Enabling technologies for 6G-NTN

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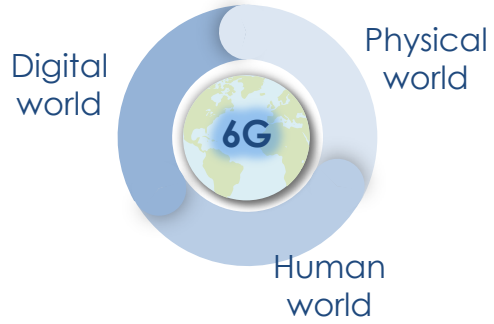
The role of Non-Terrestrial Networks in 6G

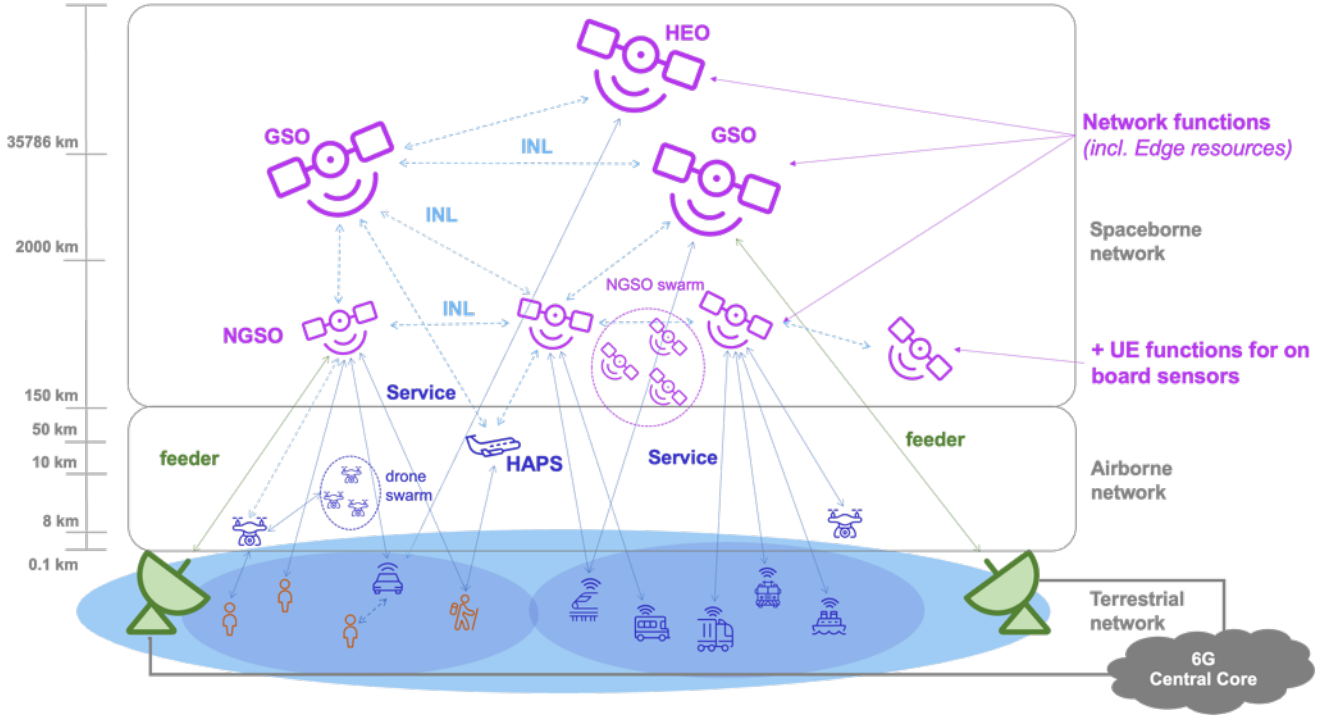
- 6G systems are expected to achieve more than "just" extremely fast connectivity
  - digital twinning between domains: convergence of the physical, human, and digital worlds
  - connected intelligence
  - immersive communications: high-resolution visual/spatial, tactile/haptic, and other sensory data



- Non-Terrestrial Networks will be pivotal to provide a ubiquitous, continuous, flexible, and resilient infrastructure for
  - **Direct connectivity** to smart phones outdoor and in light indoor/in-vehicle (emergency communications)
  - **Connectivity mobile platforms** (trains/planes/ships/drones/HAPs)
  - **Broadcast/multicast**
  - **Low latency communications to support vertical markets** (railway, automotive, aeronautical, etc)
  - **Network based positioning**
  - **IoT applications** (global NB-IoT/mMTC coverage, remote/control monitoring of critical infrastructures, smart good tracking)

The NTN path from 5G to 6G

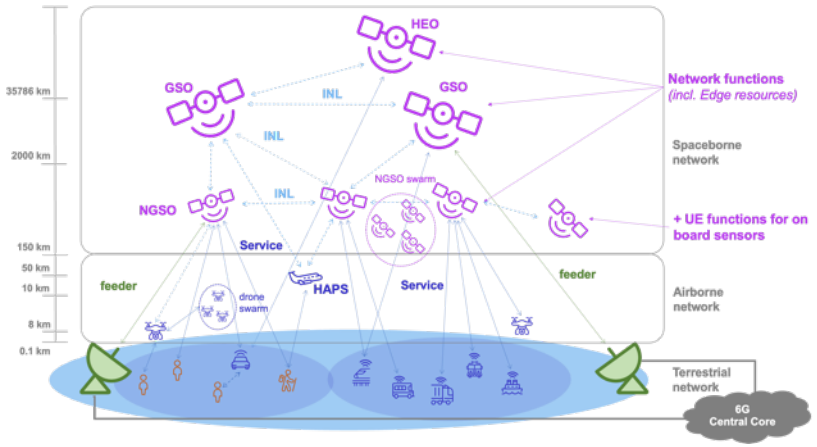
- The current NTN standardization framework provides a solid ground for NTN integration into 5G
- 5G advanced will introduce enhancements with additional capabilities and increased performances
- **6G will target a fully unified T-NT infrastructure based on multi-dimensional multilayer architecture**



6G NTN: KPIs and Innovations

KPIs

- Latency, 5 times improvement:
  < 10 ms
- Positioning, 10 times improvement:
  <10 cm accuracy
- Data rates, 5 times improvement:
  Ultra-small terminals: >1.6 Gbps / 400 MHz
  Handheld: up to 20 Mbps / 5 MHz
- Light Indoor/in-vehicle connectivity
  low data rates



Enabling Technologies

Architecture and system design

Multilayered constellation from GEO to drones, Innovative LEO and vLEO orbits, optical inter and intra node-links design, cell-free MU-MIMO, traffic-driven coverage

Networking, edge computing and communications

Softwarization, virtualization, and orchestration of network resources, functional split, advanced IP, routing in the sky, resource management, integrated edge communication and computing

Flexible and integrated waveforms

Low PAPR and low OOBE solutions, Non-orthogonal techniques to increase the connection density, novel RA procedures to allow multiple transmissions per beam, multipoint transmission from the sky, distributed beamforming

Dynamic Spectrum Access and New spectrum

Coordinated and uncoordinated sharing among different access technologies, inter and intra layer, higher frequency bands, Q/V and above

Positioning

Network based positioning

AI/ML

Network and system orchestration, Radio Resource Management, Network traffic forecasting, Physical layer management, Channel estimation,

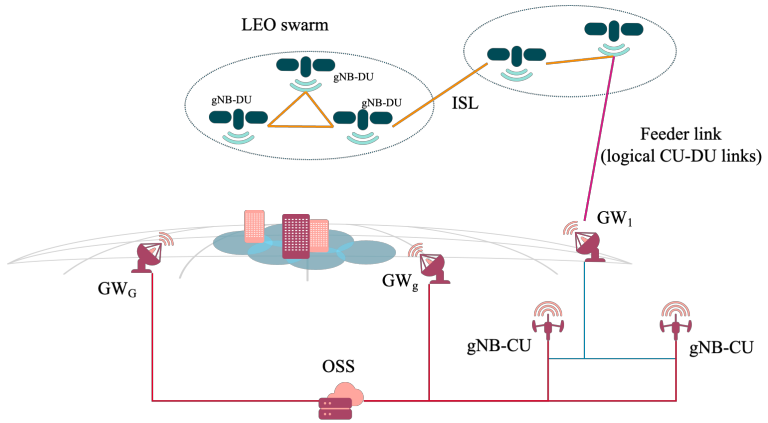
Antennas and components

Active antennas for link budget and flexible coverage, Refracting RIS for indoor coverage, regenerative payload, high-parallel energy efficient HW, Optical devices

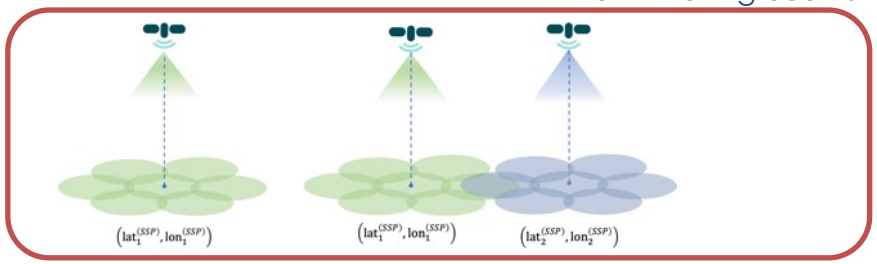
Cell-free MU-MIMO and DSA

Cell-Free MU-MIMO: initial results

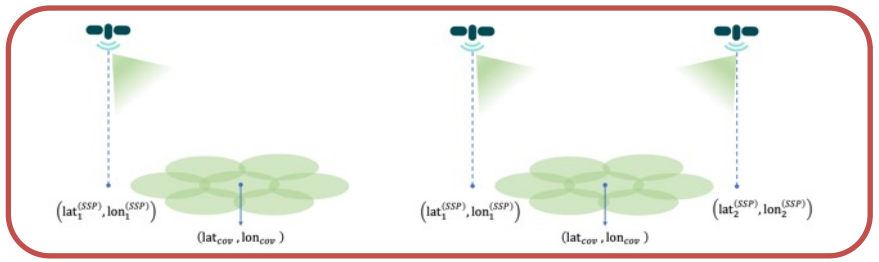
- Multipoint transmission from multiple LEO nodes with beamforming
  - Centralised computation
    - On-ground (gNB-CU) scheduling and beamfomring computation
    - ISLs inter-swarm
  - Distributed computation
    - On-board (gNB-DU) scheduling and beamforming computation
    - Master LEO node managing the satellite formation
  - Earth moving or Earth fixed (beam steering) beams



Earth moving beams



Earth fixed beams



Sources:

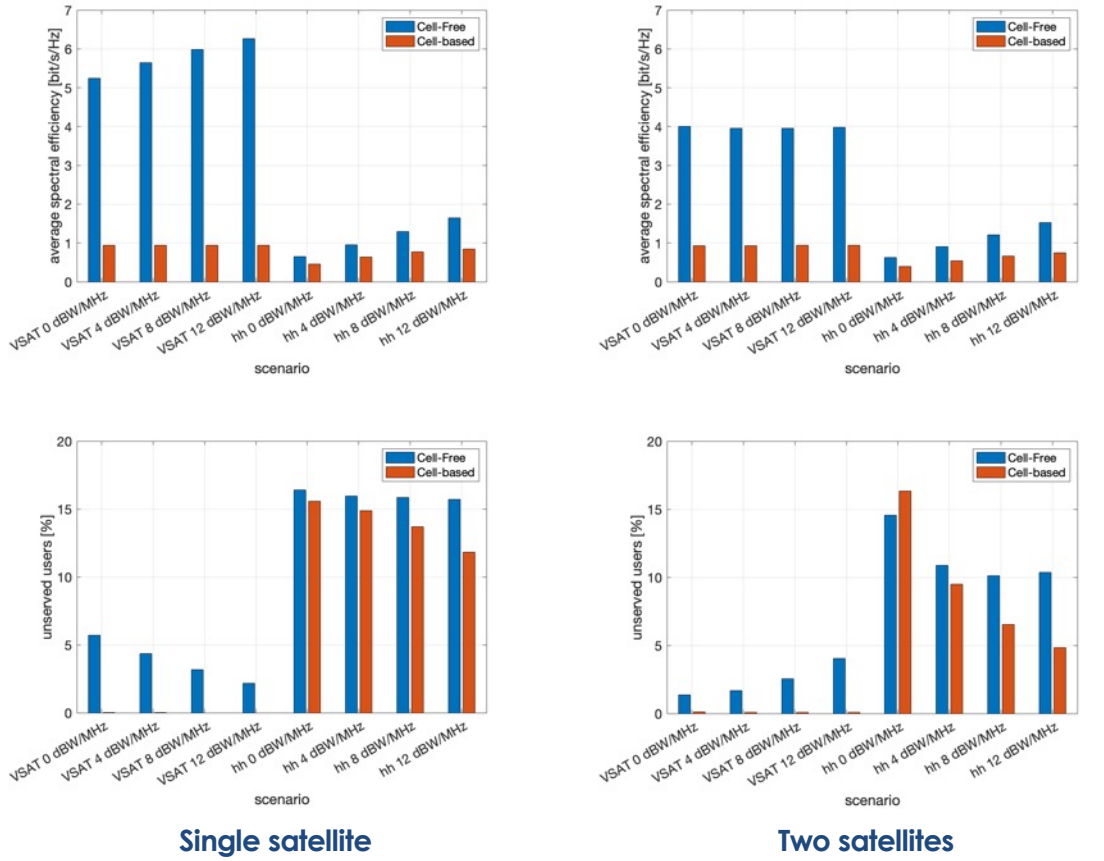
A. Guidotti et al., "Location-assisted precoding in 5G LEO systems: architectures and performances," accepted to EuCNC 2022

EC SPACE-29-TEC-2020 Project DYNASAT, D3.2, "Bandwidth Efficient Techniques design," Dec. 2021

Cell-Free MU-MIMO: initial results

- Spectral efficiency
  - VSAT: 3-5 bit/s/Hz gain with CF
  - handheld: up to 1 bit/s/Hz

- Outage
  - The impact of harsh propagation conditions is detrimental due to the clutter loss and the impact of the moving satellite(s)
  - A second satellite leads to path diversity and a better performance
  - In clear-sky or LOS conditions[1], no loss is observed with a single satellite

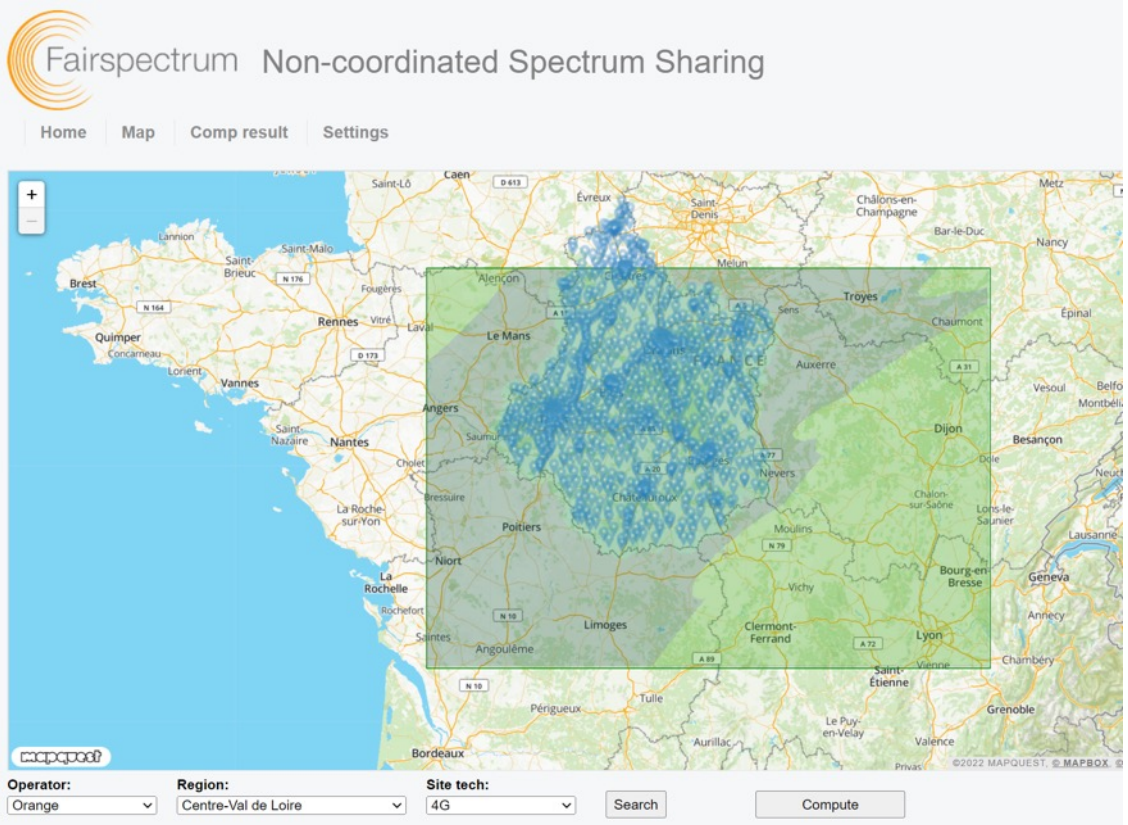


Earth moving beams, NLOS dense urban

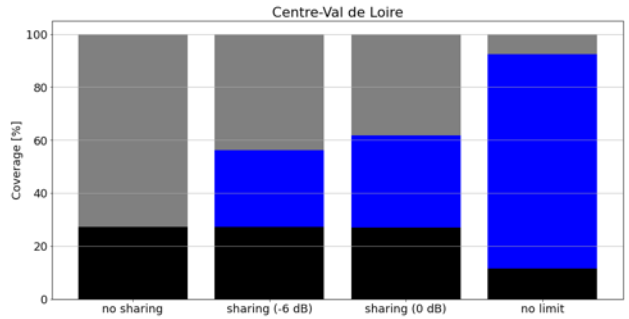
Source: EC SPACE-29-TEC-2020 Project DYNASAT, D3.5, "Bandwidth Efficient Techniques evaluation," May 2022

[1]3GPP LOS channel: scintillation, gaseous absorption

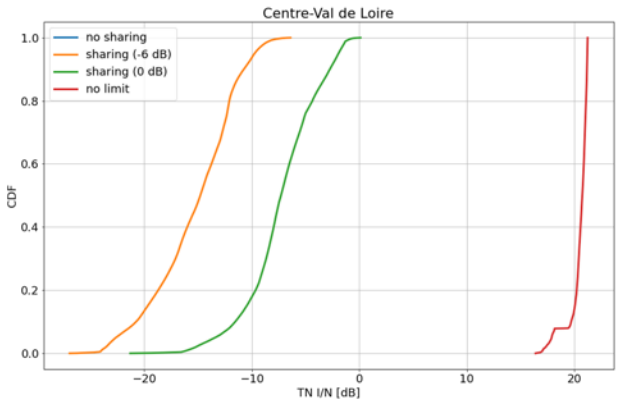
Dynamic Spectrum Access: NTN and TN spectrum sharing
Non-overlapping coverage areas



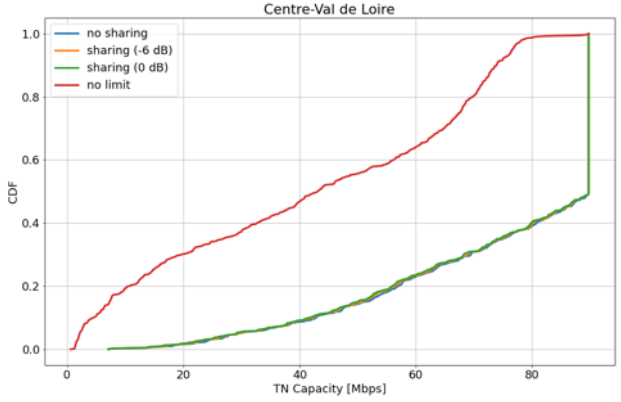
Coverage



Interference



Capacity

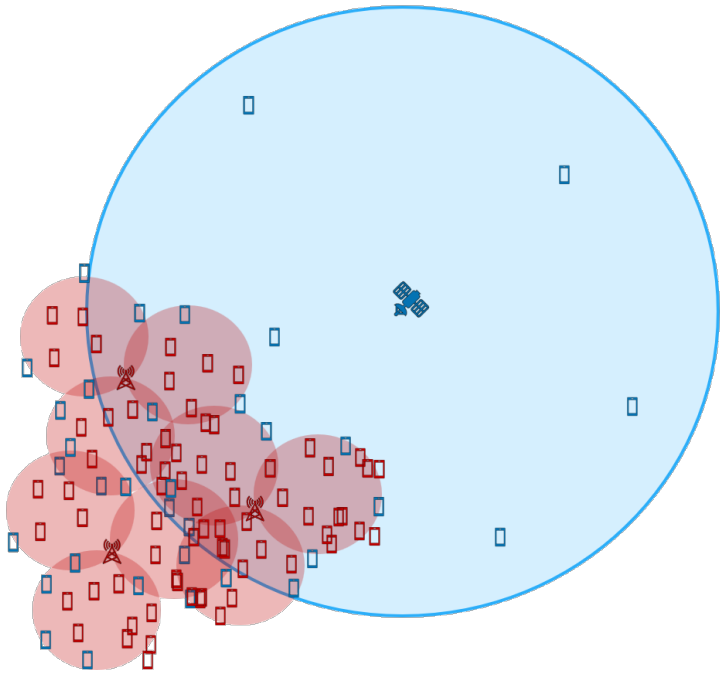


- Real French mobile sites
- Realistic LEO satellite constellation (184 beams)
- Optimize beams so that I/N is below a threshold

Live demonstration at EUCNC'22 in Grenoble on Jun 7-10 by FairSpectrum

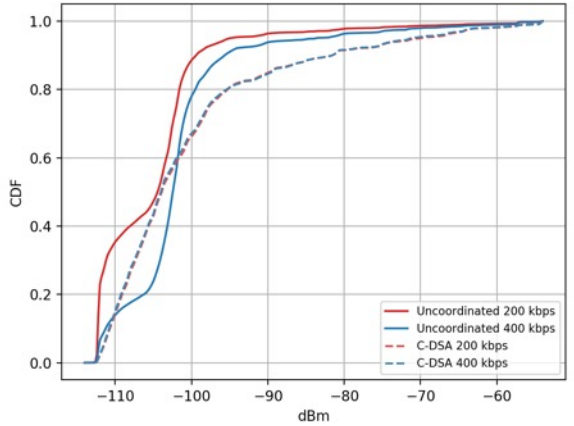
Source: FairSpectrum, EC SPACE-29-TEC-2020 Project DYNASAT, D4.5, »DSA System performance evaluation" May 2022

Dynamic Spectrum Access: NTN and TN spectrum sharing
Overlapping coverage areas



Sharing based on with 3GPP frame structure

Interference



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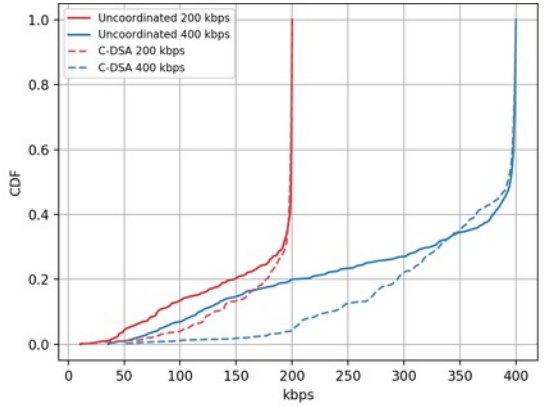
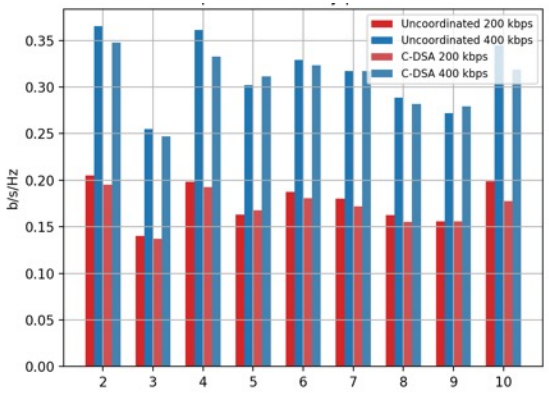


Spectral efficiency



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Conclusions

- The integration of a NTN component into 5G is a reality since Rel. 17
- 5G advanced will bring additional capabilities to the integrated NTN component
- 6G aims at a fully unified T-NT infrastrucure thus requiring revolutionary NTN techniques and building blocks
  - Multi-dimensional multi-layer NT architecture
  - Innovative constellation design (integrated and multi-layered)
  - Unified and flexible waveform considering the NTN environment conditions already at the design phase
  - Integrated edge communication and computing in the sky
  - Advanced IP and routing in the sky
  - NTN supported network based positioning
  - Coexistence and Dynamic Spectrum Allocation
  - Higher frequencies Q/V and above
  - Security and Quantum
  - Regenerative and flexible payloads for full virtualization and orchestration of network resources
  - AI/ML down to Physical Layer and up in the sky (model exchanges, data, etc)
  - Antennas and new components (Energy efficient and high parallel HW, Optical, etc)

Current initiatives…

- **NetworldEurope**
  - Strategic Research and Innovation Agenda to be published August 2022
- **H2020 DYNASAT** (Dynamic spectrum sharing and bandwidth-efficient techniques for high-throughput MIMO Satellite systems)
  - research, develop, and demonstrate techniques for **bandwidth efficient transmission** and **efficient spectrum usage** for a **high-throughput 5G/6G satellite access** network infrastructure, based on **advanced NGSO-mega-constellations**

http://dynasat.eu/

https://www.linkedin.com/company/dynasat/

https://twitter.com/dynasat_project

- **ESA EAGER** (Technologies and techniques for satcom beyond 5G networks)
  - research and identification of **innovative technologies and techniques** targeting **highly efficient and deeply integrated** satellite networks in **5G-Advanced and 6G** communication systems

https://www.linkedin.com/company/eager-project/

https://twitter.com/eagersatcom

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