Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
RESTART

Integration of Terrestrial and Non-Terrestrial Networks: challenges and perspectives within the RESTART project

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Workshop on Space Data Management
(Venice 8-9 May)

RESTART, Spoke 2, and ITA NTN project

- The RESTART program is funded by the European Union under the Italian National Recovery and Resilience Plan (NRRP) of NextGenerationEU.
- It aims to foster scientific and technological developments and innovation in the sector of telecommunications and related applications

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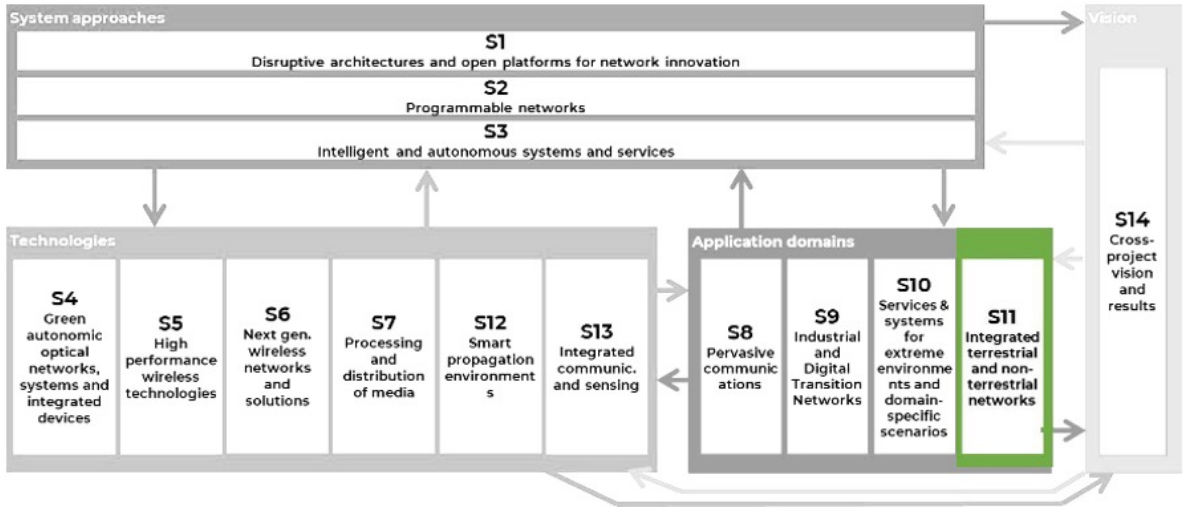
RESTART, Spoke 2, and ITA NTN project

- Partners are organized in 8 Spokes and contribute to 14 structural projects and many other focused projects

1 - Pervasive and Photonic Network Technologies and Infrastructures	S4	S8
2 - Integration of Networks and Services	S14	S11
3 - Wireless Networks and Technologies	S5	S6
4 - Programmable Networks for Future Services and Media	S2	S7
5 - Industrial and Digital Transition Networks	S9	
6 - Innovative Architectures and Extreme Environments	S1	S10
7 - Green and Smart Environments	S12	S13
8 - Intelligent and Autonomous Systems	S3	



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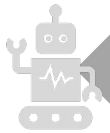
Spoke 2: overview

Significantly contribute to the definition of the future 6G infrastructure

Studying future integrated terrestrial / non-terrestrial networks



Identify the technological innovations enabling future generation networks

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Spoke 2: context and motivation

Low cost
High density

High cost
Low density

Cities

Mountains, deserts, oceans

Ground
Coverage

Aerospace
Coverage

Need for a ubiquitous, resilient, and **three-dimensional wireless connectivity** based on integrated T/NT networks

Networks can play a key role in mitigating their detrimental effects and pursuing Sustainable Development Goals

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Spoke 2: projects

Structural Project 11 ITA NTN **Integrated Terrestrial and Non-Terrestrial Networks**	**Structural Project 14 Net4Future** **Cross-project Vision and Results**	**Focused Project ARCADIA** **grAphene-based THz wiReless Communications: chAnnel characterization and components moDeling and sImulAtion**
Investigate future integrated T/NT networks to provide ubiquitous and resilient wireless connectivity	Analyze a functional end-to-end architecture of future networks, by identifying technological enablers and innovation potential	Investigate end-to-end **THz communication systems** via robust simulation framework

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Integrated Terrestrial And Non Terrestrial Networks (ITA NTN)

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PI of s11 ITA NTN project

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ITA NTN: main goals

Goal 1: design a 3D multi-layered communication architecture for integrated T/NT networks

Goal 2: evaluate the link budget for free-space, optical, and radiofrequency links

Goal 3: design advanced transmission techniques

Goal 4: conceive innovative methodologies for the orchestration of communication and computational resources

Goal 5: evaluate the performance of conceived approaches

Structural Project 11
ITA NTN
Integrated Terrestrial and Non-Terrestrial Networks

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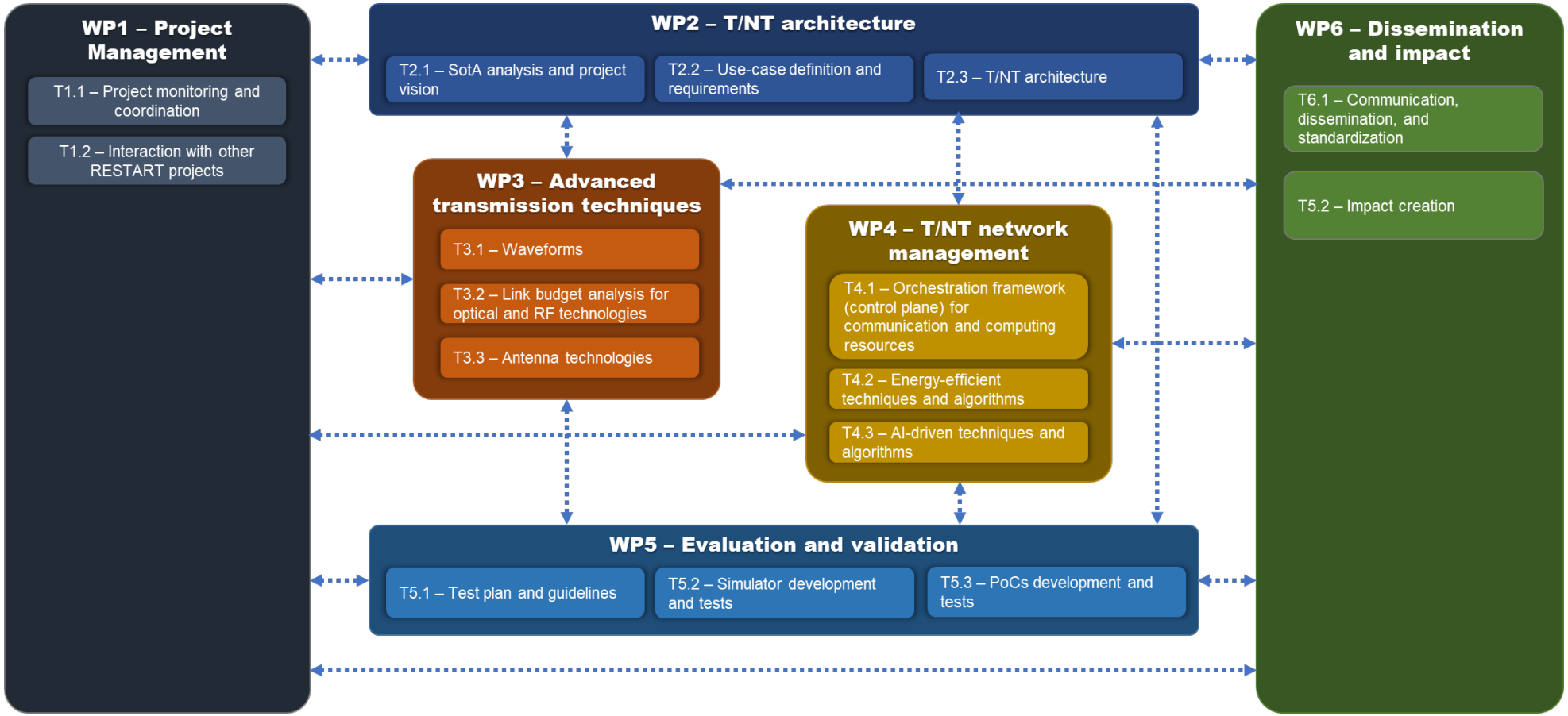
ITA NTN: PERT diagram



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WP1 - Project Management

This WP coordinates and monitors the activities throughout the ITA NTN project, thus steering decision-making to ease interactions among WPs.

Tasks:

T1.1: Project monitoring and coordination

T1.2: Interaction with other RESTART projects

WP2 – T/NT architecture

WP2 investigates the current State of the Art of T/NT networks and defines a novel integrated NTN architecture through the characterization of use cases and related requirements. It will define functional requirements for the links and KPIs.

Tasks:

T2.1: SoTA analysis and project vision

T2.2: Use case definition and requirements

T2.3: T/NT architecture

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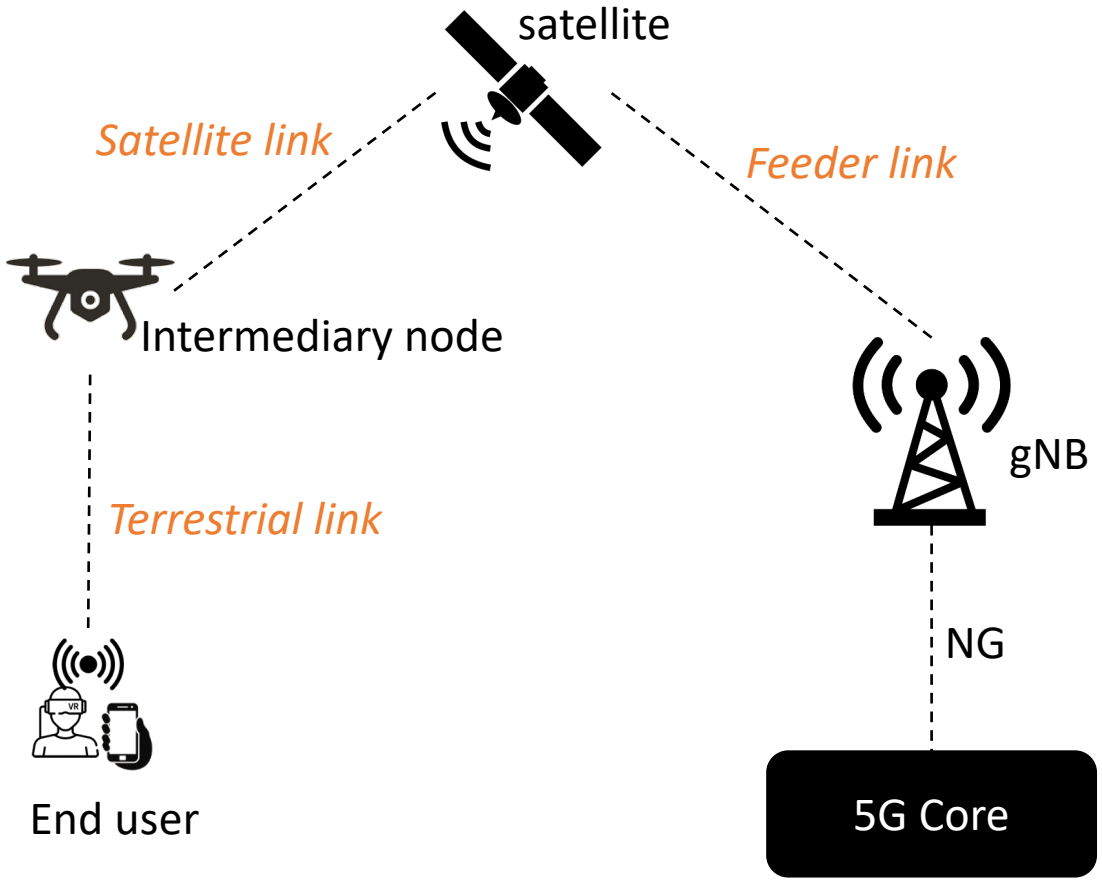
Simplified overview of the 3-dimensional scenario



- The end user would establish a communication with a remote gNB via a multi-hop and wireless connection, involving an intermediary node and a satellite
- Intermediary node and satellite may operate in both transparent or regenerative modes
- Intermediary node and satellite communicate via 5G NR; satellite and gNB communicate via 5G NR

WP3 - Advanced transmission techniques

This WP proposes innovative transmission techniques, based on optical frequencies or sub-6GHz spectrum, millimeter waves, and THz band..

Tasks:

T3.1: Waveforms

T3.2: Link budget analysis for optical and RF technologies

T3.3: Antenna technologies, MIMO, and NOMA techniques

Preliminary evaluation of:

- Free-space, optical, and radiofrequency communication links available in such a 3D multi-layered communication architecture
- Technologies related to optical internode communications
- Design of optical antennas, channel modelling, turbulence impairments, propagation phenomena, and physical layer settings
- Multiple access techniques, MIMO schemes aided by Distributed Antenna Systems (DAS) and Coordinated Multi-Point (CoMP
- Beyond Orthogonal Frequency Division Multiplexing (OFDM), multicarrier waveforms for time-varying channels
- Non-Orthogonal Multiple Access (NOMA) techniques with successive interference cancellation (SIC)

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WP4 - T/NT network management

WP4 designs and develops a novel NTN Orchestration Framework that enables the development of energy-efficient and AI-driven algorithms for optimal resource allocation.

Tasks:

T4.1: Orchestration framework (control plane) for communication and computing resources

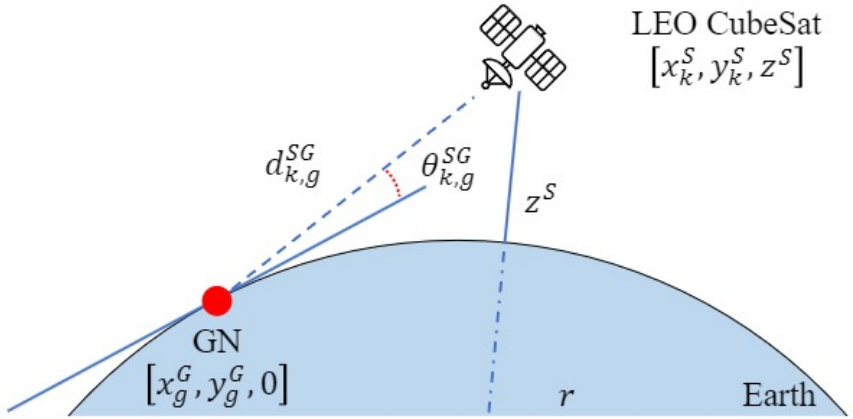
T4.2: Energy-efficient techniques and algorithms

T4.3: AI-driven techniques and algorithms

T/NT Optimization

Enable the data transmission of IoT devices to a LEO satellites. These nodes are recharged by a UAV equipped with an array antenna.

- A mathematical model, which accounts for the stochastic nature of the channel, has been developed to characterize the communication links.
- A non-linear energy-harvesting model has been also developed to be employed for system design and assessment.



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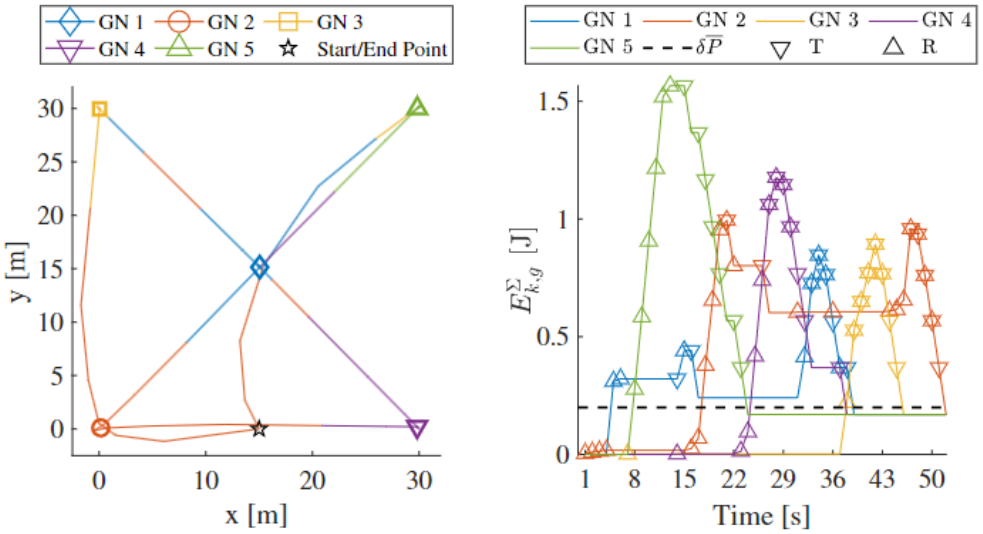
T/NT Optimization



The objective is to fairly maximize the harvested energy by jointly optimize the transmission plan of the nodes, the trajectory and speed of the UAV, and the array antenna beamforming vectors.

The proposed solution has been tested in multiple scenarios, under different parameter configurations, which include transmission power, number of nodes, and array antenna size.

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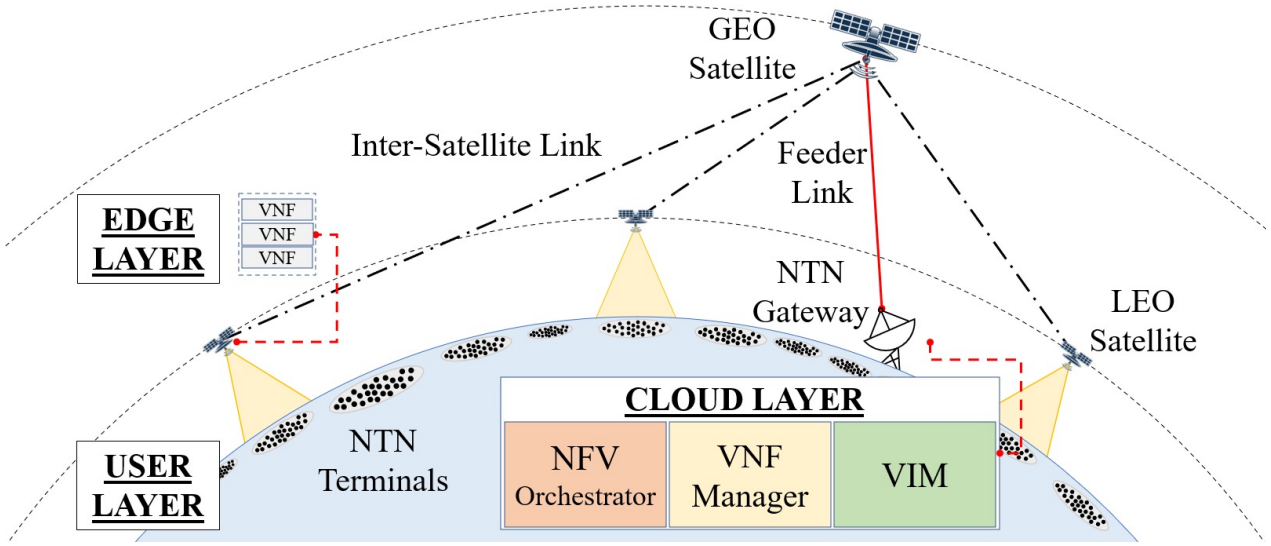
NTN architecture and novel orchestration strategies



Definition of a novel network architecture able to collect service requests and related quality of service constraints.

Specifically, a new communication protocol has been conceived to enable the interaction among terrestrial and space network.

Design of a system model able to catch the network configuration and quantify the deployment delay experienced by the end-users;

Formulation of an optimization problem willing to dynamically allocate VNFs among satellites over a looking-ahead time horizon, based on service requests, computational capabilities of involved satellites, visibility matrices, and expected deployment delay bounds;

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WP5 - Evaluation and validation

This WP organizes and develops a test plan to assess the conceived solutions through the definition of dedicated metrics, PoCs, and a simulation platform.

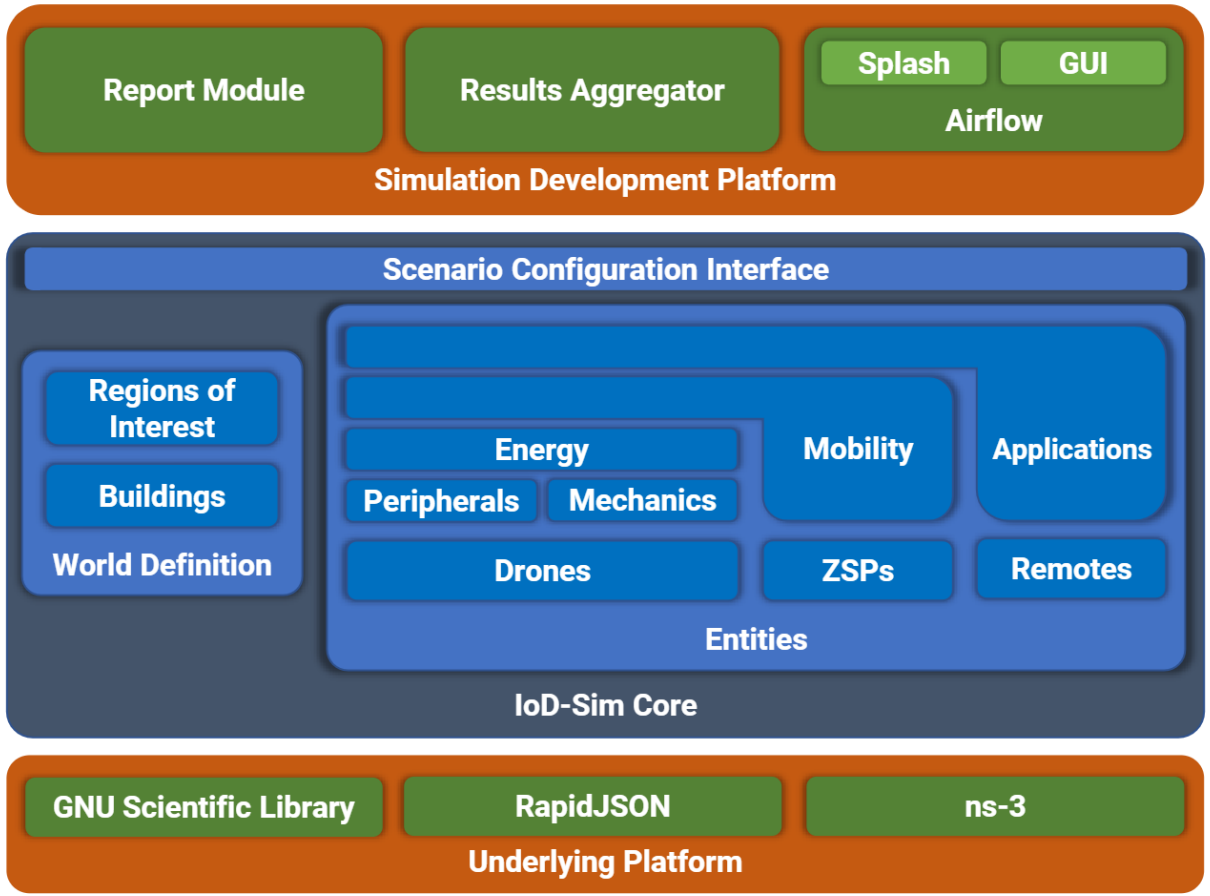
Tasks:

T5.1: Test plan and guidelines

T5.2: Simulator development and tests

T5.3: PoCs development and tests

Internet of Drones Simulator



IoD-sim is a comprehensive open-source simulation platform able to create realistic simulations by extending the available features of ns-3 to address the relevant aspects of the IoD.

The overall architecture of the proposal is designed as a 3-layer stack:

- the *Underlying Platform*, which includes a set of technologies and libraries able to perform high-precision numerical computation
- the *Core*, which embeds a set of unique IoD-related features
- the *Simulation Development Platform* that allows high-level mission design and analysis of simulation results

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Internet of Drones Simulator

The presented architecture covers key areas, such as mission design, trajectory planning, and application configuration.

Manifold features are provided for hardware configuration, energy consumption models, on-board peripherals, and integration with other network entities.

A high-level mission design tool grants a welcoming user experience via a convenient interface.

Satellite communication support is on going!

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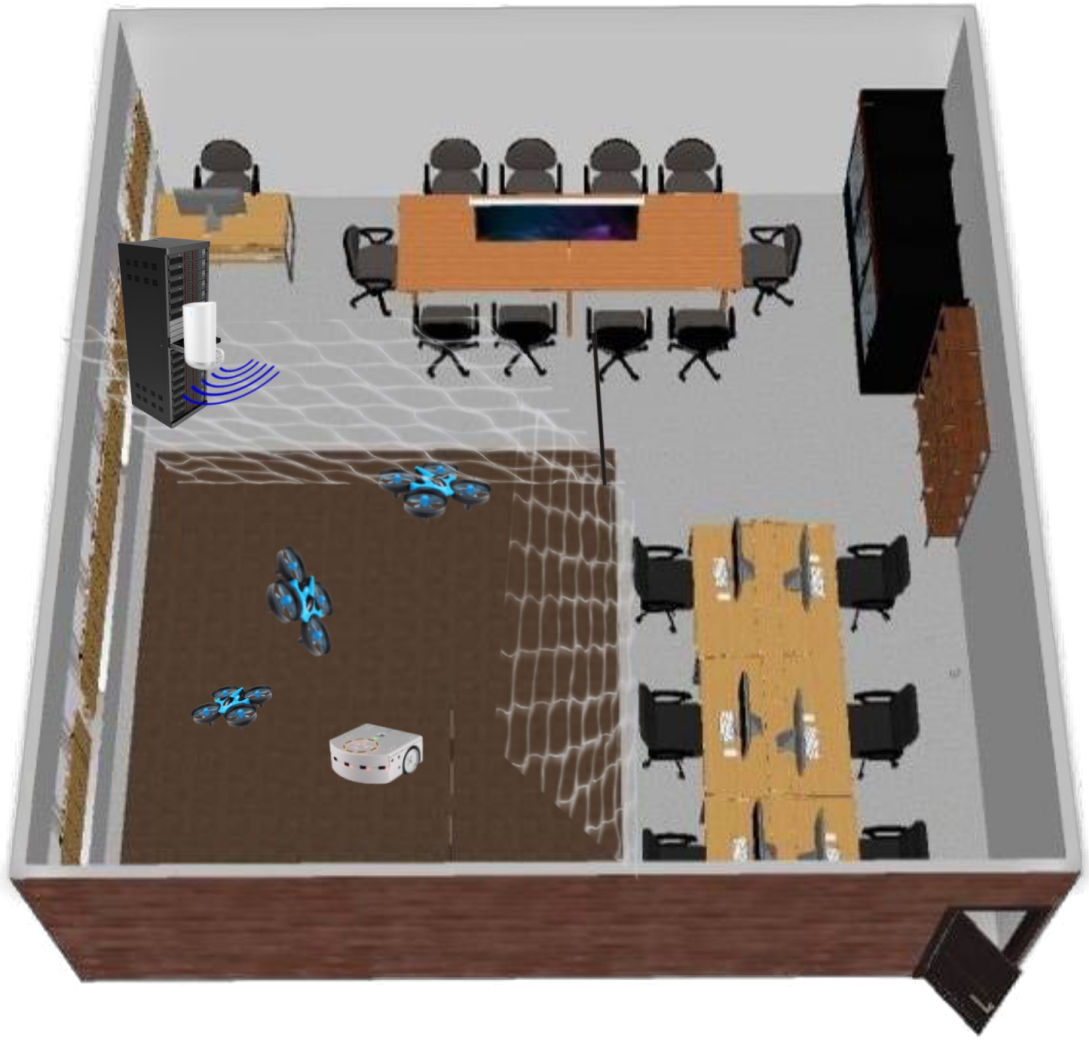
Spoke 2 – PBA: laboratory

- hybrid environment, tools remotely accessible via VPN
- end-to-end Proof-of-concepts
- enhanced experimental facilities in in the South of Italy
- mid- and long-term vision for other future funding sources



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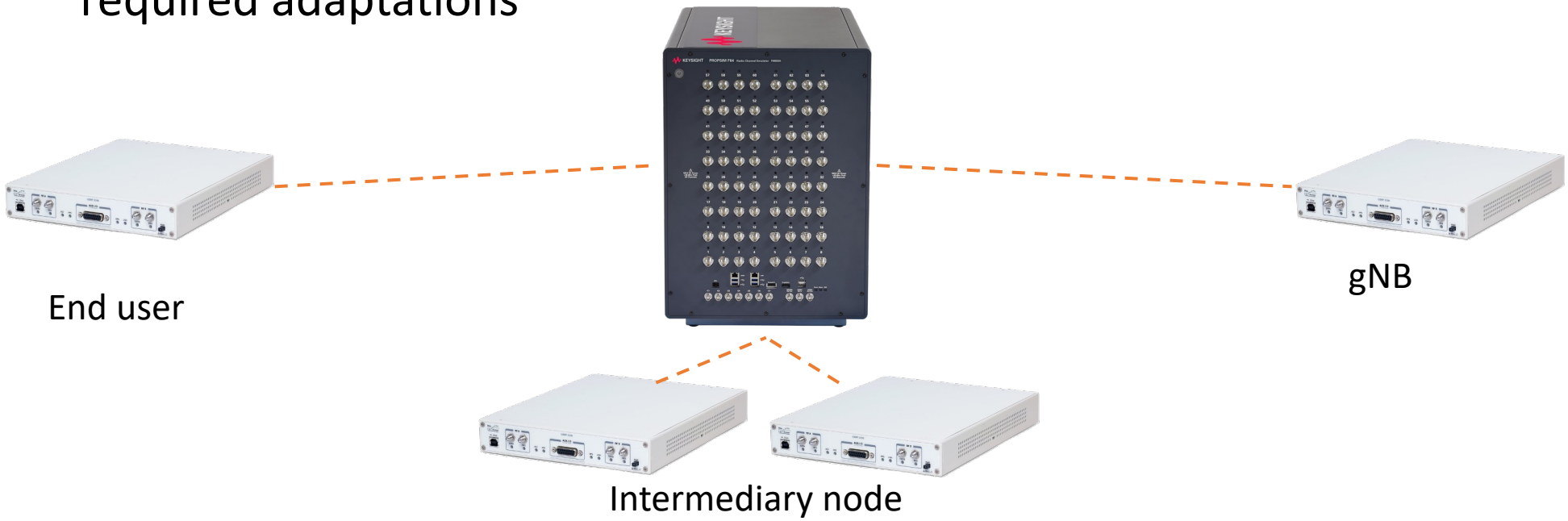
Testbed setup

- Keysight + NI: varius ETTUS USRP attached to proposim
  - It may potentially implement all the other configuraitons, but upgrades to emuation tools (i.e., OpenAir Interface) are needed to implement the required adaptations



WP6 - Dissemination and impact

This WP ensures proper dissemination of the project outputs with the maximization of its impact.

Tasks:

T6.1: Communication, dissemination, and standardization

T6.2: Impact creation

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ITA NTN: Workshop on Integrated Terrestrial and Non Terrestrial Networks

European Wireless (EW) is a key venue for European and worldwide researchers to become acquainted with the latest trends in wireless communications and networking. The ITA NTN workshop will be hosted in this prestigious conference.

The topics include, but are not limited, to:

- 5G NR and 6G standardization;
- 3D multi-layered communication architectures and protocols;
- Edge, Fog, and Cloud computing architectures;
- Smart Radio Resource Management Techniques;
- Cloud-Radio Access Network (CRAN) paradigms;
- Design, modelling, experimental characterization, and performance evaluation of novel antennas;
- Multiple-Input Multiple-Output (MIMO) schemes aided by Distributed Antenna Systems (DAS);
- Millimeter-wave, Terahertz-band, optical wireless channel models and modulation schemes;
- Link budget analysis for optical and RF technologies;
- Electronic/photonic devices and systems;
- Interference issues;
- Optimization strategies for wireless communications;
- Artificial intelligence for wireless communications;
- Network Management & Control Issues;
- SDN and NFV solutions;
- Energy-efficient algorithms for the T/NT networks;
- QoS/QoE-aware orchestration strategies of communication and computational resources;
- Security, privacy, and trust management;
- Implementation of simulation open source tools for the 5G NTN protocol stack;
- Quantum Computing and Communications for NTN;
- Experimental testbeds and measurements.

What will RESTART, Spoke 2 and ITA NTN do ?

disseminate project results through the publication of periodic whitepapers/high-standard journals

ensure **training** of qualified researchers

offer concrete benefit to the **industrial ecosystem** by sharing obtained results

increase the number of **industrial research projects and spin-offs**

attract of even **greater investments** in the ICT sector

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Questions ?

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