OPTI-6G

Technical Overview

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6GSNS

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Program Stream and Project Partners

Title: **Optical 6G Cell-Free Networks**

Call: **HORIZON-JU-SNS-2023-STREAM-B-01-03: Communication Infrastructure Technologies and Devices**

Consortium:

1 (Coordinator)	EURESCOM-EUROPEAN INSTITUTE FOR RESEARCH AND STRATEGIC STUDIES IN TELECOMMUNICATIONS GMBH	EUR	DE
2	BRUNEL UNIVERSITY LONDON	UBRU	UK
3	UNIVERSITE DE VERSAILLES SAINT-QUENTIN-EN-YVELINES	UVSQ	FR
4	RUNEL NGMT LTD	REL	IL
5	OLEDCOMM SAS	OLED	FR

Contacts and further info: https://opti-6g.sns-ju.eu/

Motivation: Market opportunities for the EU

- Main cost and market size is at the network access
- Main inhibitor of market is cost of licensed spectrum compared to unlicensed spectrum and interworking of PN and NPN operators
- Joint communication and sensing is a major development direction of 6G, and combining optical communication and 5G/6G also for sensing and positioning offers a significant opportunity.
- The main drawback is aperture angle of the IR optical emitter, which can be dealt with by IR beam-steering.

Sustainability Enhancement Aspects

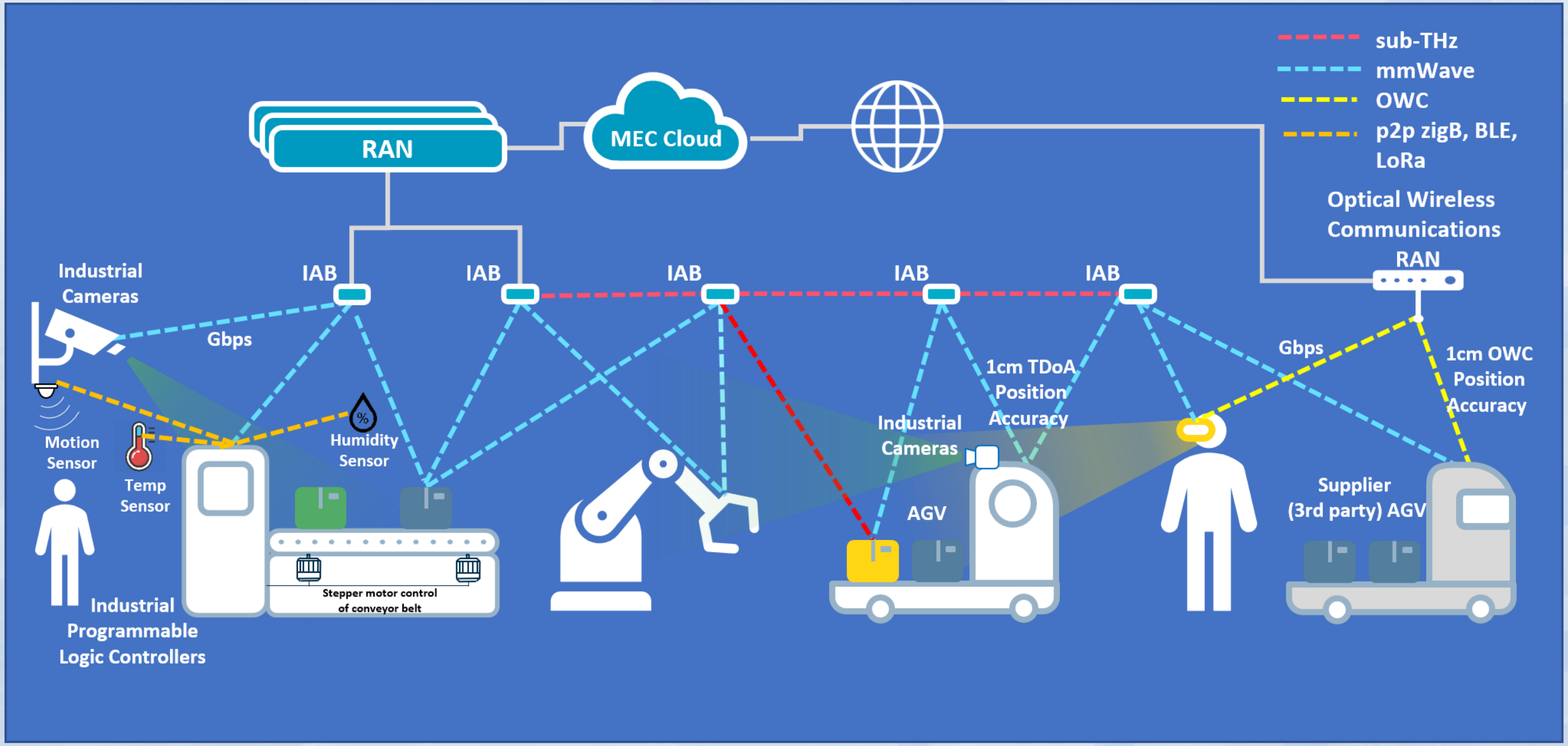
- Considerably reduce EM interference that would have otherwise been generated by Home gNBs, thereby increasing throughput in the wider 5G mobile network
- Improve mobile network access to users within buildings without incurring interference with the wider 5G mobile network, thereby increasing the value of properties / buildings.
- Support the reduction of the transmission power and EM radiation levels, leading to reduced energy and battery usage of user devices during use in buildings.

Approach

OPTI-6G will address the motivation requirements by:

- Optical wireless communications (OWC) using Vertical Cavity Surface Emitting Laser (VCSEL) array solution
- Disaggregated RAN solution
- Designing a cell-free network architecture using AI/ML as an enabler for OWC
- Combining Time Difference of Arrival (TDoA) with Angle of Arrival (AoA) and Received Signal Strength (RSS) localisation solutions

Industrial Use Case

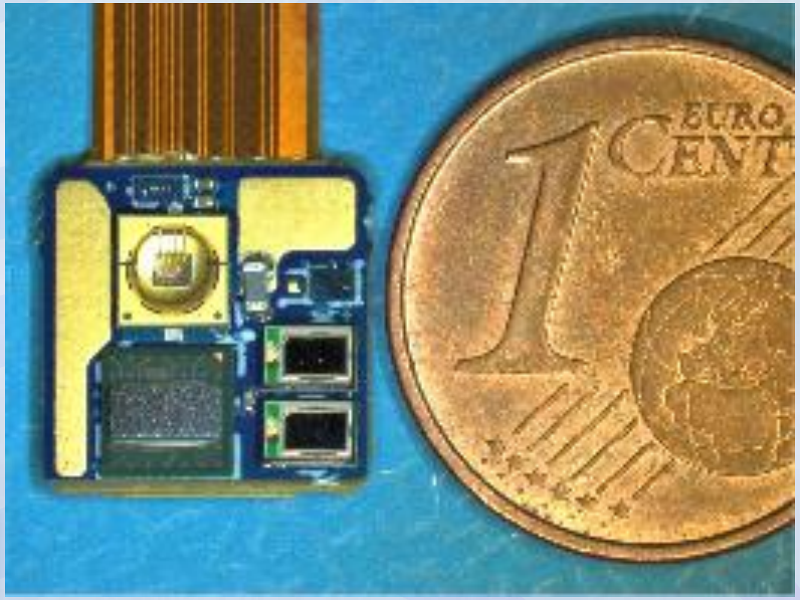


Security and guaranteed throughput, low latency, high location accuracy and high reliability performance provided by 6G to AGVs, XR Headsets, Drones, IoT devices and Robots for Industry 4.0.

OWC VCSEL array solution

The OPTI-6G project provides

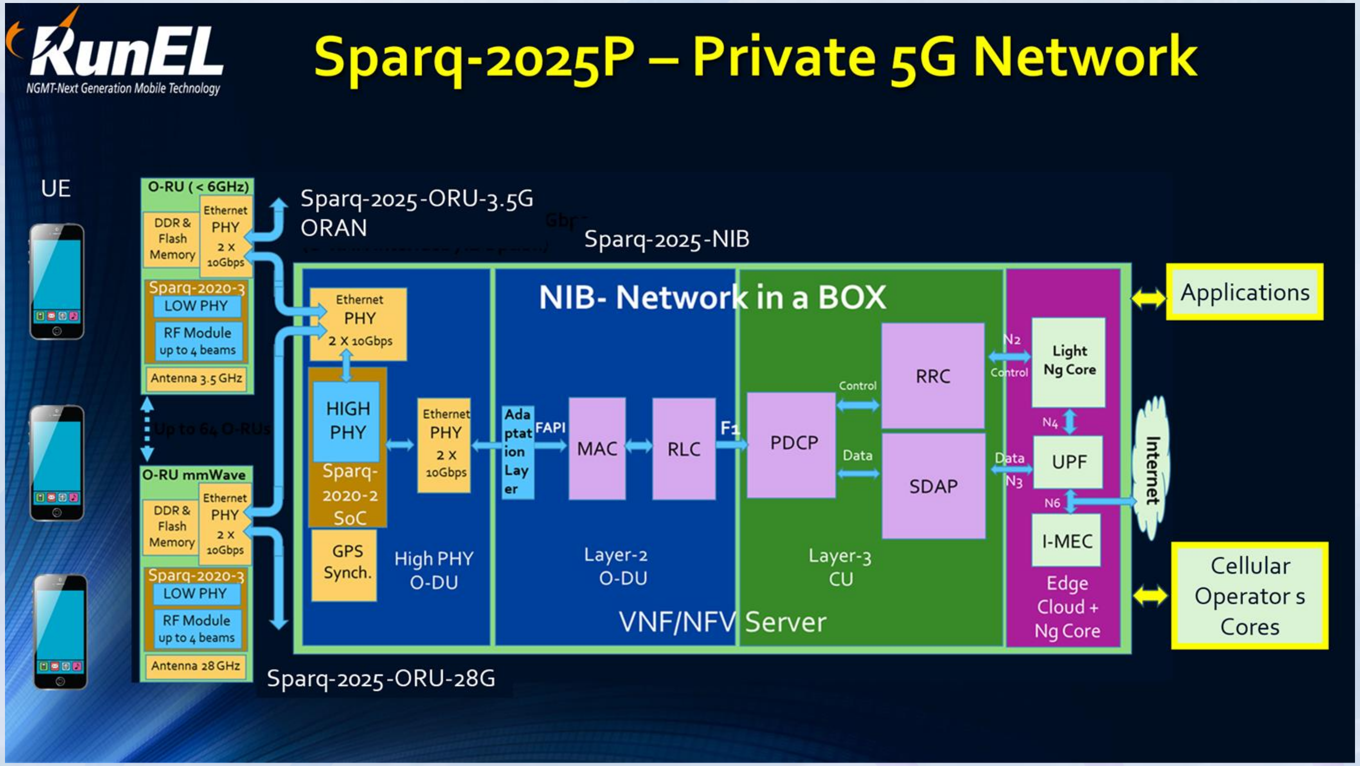
- A broadband and cell-free optical wireless communications (OWC) VCSEL array solution that operates in the near Infrared (IR) @ 1550 nm wavelength
- Provides communications services with greater than 1 Gbps data rates up to 5 m over a field of emission of 25° or 3 Gbps up to 5 m with an angle of 15° from access points that are pervasively located within buildings
- The novelty of using VCSEL arrays is that it prepares the way towards beam-steering the near IR waveform



Current optical antenna used in cell-based LiFi systems

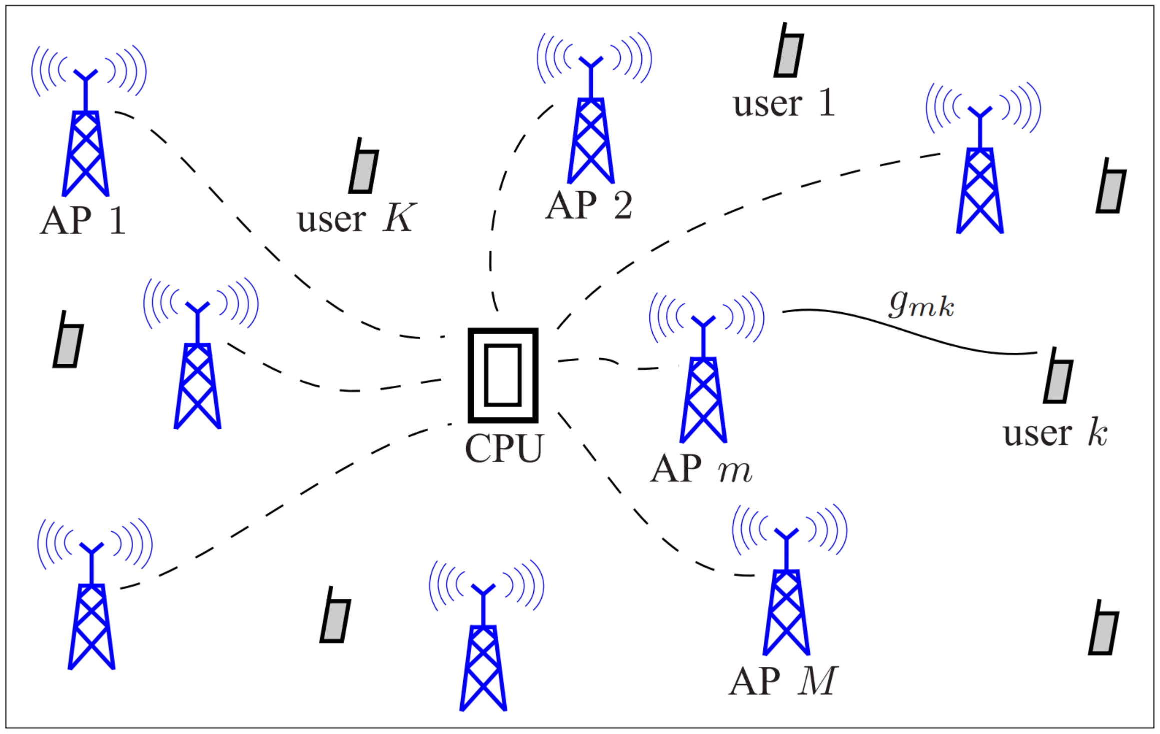
Disaggregated Sub 6 GHz RAN

- NIB (Network In a Box) includes the NgCore the CU and the DU units in one server
- 5G RAN PHY Split (ORAN Option 7.2) enables maximum virtualisation of the base station functions
- Each RU includes a high performance 64 (8x4x2) active hybrid digital/analogue weighted beam forming antenna at 3.5 GHz
- The network achieves a 2 Gbps (0.5 Gbps/beam) aggregate data rate per 100 MHz channel in each RU
- OPTI-6G connects the RU VCSEL array air interface to produce an OWC Active Optical Units (AOUs) system
- OPTI-6G design compares this OWC 5G system with an existing 3.5 GHz 5G cell-free network solution



Cell-free near IR networks

- Configured to implement multi-connectivity with cell-free network thereby
  - Improving link quality and reliability,
  - Obviating the need for building owners to subdivide their non-public mobile in-building network into cellular areas,
  - Obviating the need for building owners to get spectrum licence since the system operates at the optical unlicensed bands and its AI based distributed scheduler manages any interference between inside and outside access.



Cell-Free Network Architecture

Ngo, H.Q., Ashikhmin, A.E., Yang, H., Larsson, E.G., & Marzetta, T.L. (2016). Cell-Free Massive MIMO Versus Small Cells. *IEEE Transactions on Wireless Communications, 16*, 1834-1850.

Towards 6G

KPI performances in different 6G architectures (Cell-free vs Cellular) and Air interface spectral bands (sub 6 GHz vs OWC transmissions) will be compared

- Round trip time (sensor to controller to actuator),
- Reliability (packet error rate within latency requirements), data rate, packet size,
- Covered distance (from an access point),
- Movement speed of the user, time critical handover support,
- User equipment density,
- User equipment size and cost,
- Energy efficiency (user equipment battery lifetime),
- Location and orientation detection accuracy and service availability for different measurement methods (TDoA vs AoA)

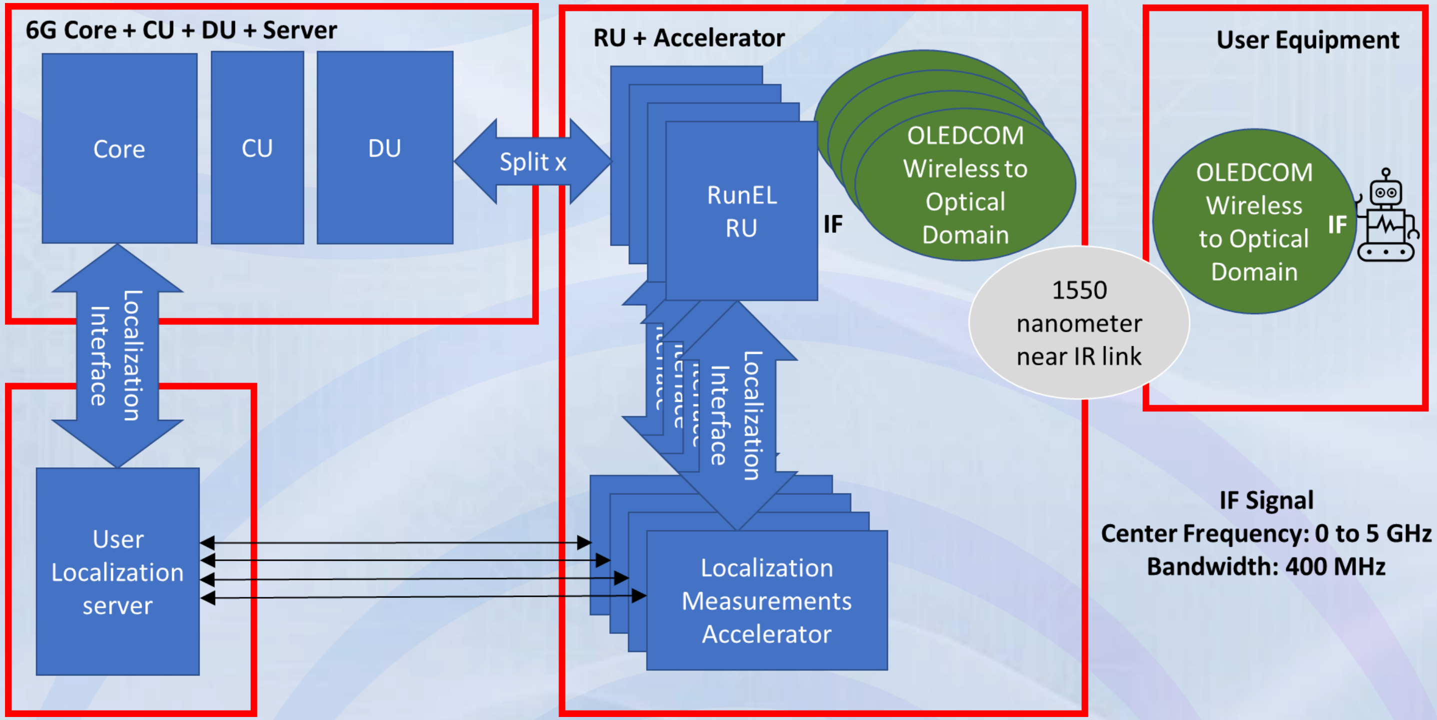
Key Performance Indicators (KPI)	5G	6G	Improvement Factor
Peak data rate (Gbps)	10	100 to 1000	10 to 100
User experienced data rate (Gbps)	0.1	1 to 10	10 to 100
User plane latency (ms)	1	0.1	10
Connection density (devices/Km^2)	10^6	10^7 to 10^8	10 to 100
Reliability	99.999%	99.999999%	100%
Energy Efficiency	1 x	5 x to 100 x	5 to 100
Spectral Efficiency	1 x	2 x	2
Positioning (cm)	20 to 100 in 2D	1 in 3D	20 to 100
Jitter i.e. latency variations (µs)	-	0.1 to 1000	-

Work plan

- **Year 1 - Definition and Design Phase**
  - Definition of use cases and derivation of user, functional and technical requirements
  - Design of near IR communication and location sensing systems
  - Definition of testing and KPI verification methodology
- **Year 2 - Construction Phase**
  - Construction of near IR communication and location sensing system
- **Year 3 - Integration and KPI Experimental Testing and Validation Phase**
  - KPI experimental testing of near IR communication and location sensing system

5G Optical Wireless Communications

- OPTI-6G OWC Communication and Sensing source is modulated with classical OFDMA. The receivers are composed of several silicon photodiodes
- The near IR uses VCSEL emitter with an angle of emission around 25° and with a power that respects eye safety
- The pattern of emission on both the AOU and UE sides are known and a position modulation will be added. This modulation can be demodulated at the receiver and the Angle of Arrival as well as the received signal strength (RSS) of the optical signal deduced
- Bidirectional communication between the Active Optical Unit (AOU) and UE also enables real-time ToA/TDoA measurement to establish UE location with sub-mm/degree location and orientation accuracy



Impacts

- Enables the addition of Active Optical Units without the need for network planning;
- Overcomes bit errors in the OWC channels that occur due to Doppler effects when UE moves fast;
- Enables indoor cellular operation at unlicensed optical spectral bands and substantially lower Capital and Operational Expenditures (CAPEX and OPEX);
- Protects the environment through the reduction of microwave radiation and power consumption;
- Accurately measures the location of user devices with 2-3 mm precision using Time Difference of Arrival (TDoA), and orientation to 2–3 degree accuracy using phase of arrival at a near IR sensor array;
- Supports larger coverage areas;
- Through lower power consumption contributes to prolonged battery life;
- Suffers less inter-channel interference and thus produces a greater goodput;
- Supports the continued growth of hot spots.

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Thank you for your attention!

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UVSQ université PARIS-SACLAY

RunEL NGMT-Next Generation Mobile Technology

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