Orange research activities

DAS 2024

Future 6G concepts

6G high-level architecture proposal

New hardware capabilities

- vRAN accelerators
- Novel radio DSPs

New RAN capabilities

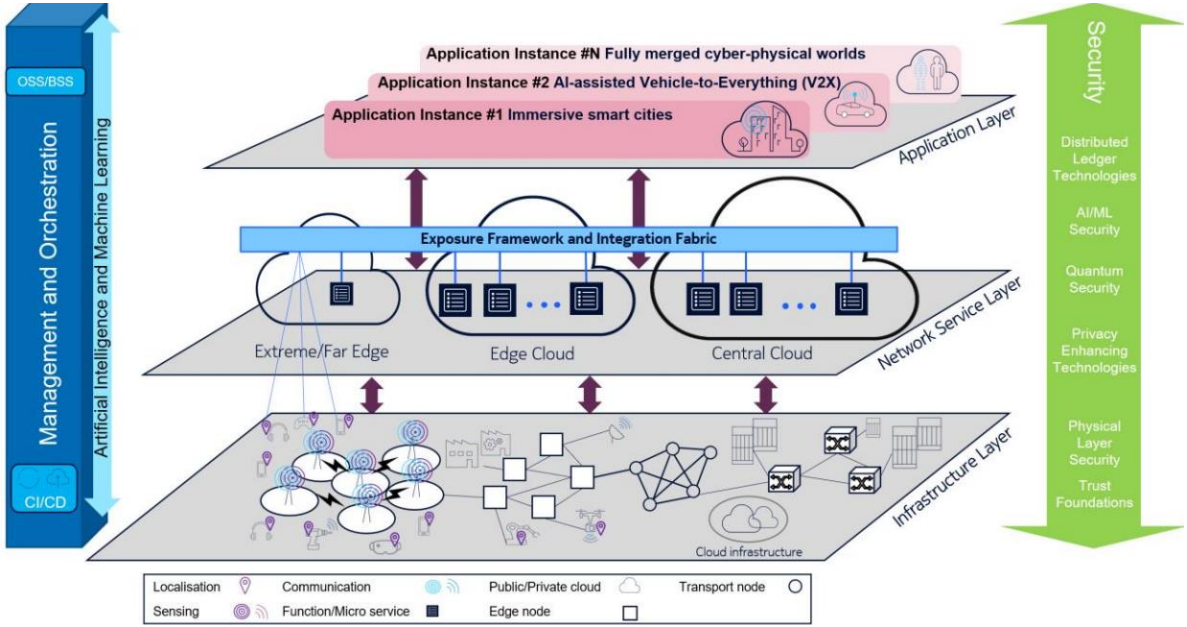
- Cell-free networks
- Massive MIMO
- Reconfigurable Intelligent Surfaces (RIS)

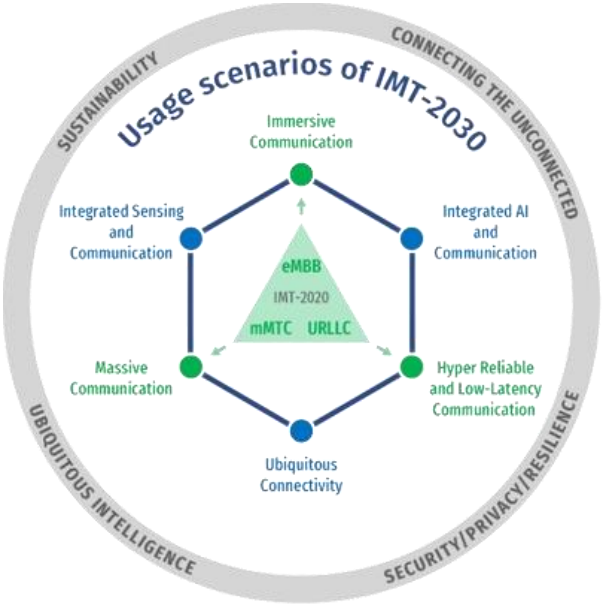
New Infrastructure capabilities

- AI/ML for network optimizations
- DevOps pipelines for upgrading network functions
- Quantum security

Highly-distributed Network

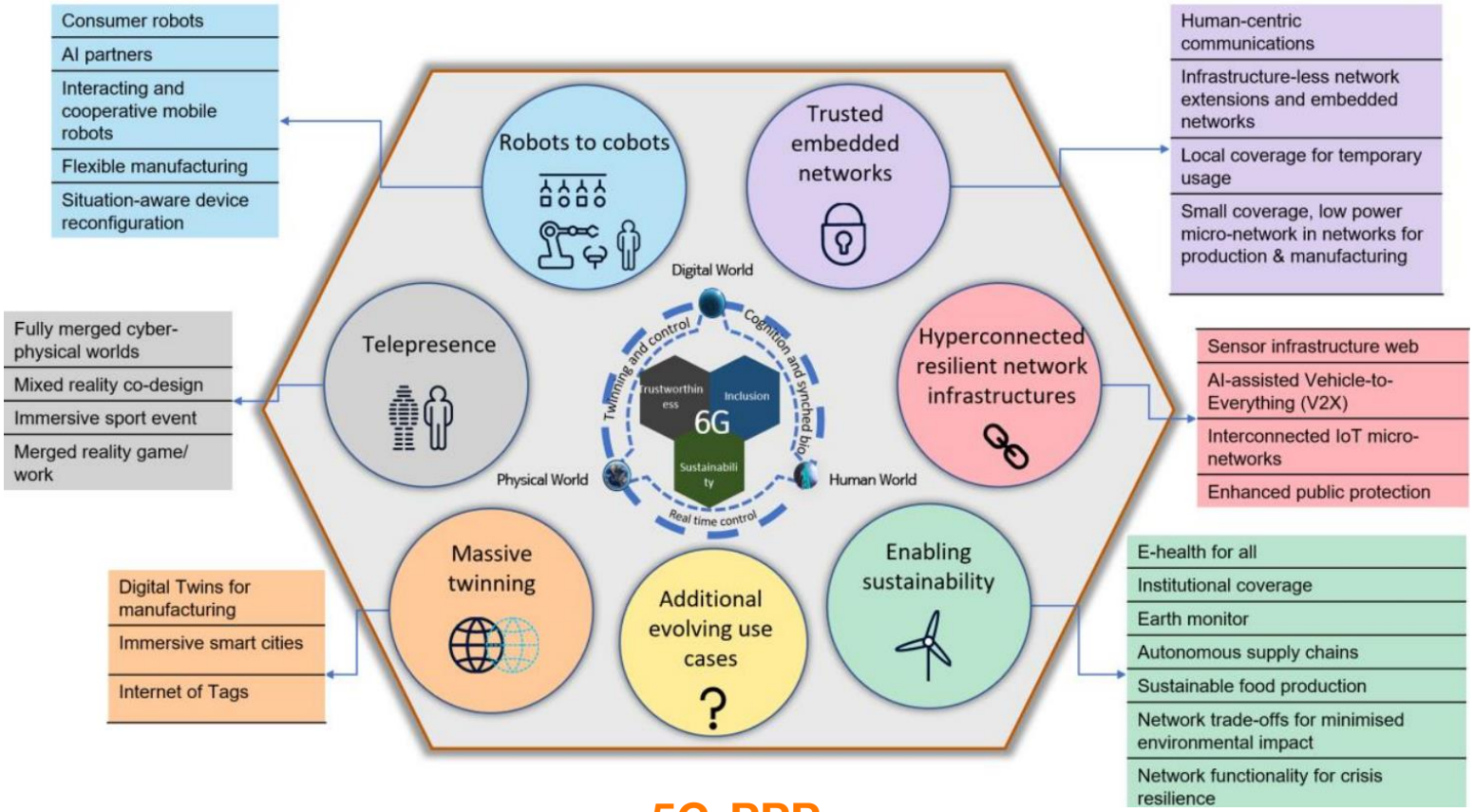
- Central Cloud
- Edge Cloud
- Extreme/Far Edge





5G-PPP

Novel 6G use cases



5G-PPP

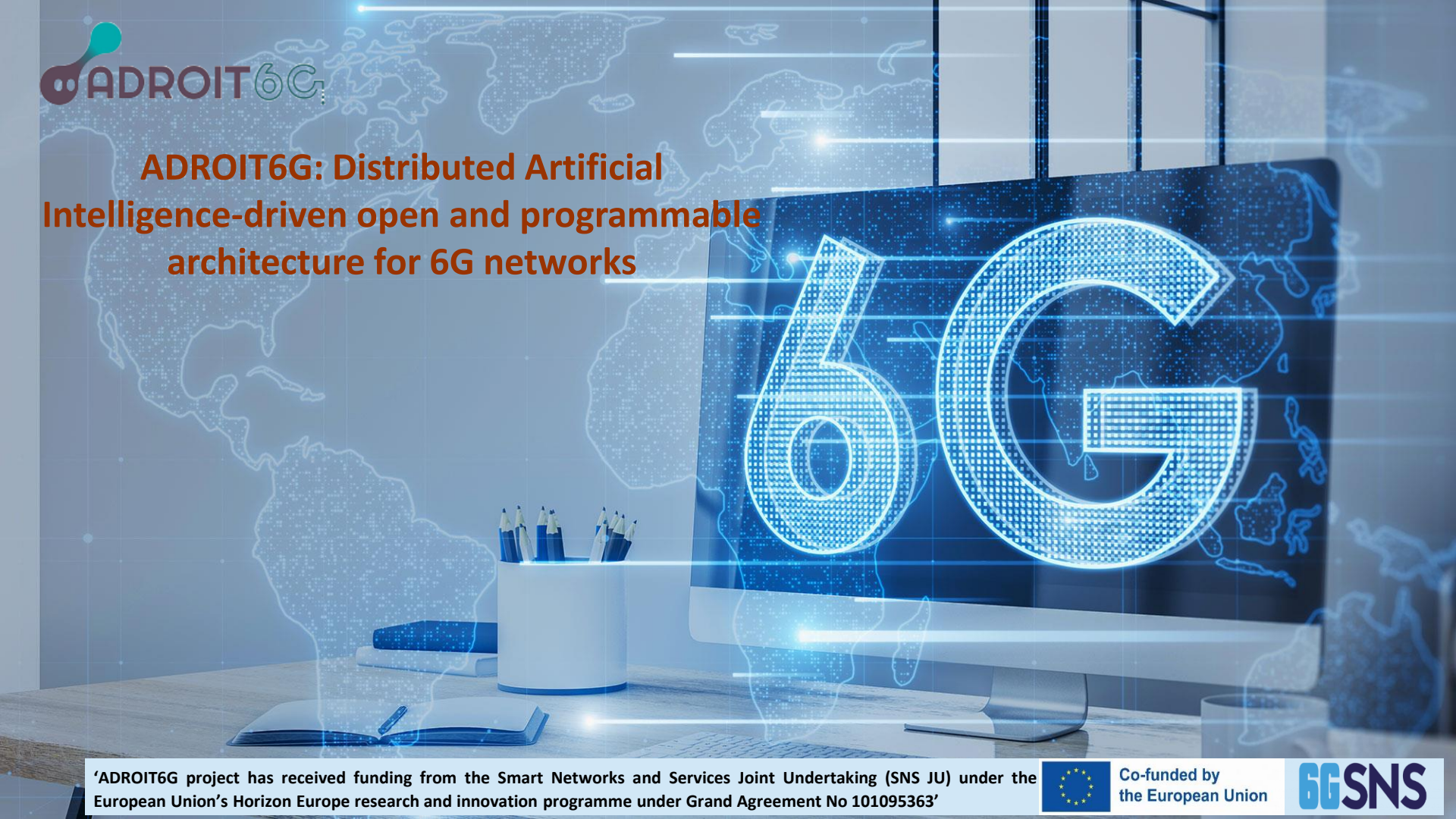
Research projects: Horizon 2020, Horizon Europe & PNRR

Consortium Partner in H2020 projects: NEXES, SLICENET, MATILDA, 5G-EVE, RESISTO, 5G-VICTORI, UNICORE, 5G-VITAL and 5G-ASP

Consortium Partner in Horizon Europe projects: EU-CIP, DYNABIC, 6Green, RIGOUROUS, ADROIT-6G and TrialsNet (with TUIASI)

Consortium Partner in PNRR projects: NetZeRoCities (with UPB)

ADROIT6G: Distributed Artificial Intelligence-driven open and programmable architecture for 6G networks



'ADROIT6G project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grand Agreement No 101095363'

Co-funded by the European Union

6GSNS

Overall Concept

ADROIT6G proposes disruptive innovations in the architecture of emerging 6G mobile networks that will make fundamental changes to the way networks are designed, implemented, operated, and maintained.

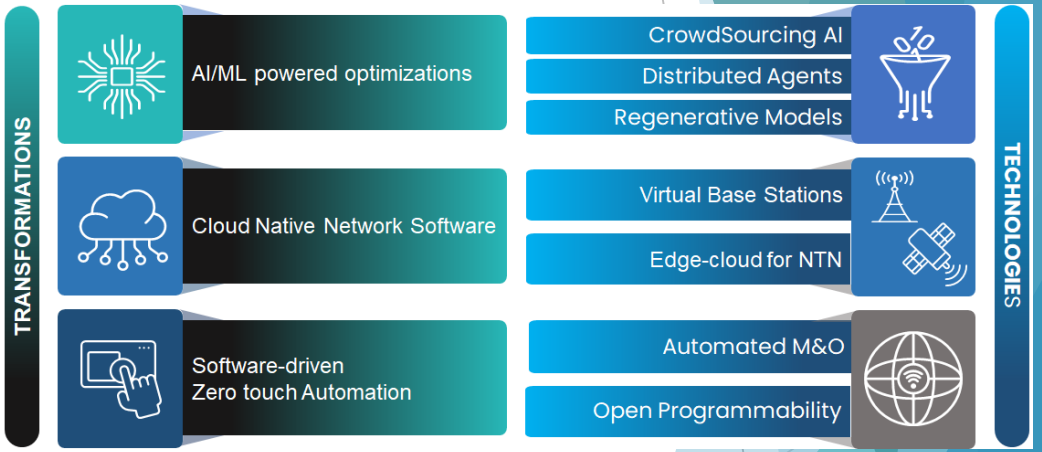
Adopting a fully **distributed AI-driven dynamic** paradigm with **functional elements** automatically **deployed on-demand** as **virtual functions** in **cloud-native environments**, across the **far-edge, edge and cloud domains**, operated by **different stakeholders**.

Project Objectives

- **O1: Propose a novel 6G system architecture that integrates a distributed AI framework for combined communication, computation and control and empowers the convergence of networks and IT systems to enable new future digital services.**
- **O2: Create an AI-driven Management & Orchestration and control framework for 6G Networks.**
- **O3: Architect a distributed and secure CrowdSourcing**
- **O4: Develop energy-aware models for multimodal Representation Learning**
- **O5: Evolve the cellular infrastructure to allow the true integration of deep-edge devices in communication and computation functions**
- **O6: Enable Non-Terrestrial Networks connectivity for highly reliable Industrial IoT Services**
- **O7: Extend and demonstrate the use of decentralized AI for Device-to-Device**
- **O8: Support data plane acceleration**
- **O9: Integrate and demonstrate the potential and user value of ADROIT6G through relevant experimentation, testing, and validation of its innovations in PoCs in lab settings**

Innovative Concepts

- **Key Transformations for 6G Evolution**:
  - **AI/ML-powered Optimisations**:
    - Harnessing Distributed Artificial Intelligence.
    - Aim for high performance and full automation.
  - **Cloud-native Network Software**:
    - Implementation across various edge-cloud platforms.
    - Integral security in the network user plan.
  - **Software-driven Operations**:
    - Zero-touch operations.
    - Full automation for network and delivered services.



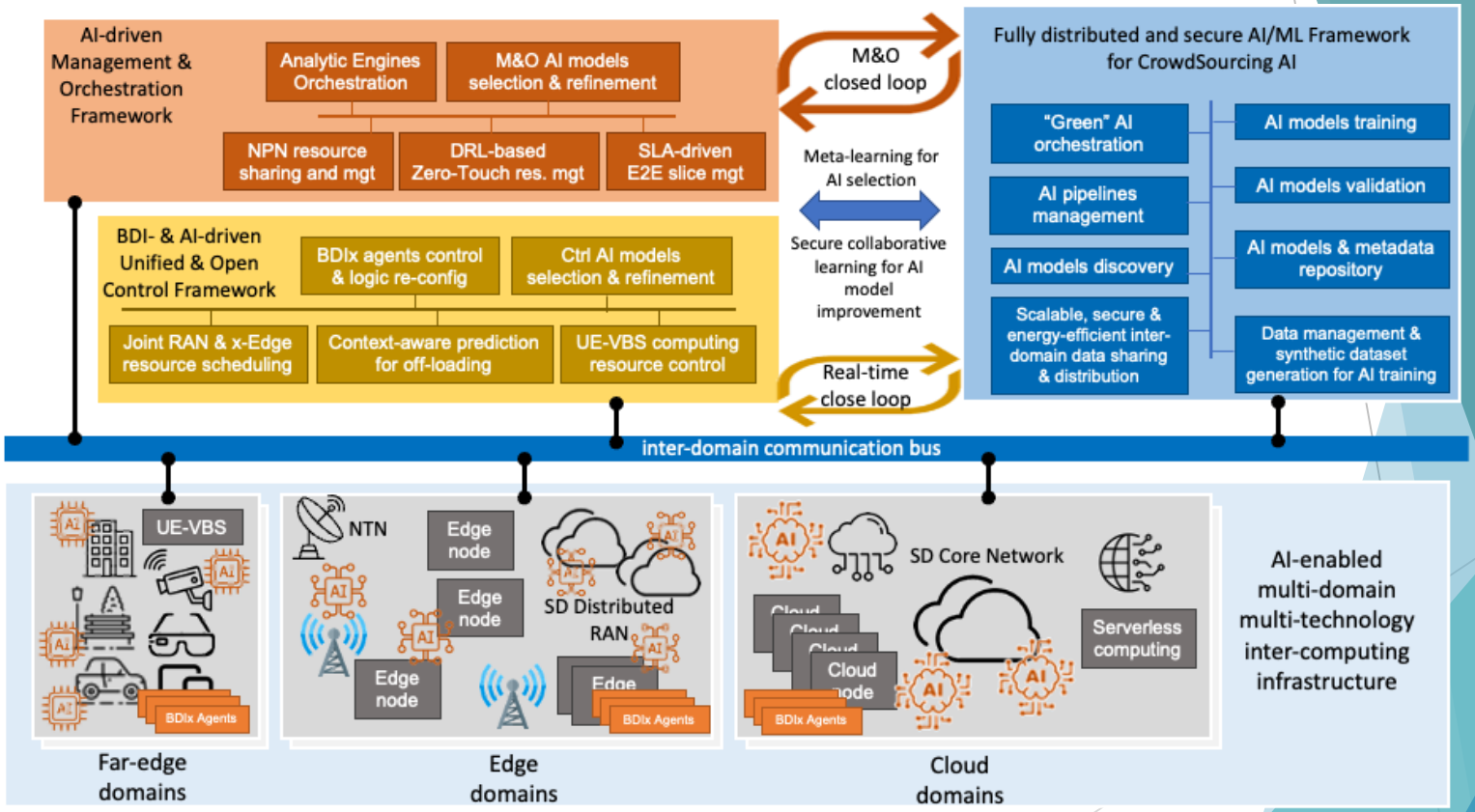
Innovative Concepts

- **AI/ML-Powered Optimisations Across the Network:**
  - **Shift to Distributed AI:** Transitioning from the standard centralized AI model to distributed AI solutions, encompassing both Federated and Decentralized Learning.
  - **CrowdSourcing AI Framework:** A pioneering concept introduced to provide domains and applications with optimal AI models, emphasizing energy efficiency, carbon footprint reduction, and secure AI/ML operations.
  - **BDI Agents:** Utilizing Believe-Desire-Intention agents as a means of decentralized learning, operable throughout the edge-cloud spectrum.
  - **Distributed Representation Learning:** Employing generative models from multimodal data to conserve resources.

Innovative Concepts

- **Transition to Cloud-Native Network Software:**
  - **Cloud-Native Cellular Infrastructure:** Modernizing cellular infrastructure to function seamlessly in cloud-native environments.
  - **UE as Virtual Base Stations (UE-VBSs):** Leveraging User Equipment as Virtual Base Stations to facilitate far-edge network component deployment.
  - **Edge Cloud Deployments & NTN:** Ensuring seamless integration between cellular and satellite communications.
- **Software-Driven, Zero-Touch Operations:**
  - **Adaptable Model:** Recognizing the unpredictability of future solution needs and emphasizing a model that supports dynamic collaboration and adaptation.
  - **Automated Management & Orchestration (M&O):** Transforming M&O into a fully automated solution, distributing all M&O functions and employing the Distributed AI framework for optimal closed-loop control.

General Architecture



Proofs of Concept

Immersive XR - Holographic Teaching
Extreme eMBB

A teacher provides the lecture at home/office, while the students attending physically the class, can watch the teacher's holographic entity delivering the lesson

Collaborative robots (cobots) in construction
Extreme URLLC & Extreme mMTC

Robots and drones that need to coordinate actions with each other in a construction site. Coordination will be conducted in three dimensions, to avoid collision and enable collaboration of robots in the air (drones).

Proofs of Concept

Terrestrial 6G IIoT
Extreme mMTC

In a production line of an **automotive manufacturing process** sensors and actuators (i.e., IIoT devices) communicate with each other, and taking actions in sub-millisecond time intervals, within a confined area, executing different robotic functionalities.

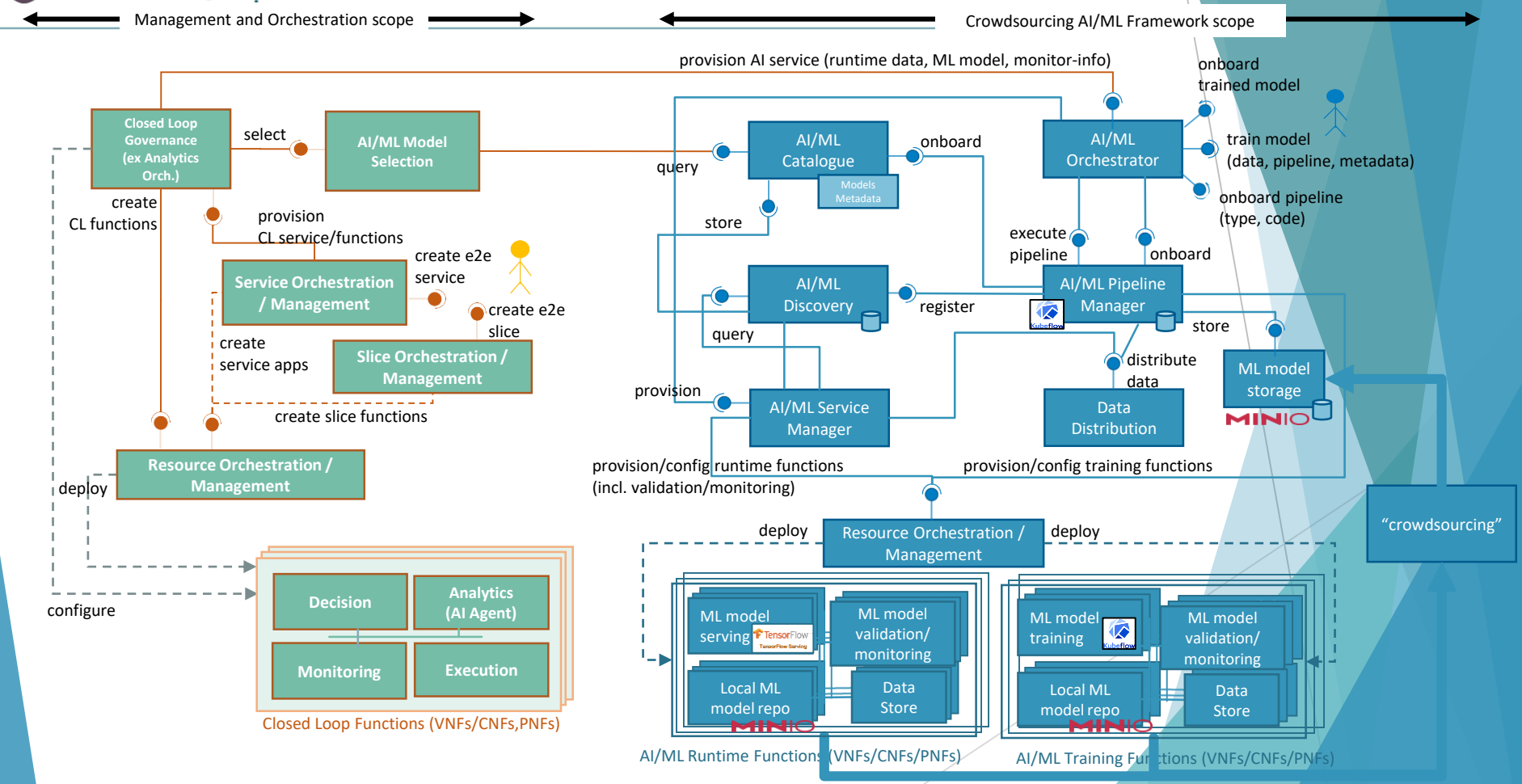
NTN for low-bitrate IIoT
Extreme mMTC

Trackside IIoT devices and **on-train terminals**, that send data to a remote cloud. Edge Cloud components on the devices, in satellites and in the remote data centre pre-process and route data and perform control depending on the application logic and in case of issues in the communication path.

KPIs for PoCs

Service class focus	All service classes	PoC 1	PoC 2	PoC 3
		Extreme eMBB	Extreme mMTC	Extreme URLLC + Extreme mMTC
Network-level KPIs	5G KPIs (baseline)	6G KPIs	6G KPIs	6G KPIs
Peak throughput (Gbps)	<20	>1000	Not critical	Not critical
Experienced upload throughput (Gbps)	<0.1	<1	Not critical	Not critical
Experienced download throughput (Gbps)	<0.2	<2	Not critical	Not critical
Maximum bandwidth (GHz)	<1	<100	Not critical	Not critical
Application latency (ms)	<10	<1	Not critical	<0.1
Jitter (μs)	N/A	<100	<100	<1
Energy efficiency (Tb/J)	N/A	nominal	high	nominal
Device density (devices/m^2)	<1	Not critical	<10	<10
Reliability (packet error rate)	10^{-5}	10^{-7}	10^{-6}	10^{-9}
Positioning accuracy (cm)	<50 in 2D	Not critical	<100	<1 in 3D
Visualised user experience	50Mbps, 2D	10Gbps, 3D	Not critical	Not critical
QoE (MOS)	N/A	>4.3	>4.3	>4.3

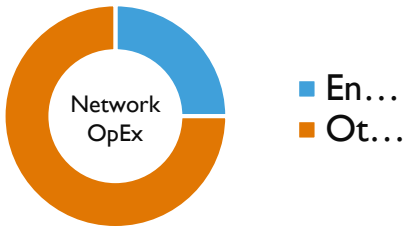
Initial High-level architecture



PROJECT OVERVIEW

CONTEXT

- 5/6G and edge computing are intrinsically **distributed and pervasive** by design.
- Relevant **increase** of **computing resources** and associated infrastructure **OpEx and CapEx**, and, consequently, their carbon footprint and energy requirements.



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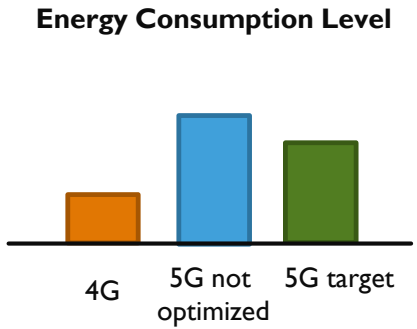

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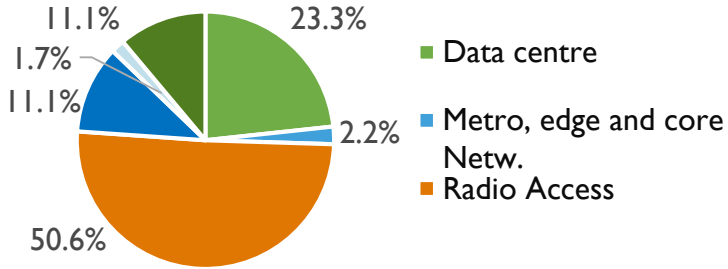


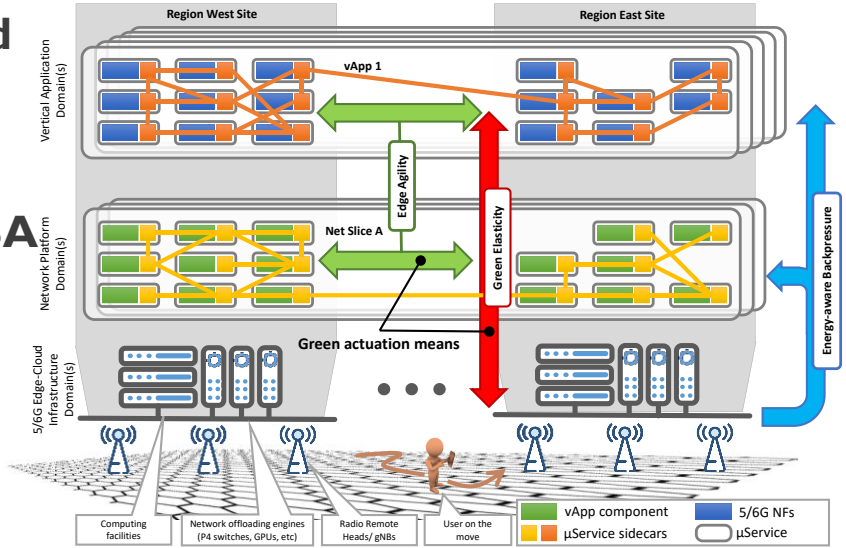
[2]

[1] "Energy Efficiency: an Overview," GSMA Future Networks, 8th May 2019. URL: https://www.gsma.com/futurenetworks/wiki/energy-efficiency-2/.

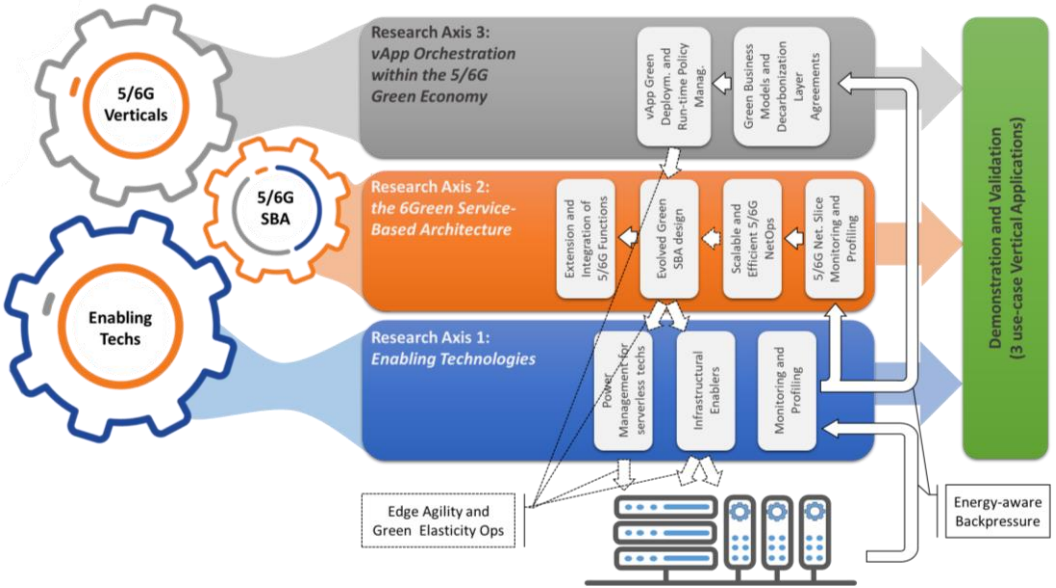
[2] Lorincz J, Capone A, Wu J. Greener, Energy-Efficient and Sustainable Networks: State-Of-The-Art and New Trends. Sensors. 2019; vol. 19, no. 22:4864. https://doi.org/10.3390/s19224864

THE 6GREEN PROJECT

- Conceive, design, and realize an **innovative service-based and holistic ecosystem** to extend "*the communication infrastructure into a sustainable, interconnected, greener end-to-end intercompute system*" and **promote energy efficiency** across the whole **5/6G value-chain**.
- Ultimate objective: enable **5/6G networks and vertical applications** to reduce their carbon footprint by a factor of 10 or more.
- How? Exploit and extend state-of-the-art **cloud-native technologies and the B5G SBA** with new cross-domain enablers to:
  - boost the global ecosystem flexibility, scalability and sustainability
  - enable all the 5/6G stakeholders reducing their carbon footprint by becoming integral parts of a win-win green-economy business.



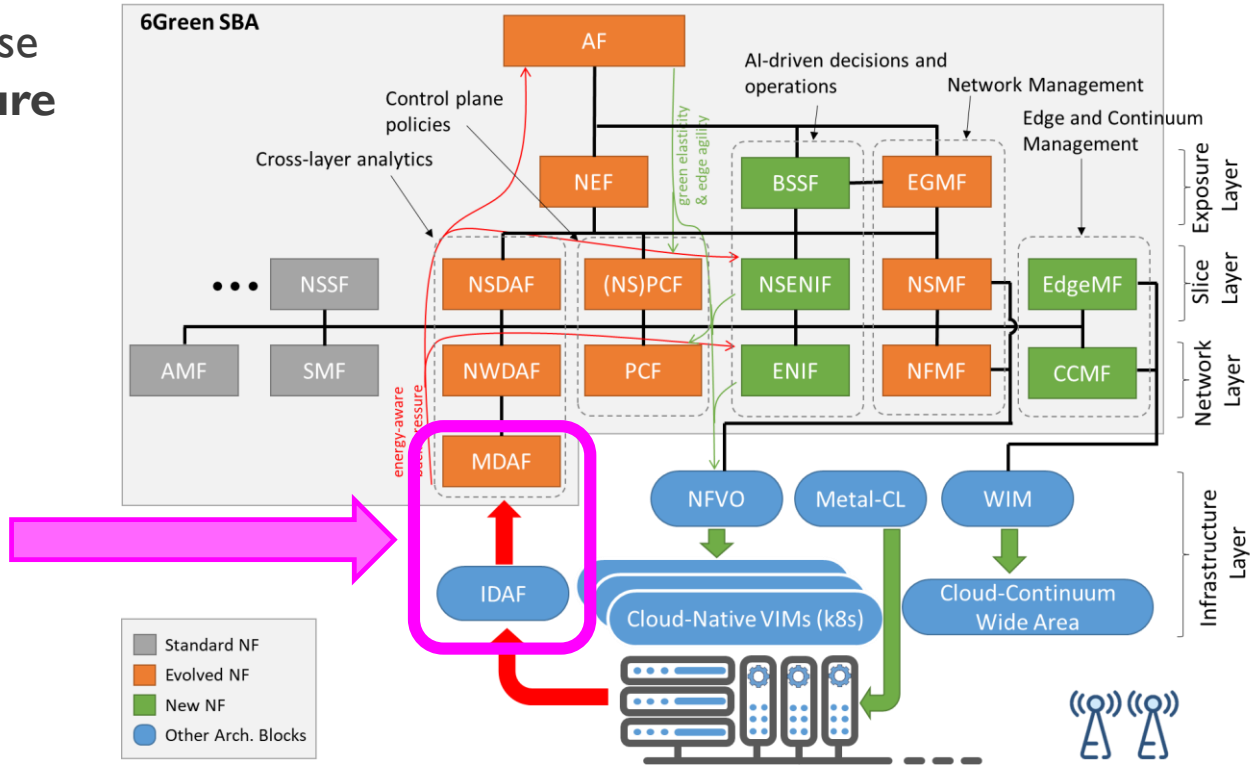
6GREEN ANATOMY



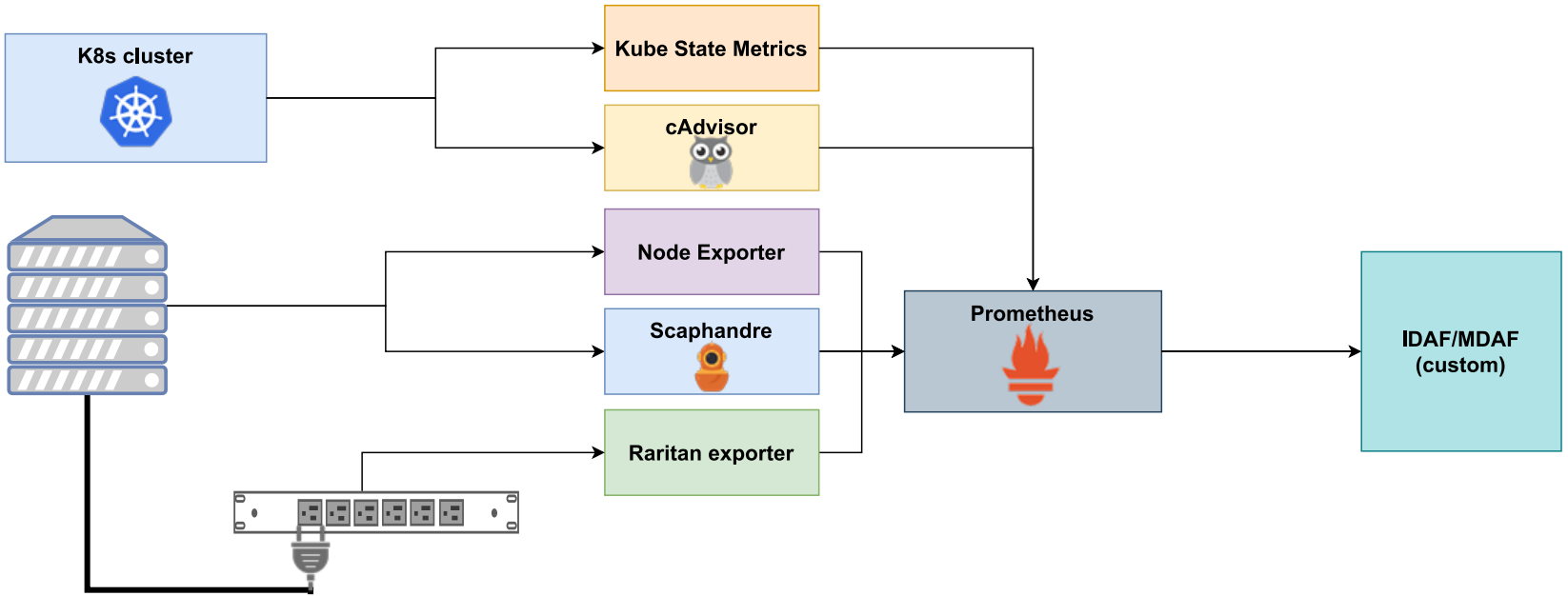
1. Critical Operation Maintenance during Energy-Constraint Disaster Scenarios
2. Energy-Efficient Augmented Reality Remote Assistance System
3. Zero-Carbon Clientless Virtual Enterprise Desktop as-a-Service

6G SBA

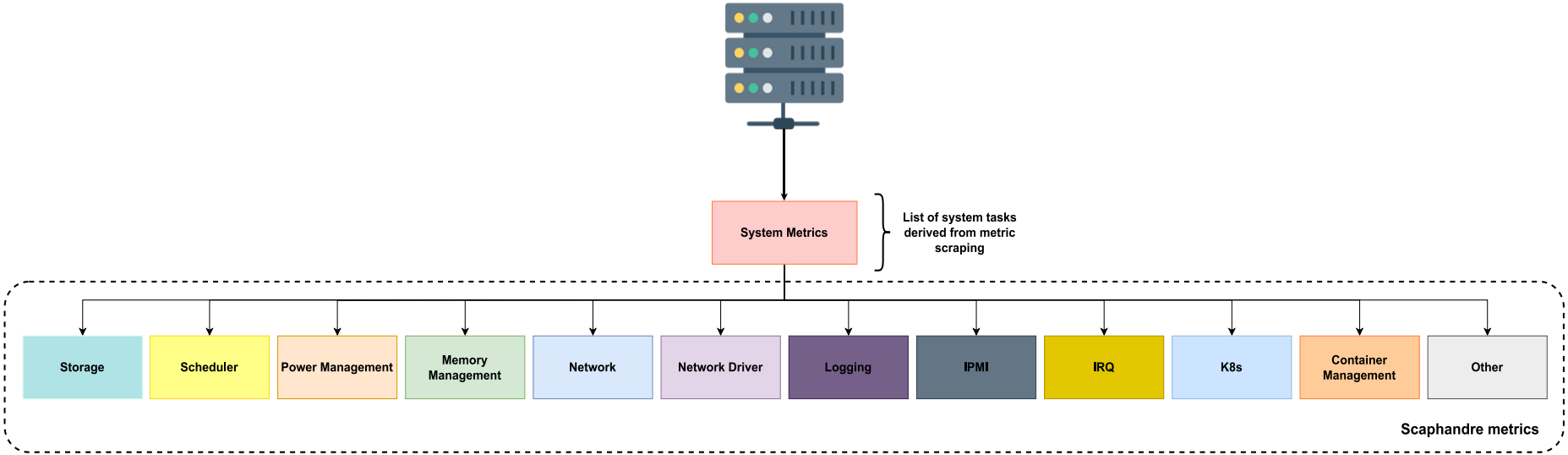
- We are working close to the **Infrastructure** Layer



MONITORING STRUCTURE AT THE INFRASTRUCTURE



SYSTEM LEVEL METRICS (SCAPHANDRE)



MDAF query

HELP python_gc_objects_collected_total Objects collected during gc# TYPE python_gc_objects_collected_total counterpython_gc_objects_collected_total{generation="0"} 1690.0python_gc_objects_collected_total{generation="1"} 263.0python_gc_objects_collected_total{generation="2"} 19.0# HELP python_gc_objects_uncollectable_total Uncollectable objects found during GC# TYPE python_gc_objects_uncollectable_total counterpython_gc_objects_uncollectable_total{generation="0"} 0.0python_gc_objects_uncollectable_total{generation="1"} 0.0python_gc_objects_uncollectable_total{generation="2"} 0.0# HELP python_gc_collections_total Number of times this generation was collected# TYPE python_gc_collections_total counterpython_gc_collections_total{generation="0"} 82497.0python_gc_collections_total{generation="1"} 7499.0python_gc_collections_total{generation="2"} 681.0# HELP python_info Python platform information# TYPE python_info gaugepython_info{implementation="CPython",major="3",minor="12",patchlevel="2",version="3.12.2"} 1.0# HELP process_virtual_memory_bytes Virtual memory size in bytes.# TYPE process_virtual_memory_bytes gaugeprocess_virtual_memory_bytes 2.359324672e+09# HELP process_resident_memory_bytes Resident memory size in bytes.# TYPE process_resident_memory_bytes gaugeprocess_resident_memory_bytes 9.5666176e+07# HELP process_start_time_seconds Start time of the process since unix epoch in seconds.# TYPE process_start_time_seconds gaugeprocess_start_time_seconds 1.71195704049e+09# HELP process_cpu_seconds_total Total user and system CPU time spent in seconds.# TYPE process_cpu_seconds_total counterprocess_cpu_seconds_total 2528.0# HELP process_open_fds Number of open file descriptors.# TYPE process_open_fds gaugeprocess_open_fds 10.0# HELP process_max_fds Maximum number of open file descriptors.# TYPE process_max_fds gaugeprocess_max_fds 1.048576e+06# HELP mdaf_enriched_k8s_container_power_microwatts MDAF power consumption of K8s containers + the additional labels (pod and namespace) which are missing from scaphandre# TYPE mdaf_enriched_k8s_container_power_microwatts gauge# HELP mdaf_aggregated_k8s_container_power_microwatts MDAF power consumption of K8s containers + the mapping of the categories of system-level metrics# TYPE mdaf_aggregated_k8s_container_power_microwatts gauge# HELP mdaf_aggregated_docker_container_power_microwatts MDAF power consumption of docker containers + the mapping of the categories of system-level metrics# TYPE mdaf_aggregated_docker_container_power_microwatts gauge# HELP mdaf_aggregated_vm_power_microwatts MDAF power consumption of VMs + the mapping of the categories of system-level metrics# TYPE mdaf_aggregated_vm_power_microwatts gauge# HELP mdaf_category_power_microwatts MDAF power consumption of each category (composed of system-level metrics)# TYPE mdaf_category_power_microwatts gaugemdaf_category_power_microwatts{category="uncategorized",node="node09"} 68334.55403949475mdaf_category_power_microwatts{category="scheduler",node="node09"} 0.0mdaf_category_power_microwatts{category="network",node="node09"} 0.0mdaf_category_power_microwatts{category="power management",node="node09"} 0.0mdaf_category_power_microwatts{category="security function",node="node09"} 0.0mdaf_category_power_microwatts{category="memory management",node="node09"} 0.0

Analytics

- ✓ Monitor the health and efficiency of processes in terms of memory and CPU usage
- ✓ Analyze power usage by specific containers within the context of their Kubernetes pods and namespaces
- ✓ Aggregate and categorize power usage by Kubernetes containers/ Docker containers to identify trends and optimize resource allocation
- ✓ Assess and categorize the power usage of virtual machines to optimize virtualized environments
- ✓ Analyze the power consumption of different system-level metric categories to identify high-power-consumption areas
- ✓ Compare power usage across containers, VMs, and monitoring tools to make informed decisions about infrastructure scaling and cost management

TrialsNet

TRials supported by Smart Networks beyond 5G

TrialsNet project has received funding from the European Union's Horizon-JU-SNS-2022 Research and Innovation Programme under Grant Agreement No. 101095871

Trials supported by Smart Network beyond 5G

HORIZON-JU-SNS-2022-STREAM-D-01-01

36 months : Jan 1st 2023 – Dec 31st 2025

TrialsNet will deploy full large-scale trials to implement a heterogenous and comprehensive set of innovative 6G applications based on various techs such as **cobots, metaverse, massive twinning, Internet of Senses**, and covering 3 relevant domains of the urban ecosystems in Europe:

1. Infrastructure, Transportation, Security & Safety
2. eHealth & Emergency
3. Culture, Tourism & Entertainment.

13 use cases developed over wide coverage areas with the involvement of extended sets of real users in 4 geographical clusters, in **Italy, Spain, Greece and Romania**. The use cases will be transversal, each single use case will be potentially implementable over different clusters, thus allowing for a holistic evaluation of the network KPIs.

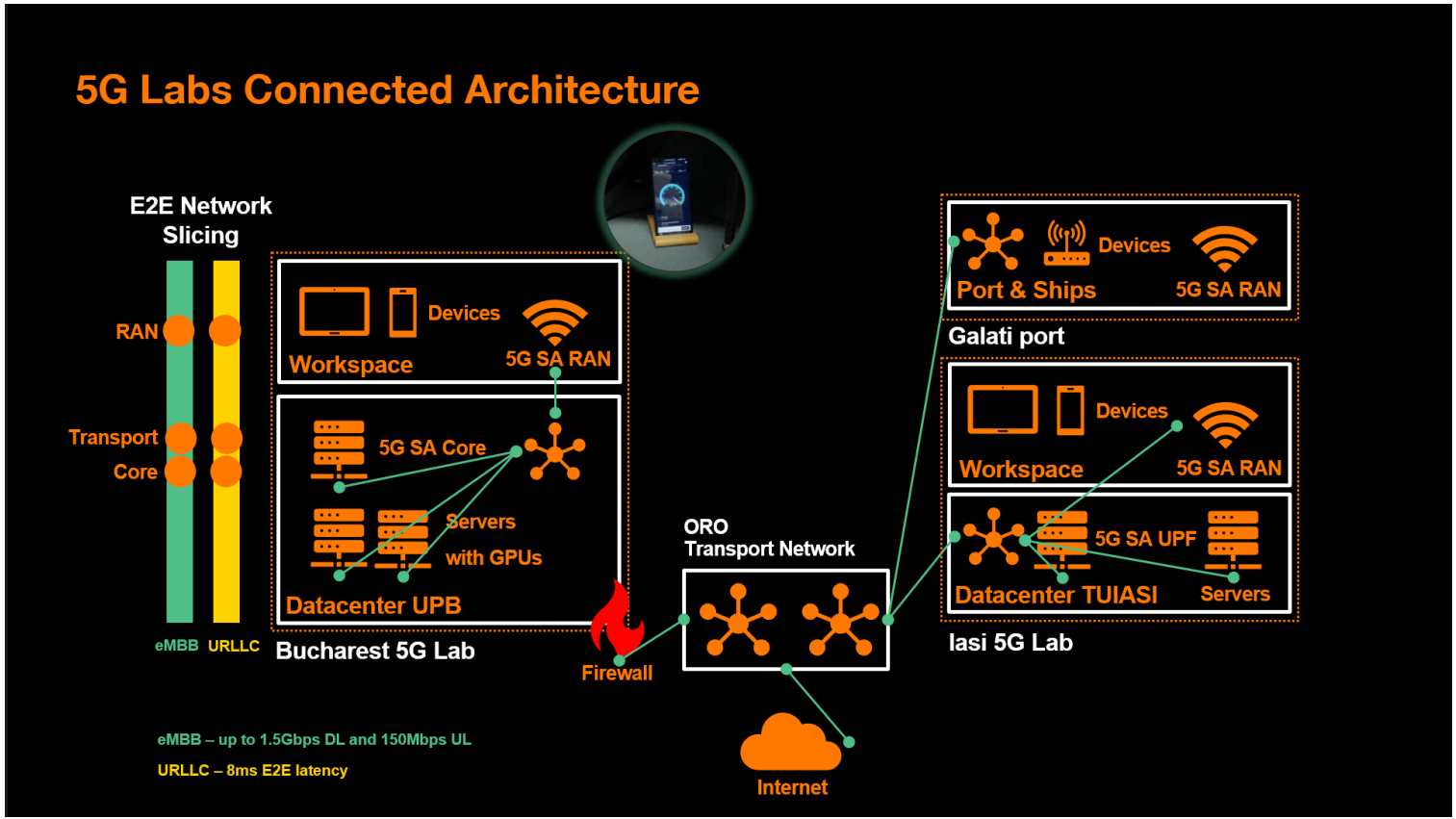
Targeting to improve the “liveability” of the urban environment in the different domains, TrialsNet will also pursue the objective to (i) understand where current networks are not sufficient to assure the performance needed by the use cases, and to (ii) derive the new requirements for next generation mobile networks.

TrialsNet RO Use Cases

Use case 1: Smart Crowd Monitoring
Objectives
With this use case, we want to take advantage of the benefits offered by 5G/6G technologies to improve the protection of people at crowded sporting events. Lower latency on the transmission of data coming from cameras and access control systems helps to reduce the reaction time to alerts whilst enabling the deployment of additional remotely controlled devices such as terrestrial robots or LIDARs

Use case 4: Smart Traffic Management
Objectives
This use case involves the design and development, deployment of the envisioned tools that will validate the concept of intelligent traffic management and successfully support the 6G-applications in large-scale environments by enabling a tight interaction between humans and the surrounding environments, through the usage of IoT Sensors, Computer Vision, LiDAR Enhanced Vision, On-Demand Intelligent and Autonomous Drones Surveillance and Cameras, within a robust, Zero-Touch Management capability of EDGE resources, as well as the large scale deployment of B5G Networks to support the use case, provided the installation, configuration, and operation of state-of-the-art network components, to cover the areas in which the use case is to be demonstrated

5G testbed details overview



5G coverage in the area relevant for UC

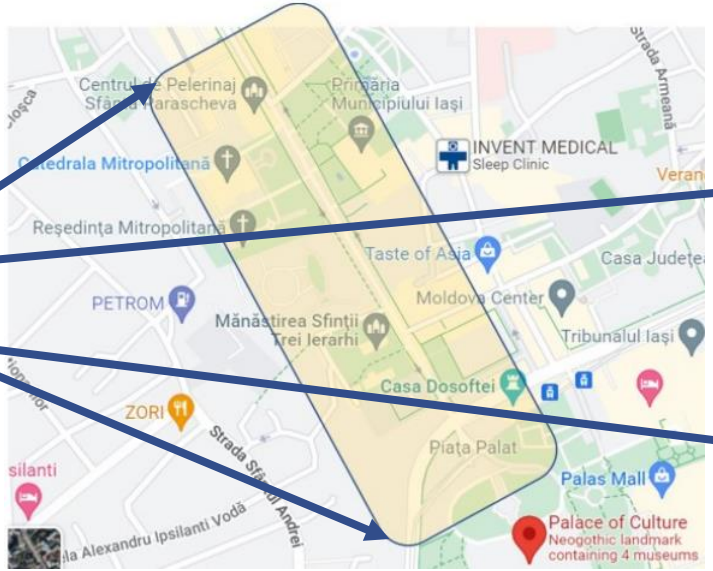
Phase1: 5G NSA
Outdoor
Large-scale tests

Phase2: 5G SA
In the Iasi 5G Lab
Small-scale tests

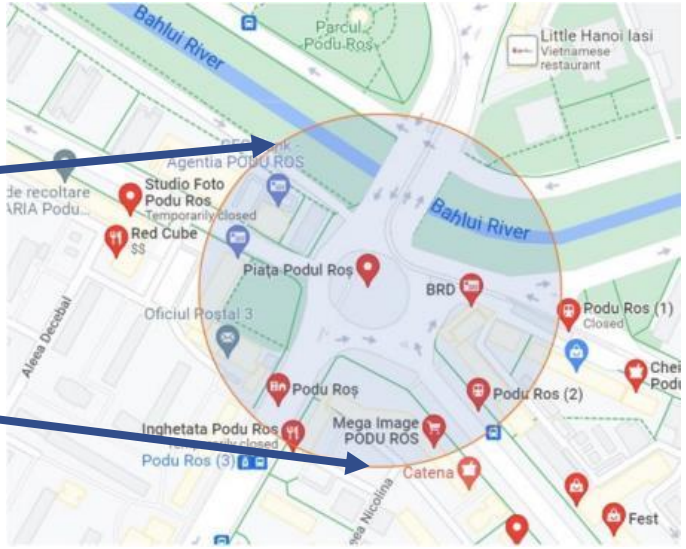
Phase3: 5G SA
Outdoor
Large-scale tests

5G

UC #1

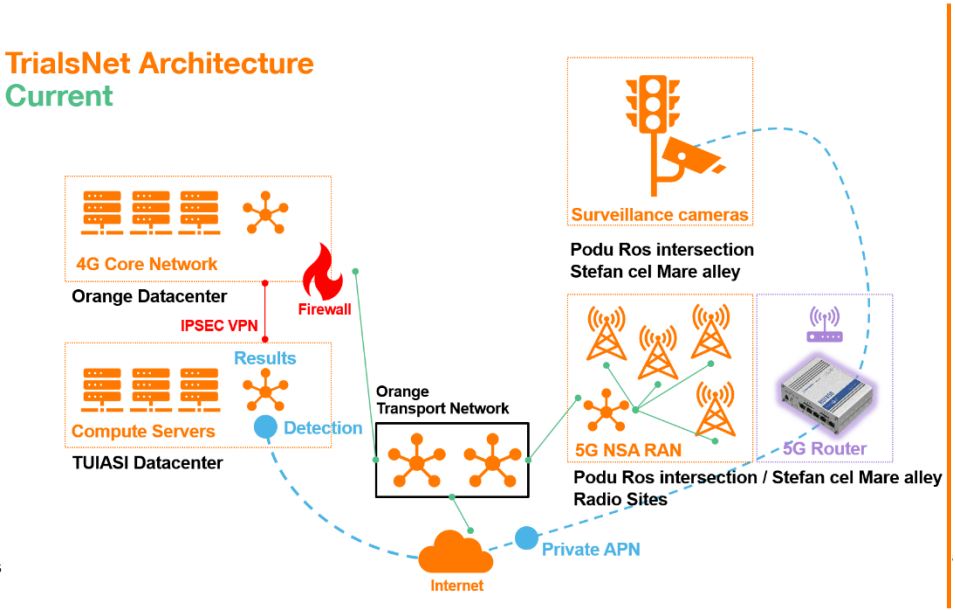


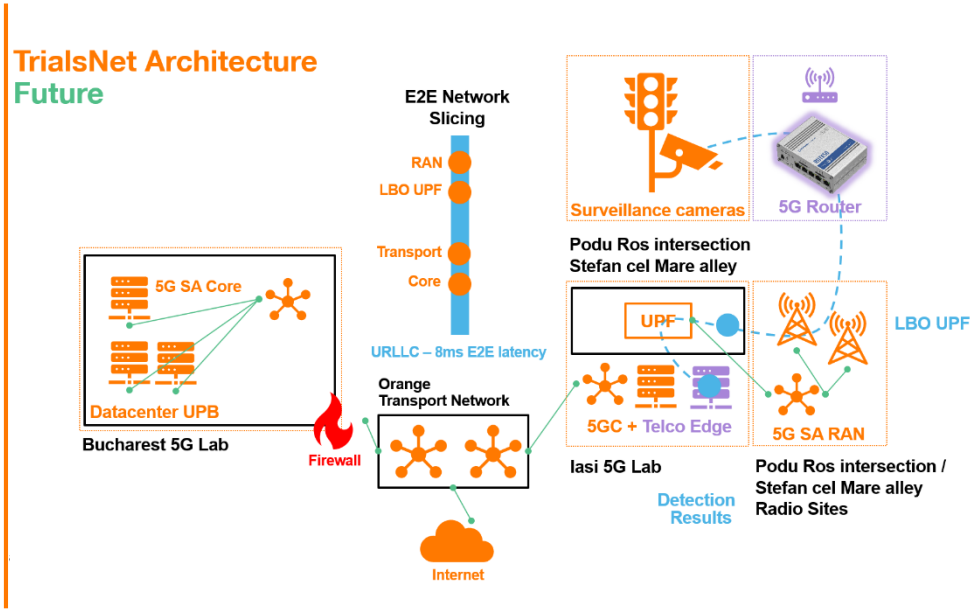
UC #4



Horizon-JU-SNS-2022
Grant Agreement No. 101095871

Architecture – Smart Crowd Management / Traffic Monitoring





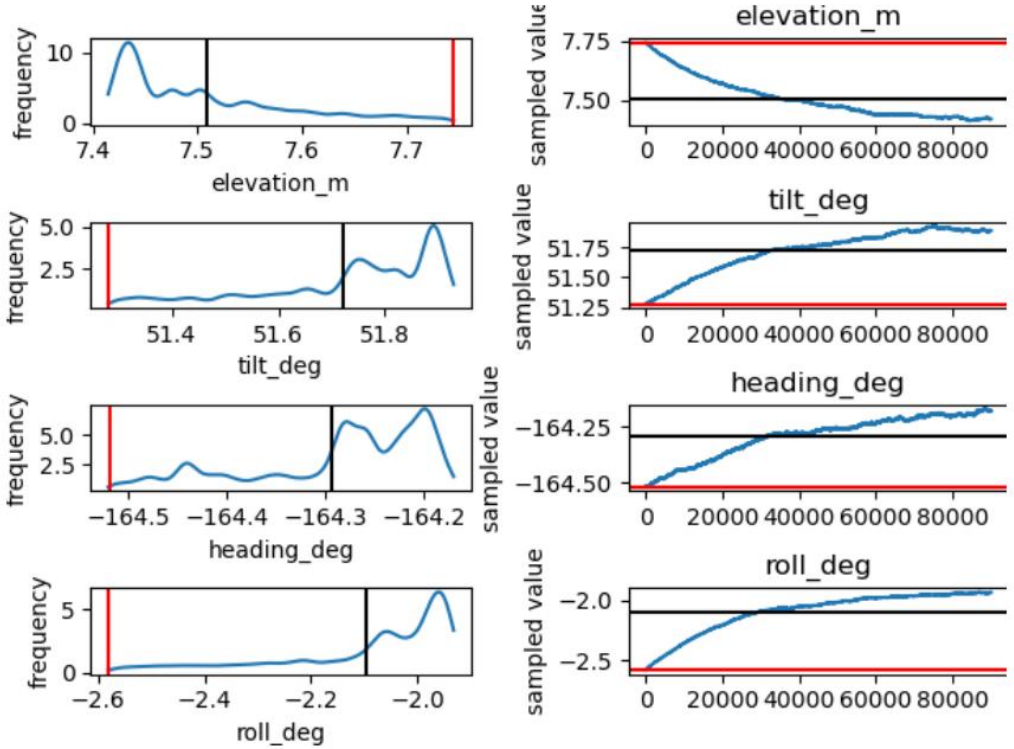
Implementation – Smart Crowd Management

Implementation – Smart Crowd Management

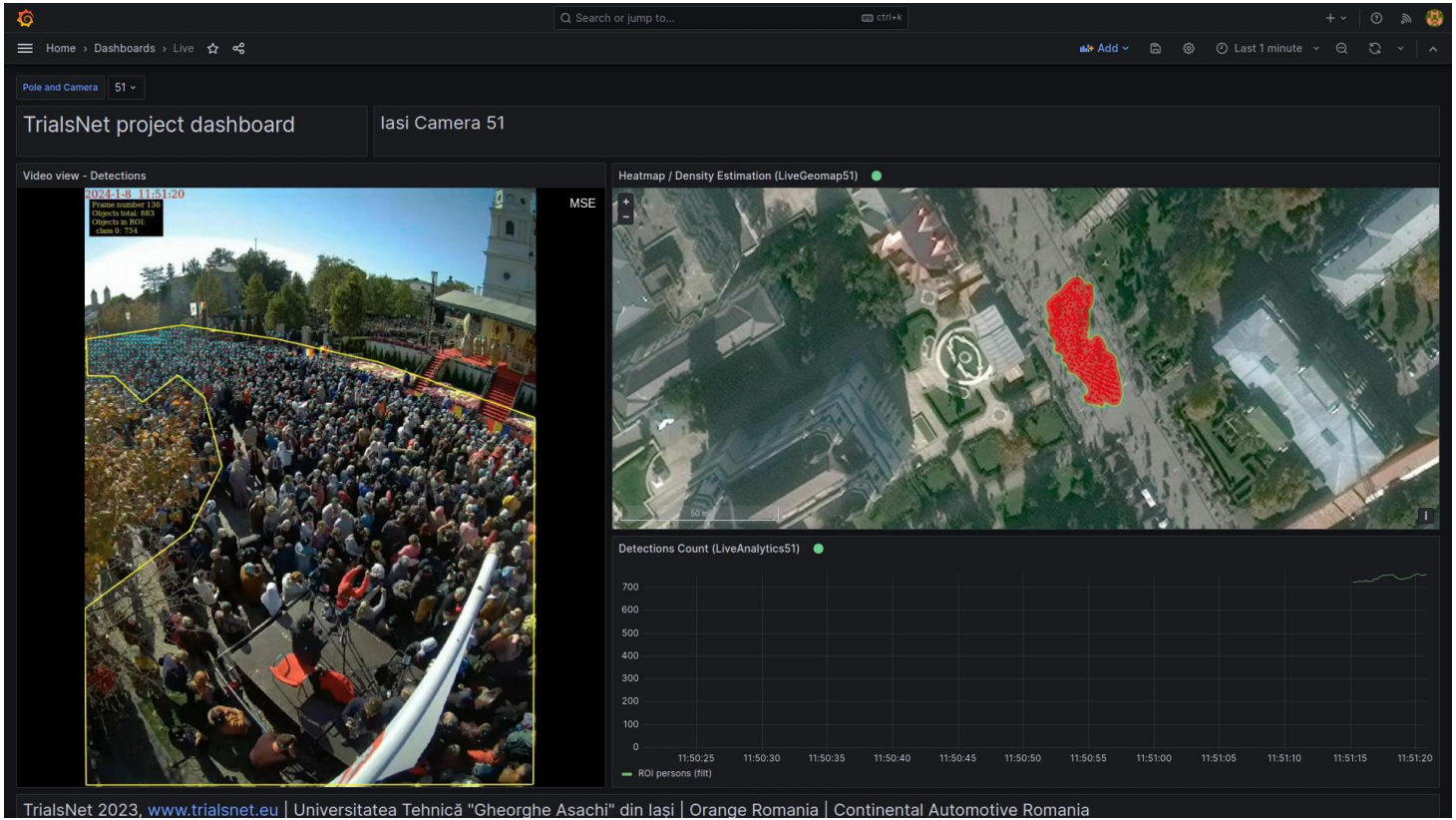
Video resolution down sampling for anonymization

Implementation – Smart Crowd Management

Camera calibration process



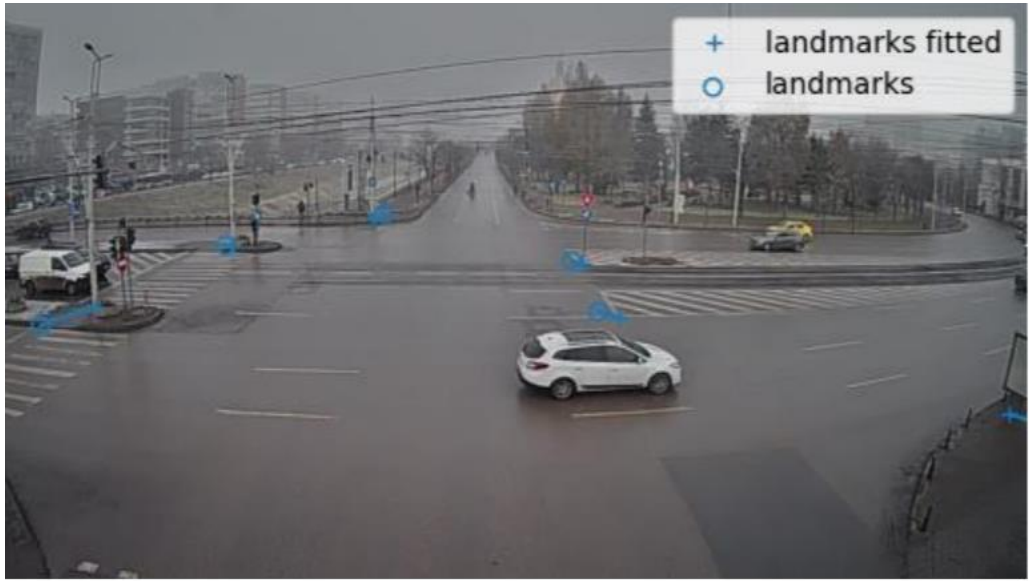
Implementation – Smart Crowd Management

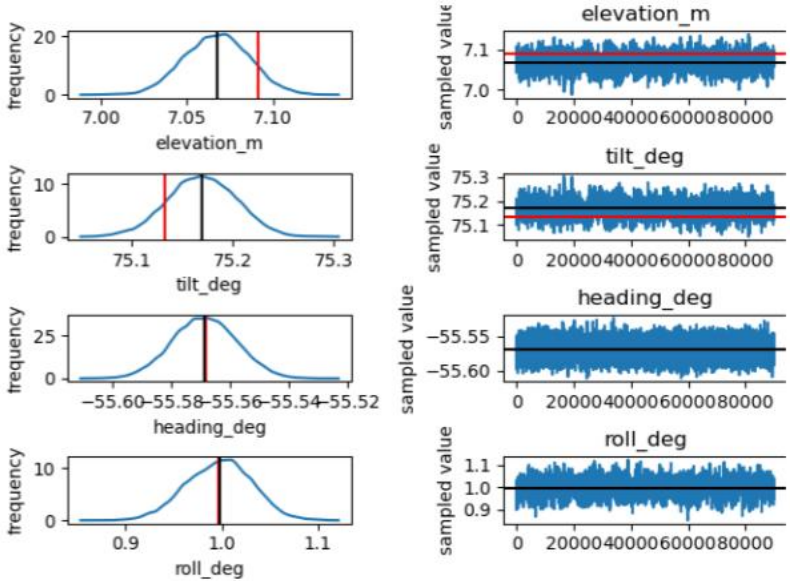


Implementation – Smart Traffic Monitoring

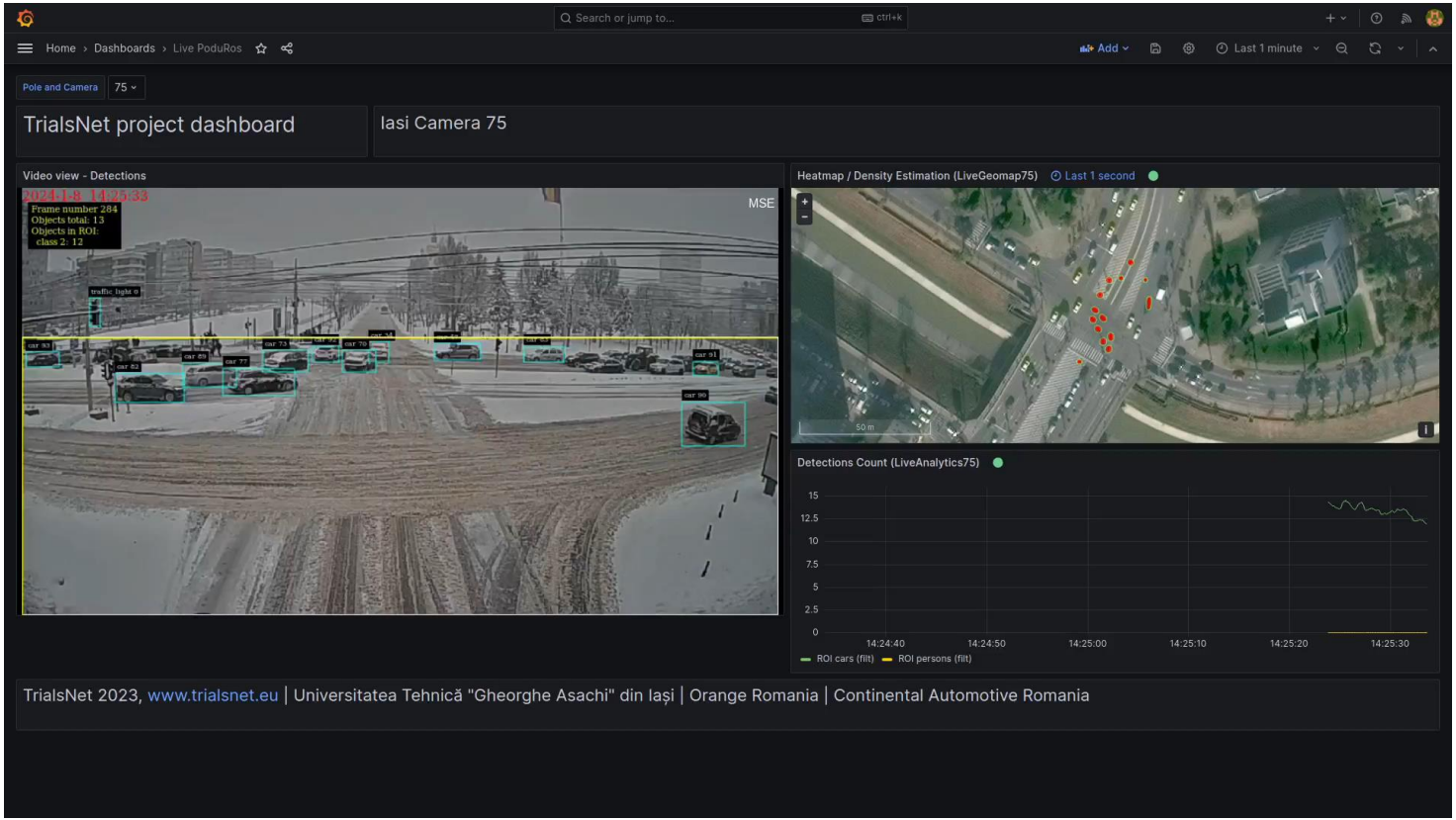
Implementation – Smart Traffic Monitoring

Camera calibration process





Implementation – Smart Traffic Monitoring



6G-PATH: *6G Pilots and TriAls THroughout Europe*

Project Presentation

6G-PATH project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101139172.

6G-Path

6G-PATH - Main Scope

6G-Path

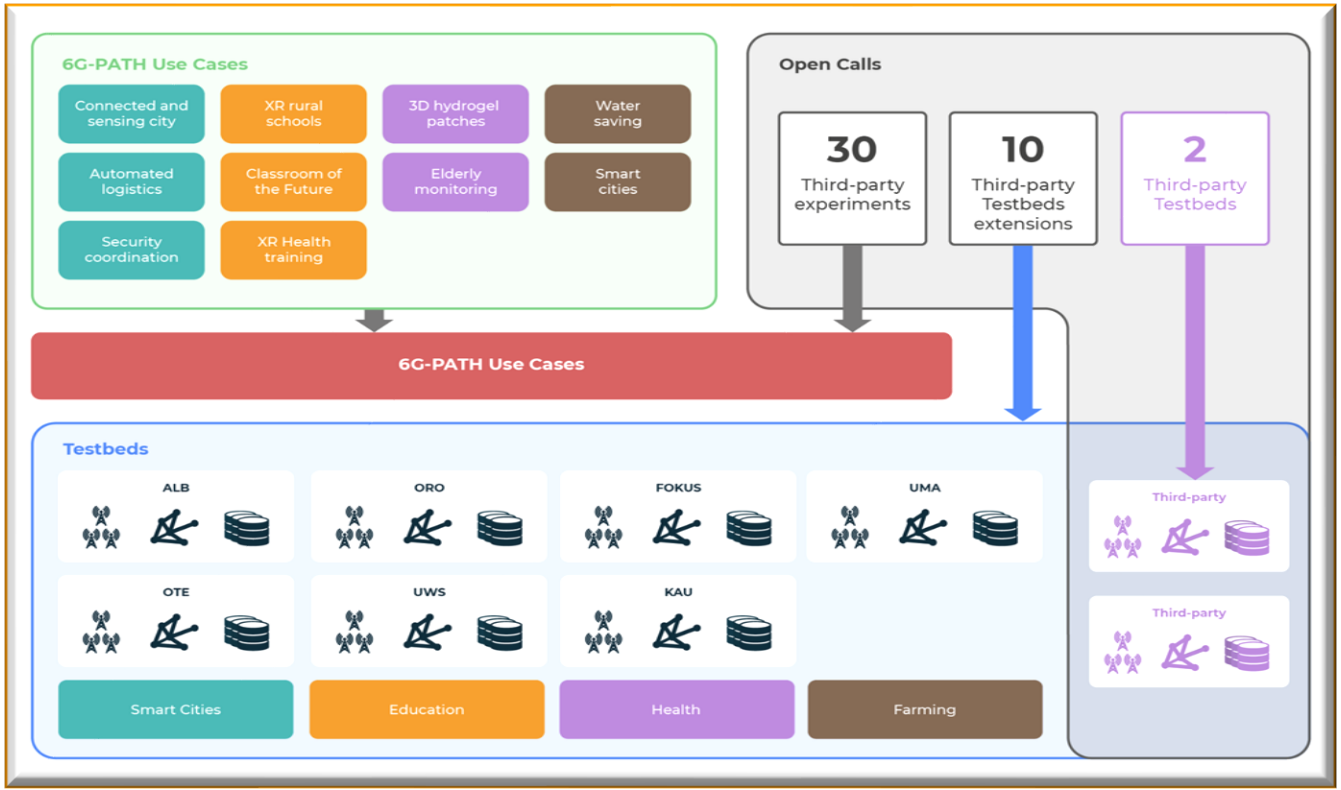
The Challenge:

- **The path towards 6G is gradually taking place** *following to the 5G's worldwide deployment both publicly and privately.*
- **Although 5G brought major benefits in many fields (e.g., performance and efficiency), more is always expected** *in terms of efficiency by the overall community* and *in terms of performance by industry and technology providers* who want to further increase their offerings and products.
- **Continuous demands for higher throughput, lower latency and more energy efficient communications needs to be supported by relevant use cases,** *being able to claim &demonstrate the needs for such requests.*

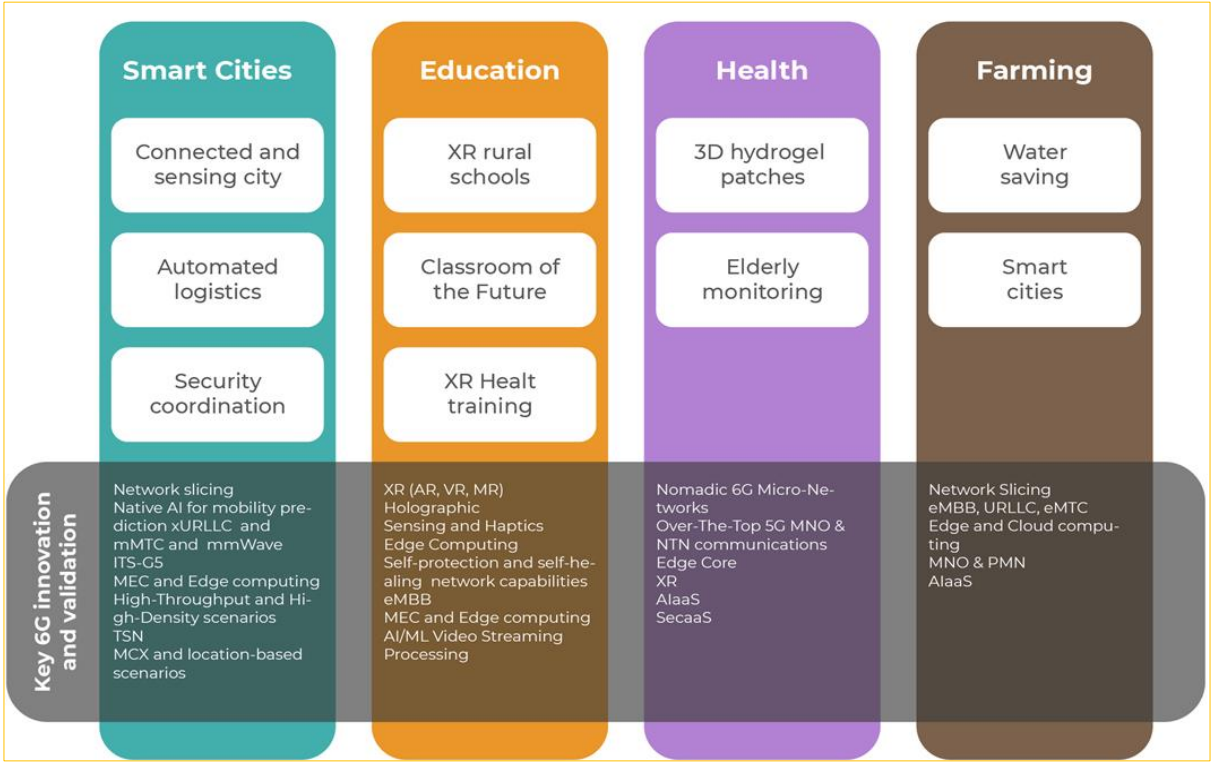
The Way forward:

- **6G-PATH's goal is to help foster the further development and integration of new and improved tools and products from EU companies with 5G/6G, while also measuring relevant KPIs & KVIs.**
- **7 testbeds will be part of the project consortium**, which will be used by **10 use cases spread across four key verticals: Health, Education, Smart Cities and Farming.**
- **A portion of the budget will be used for FSTP**, where there is vision for the integration of **2 new Pilot Sites, extension of the testbeds with 10 additional technologies, as well as 30 new Use Cases, through Open Calls**, *to further involve the community and obtain more metrics and outcomes.*
- **6G-PATH will work closely with other ongoing/starting Stream-B and Stream-C projects** in a feedback loop.

6G-PATH Ecosystem



6G-PATH – Verticals & Use Cases

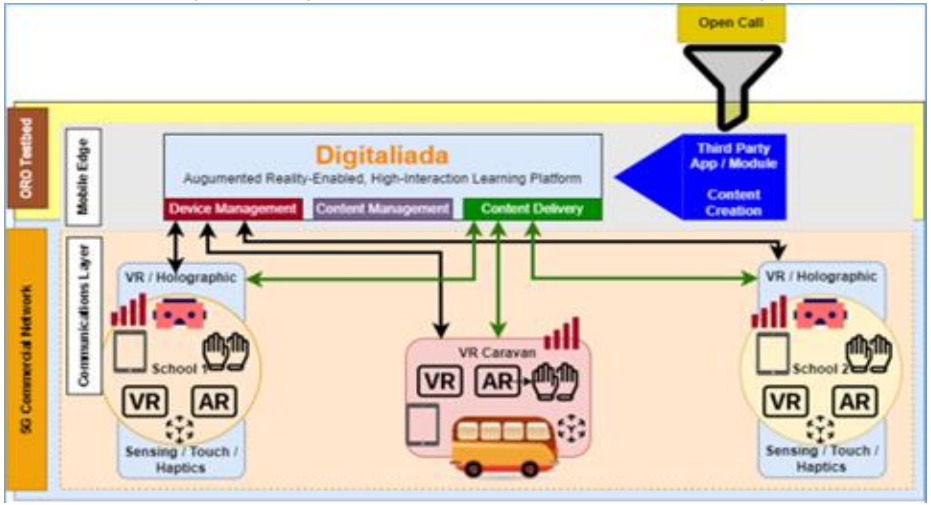


Use Case Innovations

UC-EDU-1 – XR rural school

ORO will provide data connectivity through the commercially deployed network (5GSA) and access to a fully-fledged 5G/6G Experimentation Platform equipped with latest generation of software and hardware solution. The VR Caravan, operated from Iasi, Romania, and both rural schools will have the necessary coverage to ensure a good quality experience for both students and teachers.

This use case also considers the possibility of increasing the teaching experience and materials through the Track C of the Open Calls, where external entities may contribute with the development and integration of new contents. The use case will also drive, together with the Digitalia program, the necessary training so that teachers and other faculty staff can contribute.



UC-EDU-1
XR rural school

Champion: OROF
Testbed: ORO
Operator: ORO
Partners: -

6G-MUSICAL PROJECT OVERVIEW

The 6G-MUSICAL project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101139176.

6G – MUSICAL Motivation / Vision I

The Past

- Two Services over Radio Technologies
  - ***Localization and Tracking***: Radar
    - Users: Big organisations
  - ***Communication***: the *x*Gs
    - Massified and democratised
    - ***Internet Everywhere to the masses***



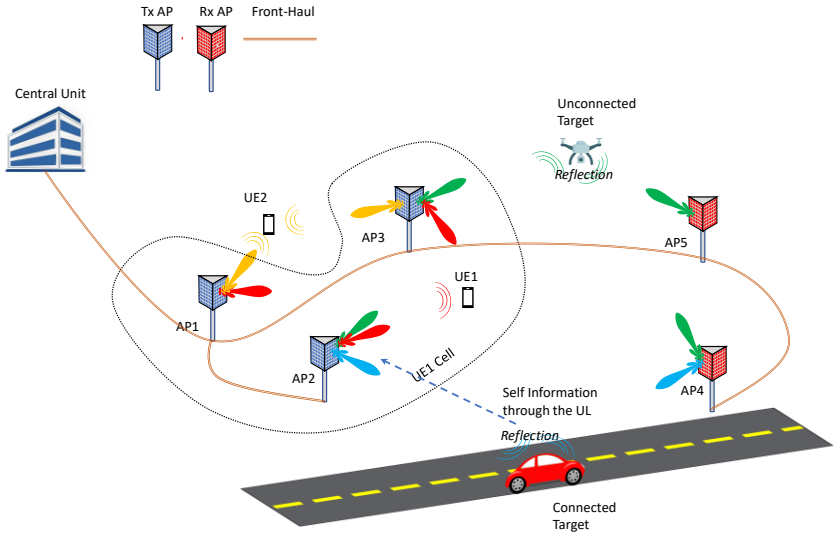
6G – MUSICAL Motivation / Vision II

The Motivation: A future different from the past

What the Future (6G) Demands?

- **Convergence of Services Over a Unified Network**
- ***Radio- Sensing embedded in 6G***
- **What does it bring?**
  - Radio-sensing in a globally deployed network
    - **Sophisticated, localisation, tracking services**
      - Now accessible to the commons
    - Massification will spur innovation
    - High-resolution 3D imaging, object reconstruction

The vision: Integrated Radio Sensing and Communications

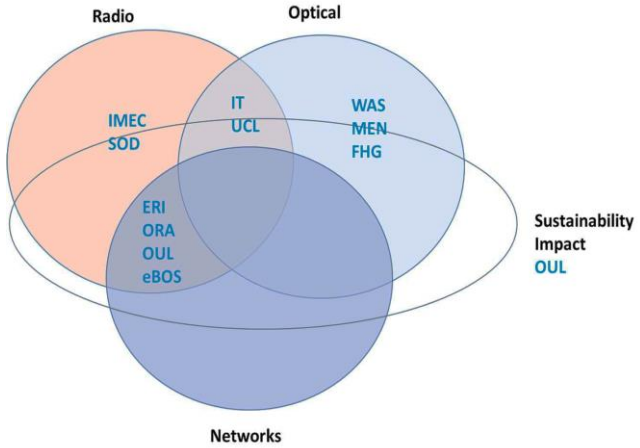


6G-MUSICAL – The Difference

Where does 6G-MUSICAL stand out?

- **Tight integration**
  - Joint waveforms
  - Joint resource allocation
  - Massive levels of cooperation between edge nodes
- **Considers both connected and unconnected objects**
- **Accurate synchronisation among the edge nodes**
  - High accuracy in positioning or high resolution in 3D imaging

    ➔nodes perfectly synchronised



Merging of optical and radio technologies

6G-MUSICAL – The Objectives & Main Use Cases

Five Specific Technology Objectives

1. Definition of **physical and logical network architecture**;
2. **PHY waveforms** for communication and radio sensing;
3. **Cooperative MIMO multi-static sensing algorithms** for high accuracy and high resolution;
4. Low-noise and **highly-stable reference sources** for carrier and timing synchronisation**;**
5. Design of **dynamic resource allocation schemes** for optimisation of power and spectrum usage;

One wide objective

- **Business Cases** and **Sustainability**
  - Define and validate the business cases and sustainability issues associated with integrated communication and sensing in 6G

Use Cases

- **Sensing as a Service** provided by the edge infrastructure for:
  - 3D object reconstruction
  - Drone detection, classification and monitoring
  - Mobile crowd sensing

Use Cases

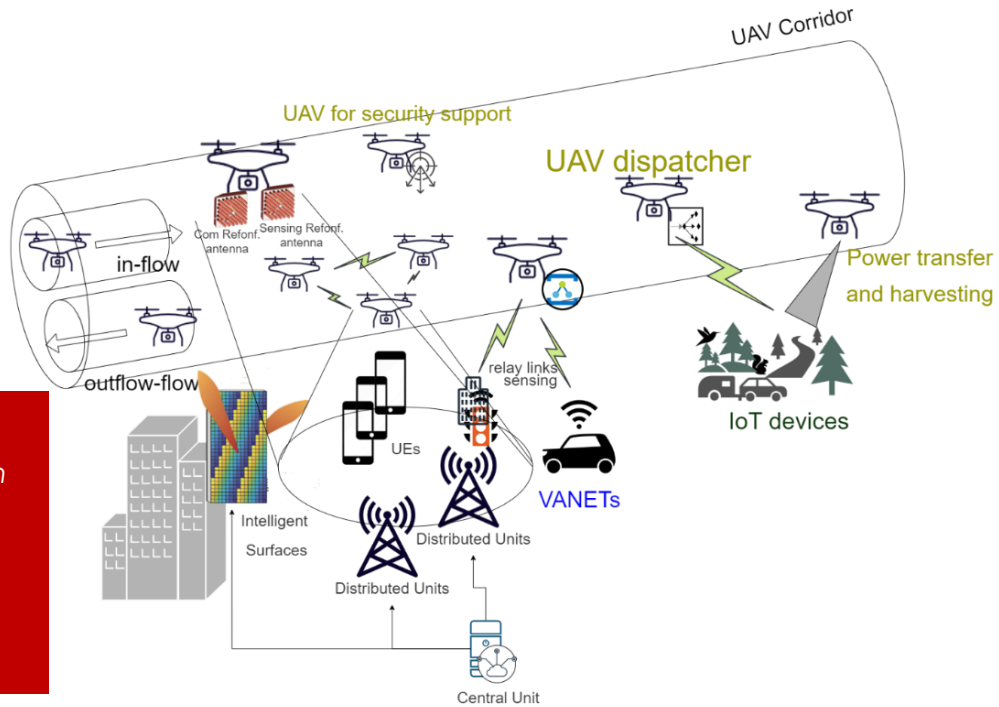
- **Vehicle-to-everything (V2X)**
  - High precision localization
  - Simultaneous localization and mapping
  - Smart autonomous convoys

INTEGRATED SENSING, ENERGY AND COMMUNICATION FOR 6G NETWORKS

'6G-INTENSE project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grand Agreement No 101139266'

iSEE-6G INTEGRATED SENSING, ENERGY AND COMMUNICATION FOR 6G NETWORKS

- Beyond joint communication and sensing
- Definition & development of Joint Communication, Computation, Sensing, and Power transfer (JCCSP) unified radio paradigm



Use Case: 6G-enabled/supported Aerial Corridors

- *JCCSP-oriented passive and active antennas solutions with intelligent reconfiguration capabilities*
- *JCCSP-optimized Physical Layer design*
- *JCCSP-enabled cross-layer schemes design*
- *Positioning with MEC support using 6G and UAVs network.*

Co-funded by the European Union

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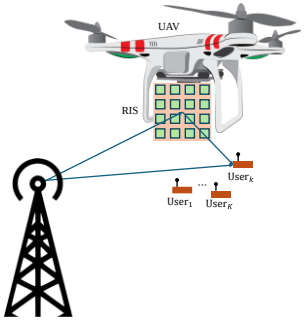
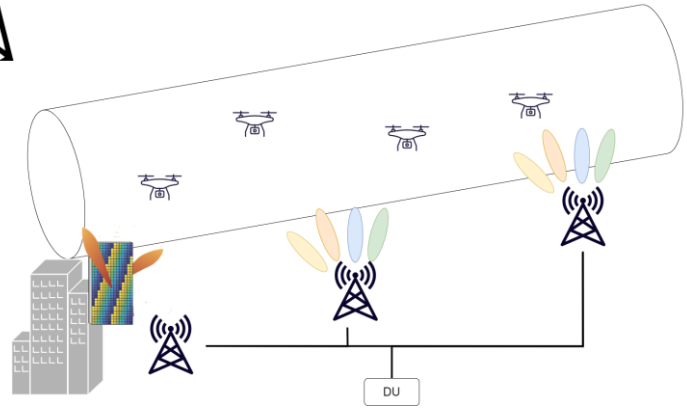
UAVs (and corridors) as USE CASE

UAVs with multiple roles in 6G:

- Contributors for the "cell-free" 6G paradigm in conjunction with multi-dimensional antennas, reconfigurable intelligent or holographic surfaces, and more – providing exceptional beamforming capabilities in the three-dimensional (3D) space.
- Targets as well as sensors for JCS – active and passive sensing.
- Support next generation of backscatter communication.
- Energy harvesting and power transfer to become the means for wireless charging.
- Means for designing energy efficient communication systems and green communications in general offering new 3D tools for radio planning and optimization, as well as enabling energy-efficient relays.
- Flying mobile edge computing devices servicing low-end devices under the massive connectivity IoT paradigm.





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Thank you!

Orange Team