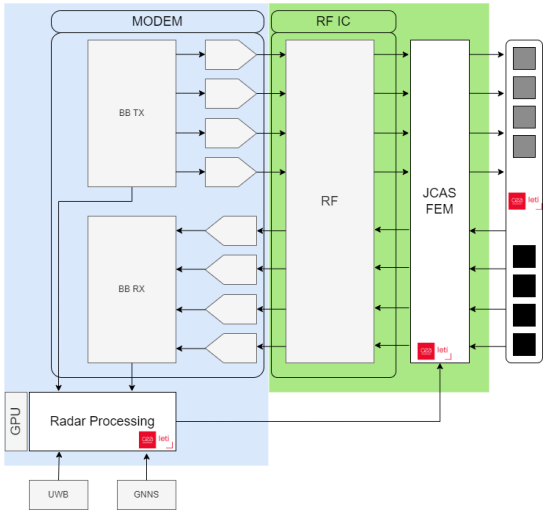
Joint communication and Sensing





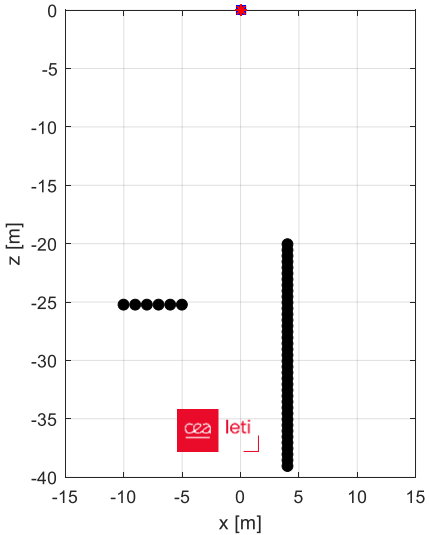




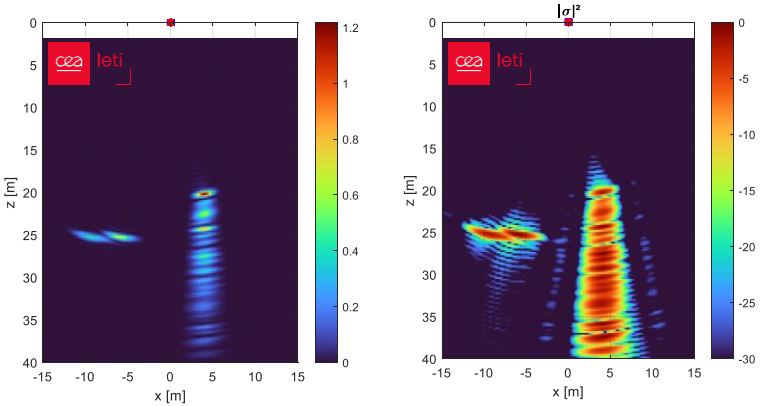


- Front End Module (FEM)
  - > Full Duplex FEM,
  - > Isolation to be optimized,
  - > Calibration primitives.
- Signal processing
  - > Radar processing with comm sig,
  - > Scheduling/ranking physical channel
  - > Multi modal fusion.

Joint communication and Sensing



26 GHz, 200MHz BW
16T,16R



SYSTERA

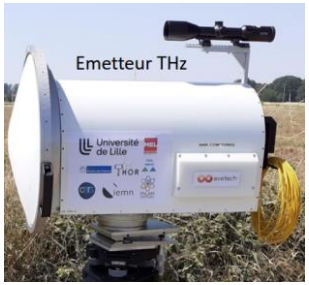
Beyond 90 GHz: Devices and SYStems enabling Ultra High Data-rates links in sub-THz

SYSTERA - Devices and SYStems enabling Ultra High Data-rates links in sub-TERAhertz

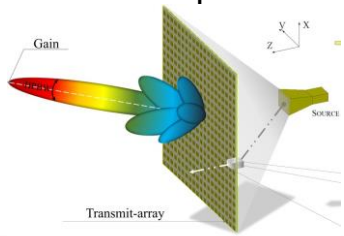
Objectives & goals : enabling technologies for beyond-90 GHz communications

- Architectures & waveforms towards very-high frequency / very-high throughput
- Propagation of very-high frequency waves & advanced materials use
- D-band & H-band system implementation, amplification and frequency generation
- Demonstration of these bands potential throught assembly of developped bricks

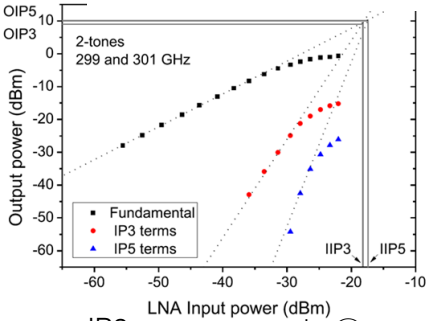
CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
140.40GHz	142.56GHz	144.72GHz	146.88GHz	149.04GHz	151.20GHz	153.36GHz	155.52GHz
1.76Gbauds	1.76Gbauds	1.76Gbauds	1.76Gbauds	1.76Gbauds	1.76Gbauds	1.76Gbauds	1.76Gbauds
EVM=9.7%	EVM=10.3dB	EVM=11.2%	EVM=10.7%	EVM=9.0%	EVM=10.1%	EVM=9.8%	EVM=9.5%
7.04Gb/s	7.04Gb/s	7.04Gb/s	7.04Gb/s	7.04Gb/s	7.04Gb/s	7.04Gb/s	7.04Gb/s
EVM=9.1%	EVM=9.4%	EVM=9.6%	EVM=9.0%	EVM=9.3%	EVM=9.8%	EVM=9.0%	EVM=8.6%
10.5Gb/s	10.5Gb/s	10.5Gb/s	10.5Gb/s	10.5Gb/s	10.5Gb/s	10.5Gb/s	10.5Gb/s



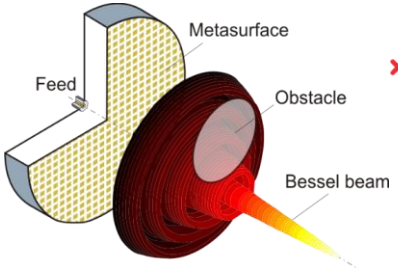
Outdoor demos



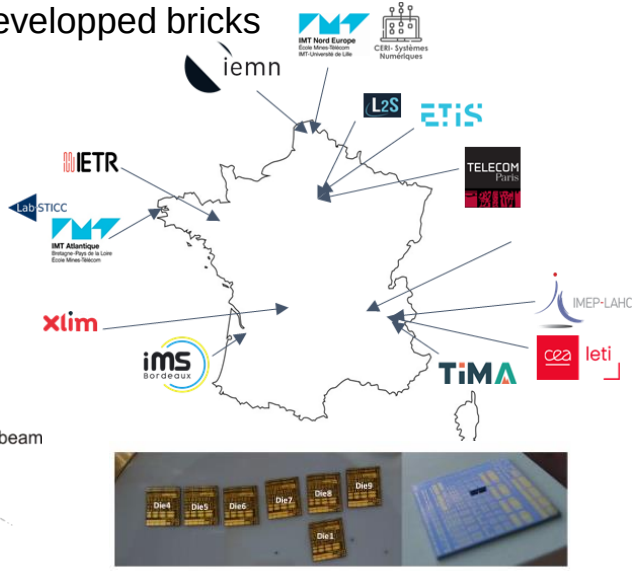
Transmit arrays



IP3 measurements @ 300 GHz



THz beam manipulation



Heterogeneous integration

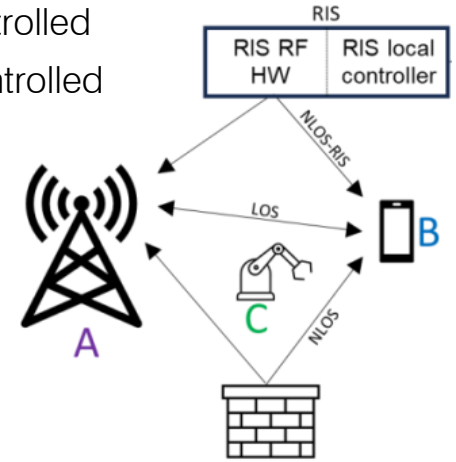
SYSTERA – Scientific advances

Focus: RIS performance assessment

A: network controlled

B: terminal controlled

C: machine controlled



Deliverable D5.3 HEXA-X-II

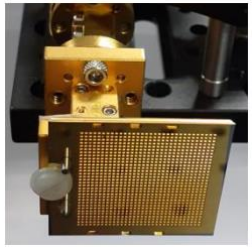
RIS approach: how to characterize it within a system?

In SYSTERA, we aim to contribute for > 90 GHz RIS validation:

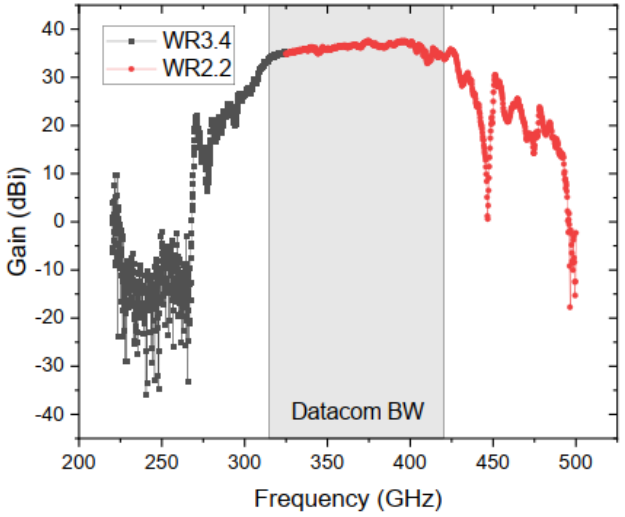
- OTA (Over The Air) validation
- Single device and up to system validation
- Many RIS approaches => need to make the link between RIS approaches and experimentations to validate the concepts.

SYSTERA – Scientific advances

Focus: from component to system-level - Antenna measurement

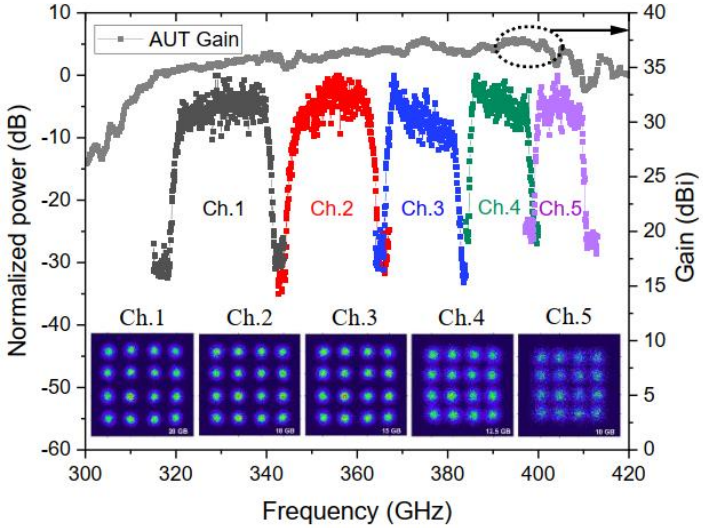


Stand-alone antenna



Methods for gain extraction

The antenna in the 'use case' (PHY-layer)



Validation of the antenna <u>inside a THz system</u>

N. Khelil et al, EuMW 2024, Paris

Plateforms and demonstrators for future networks

NF-FPNG
French Network of Test Platforms for the Next Generation of Mobile Communications

Scientific challenges and objectives

Set up a network of platforms at the highest technological level, open to the xG community, to meet the many characterization and experimentation needs, and establish proofs of concept to support the research projects of the various targeted projects.

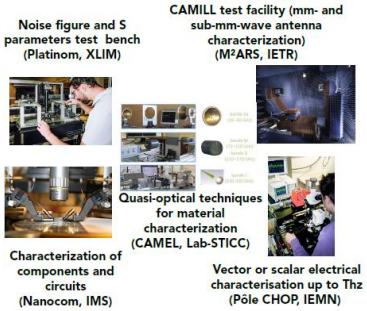
NF-FPNG
French Network of Test Platforms for the Next Generation of Mobile Communications

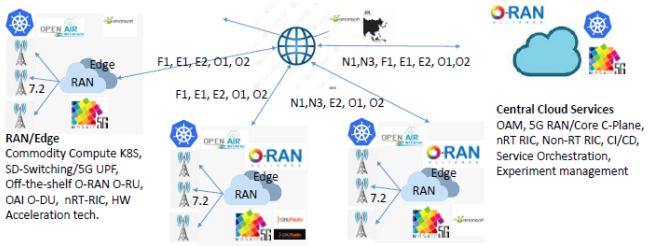
Articulation in three sub-assemblies:

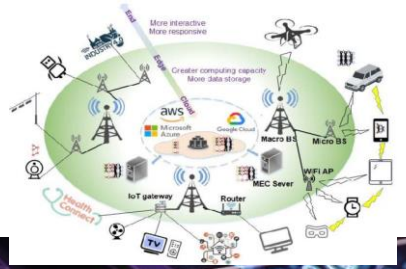
- RF-Net (Radio Frequency Test Facility Network)
  - ➢ Component and hardware subsystem characterization

- SLICES-FR - Network infrastructure for high-performance networking and computing
  - ➢ Deployment of xG network infrastructures, to evaluate technological building blocks for multiple usage scenarios

- NGC-AIoT - Next Generation Cellular – AI and IoT
  - ➢ Deployment of connected object networks and associated processing/computing (edge computing / AI)







pepr-futurenetworks.fr

Thanks for your attention!

Looking forward for fruitful collaborations with other xG initiatives in the world ☺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