NON-TERRESTRIAL NETWORK (NTN) IN 6G

6G-NTN technical manager
Nicolas.chuberre@thalesaleniaspace.com

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Facts and figures

Addressing call: ["SNS-2022-STREAM-B-01-03: Communication Infrastructure Technologies and Devices"]

Overall goal: Develop an NTN component fully integrated with the 6G infrastructure able to provide enhanced Mobile BroadBand (eMBB) and Ultra Reliable Low Latency (URLL) services to vertical industries and consumers terminals in outdoor and light indoor conditions.

Targeted TRL: 2 - 4

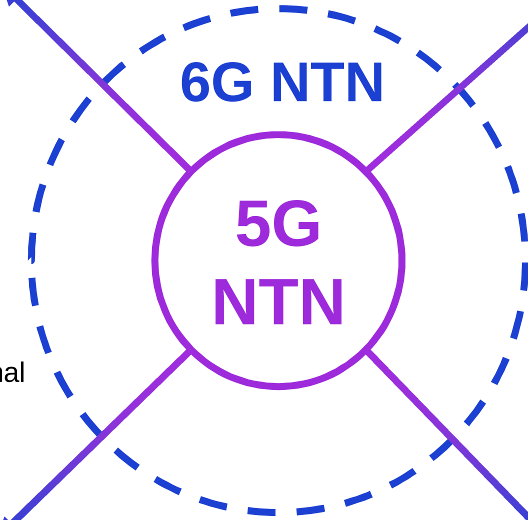
Duration: 36 months

Project kick-off: 1 January 2023

Alessandro Vanelli-Coralli, Project Coordinator (UniBo), **Nicolas Chuberre,** Technical Manager (TAS-F), **Sandro Scalise,** Innovation Manager (DLR), **Monique Calisti**, Communication & Dissemination Manager (MAR)

6G-NTN project ambitions is to become the flagship R&I project for **developing the 6G NTN component** and **driving its standardization** phase in 3GPP as part of Rel-20+

6G-NTN Ambitions



Improve user experience

- Increasing data rate wrt 5G
- Increased reliability
- Coverage extension to light indoor/In car areas
- Increased Location accuracy/reliability
- Reduced Latency

Improve network capabilities

- Resiliency
- Spectrum sharing NTN/TN and across orbit
- Environment footprint (energy saving)
- Reinforced security
- Capacity/connection density
- GNSS free operation
- Fast network deployment
- Sensing capability

Improve support usage scenarios

- Terminal design adapted to installation/operational constraints (vehicles/Drones)
- Automotive, public safety, transport (aeronautic, railway, road and maritime), utilities, media & entertainent, defence,

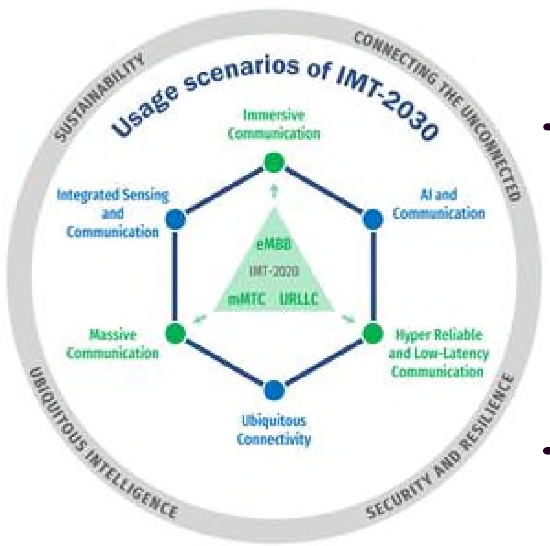
Interoperability with 5G

- Multi connectivity at RAN level
- Towards seamless mobility in connected mode

6G should leverage and integrate 5G

Overview of Use Cases

Use Cases enabled/enhaced by 6G-NTN



- **UC5:** Consumer Handheld Connectivity and Positioning in Remote Areas,
- **UC6:** Continuous Bi-directional Data Streams in High Mobility,
- **UC7:** Direct Communication over Satellites.

- **UC1:** Maritime Coverage for search and rescue coast guard intervention,
- **UC3:** Urban air mobility,
- **UC2:** Autonomous power line inspection using drones,
- **UC4:** Adaptation to PPDR or Temporary Events,

System Requirements (Possible 3GPP SA1 Inputs)

6GNTN

Improved user experience

- Provision of emergency services (at least SMS) via satellite in light indoor/in car conditions
- Provision of trusted and accurate determination of UE location via satellite networks
- Provision of Enhanced connectivity to consumer Handheld (e.g. for video, in-car/light indoor)
- Provision of broadband connectivity to (semi) autonomous cars and drones (including Urban air mobility) and true seamless global service continuity (zero packet loss/zero interruption/no service rate degradation) in high mobility thanks to NTN/TN combination
- Support of additional types of terminals for satellite connectivity whether vehicle or drone mounted

Improved network capabilities

- Fast set-up of an autonomous network over a specific region via satellite (with ISL) and/or HAPS with no or intermittent connectivity to core networks (e.g. for crisis response)
- Energy efficient service delivery in multi access technology network (i.e. NTN/TN)
- Flexible spectrum usage in multi access technology network (i.e. NTN/TN)
- Hot resiliency with respect to Temporary network node failure in multi-layer network (i.e. 3D multi orbit and meshed network = NGSO, GSO, HAPS and/or drone based network node)
- Enable optimized traffic routing between bidirectional and unidirectional access links

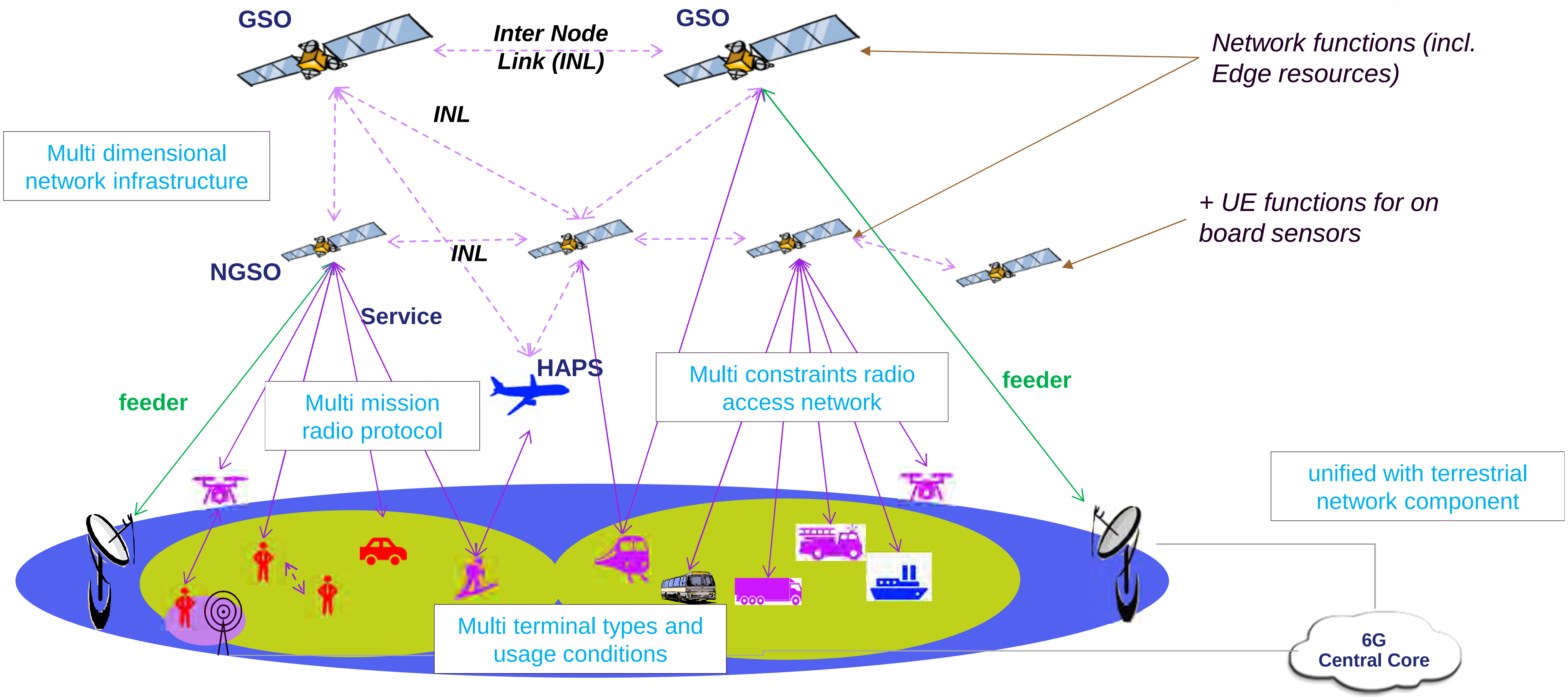
Performance Requirements

Target service performances	NTN in 5G (As per 3GPP &/or ITU-R IMT2020 satellite requirements)	NTN in 6G
Peak data rate (DL/UL) wrt Handheld & low cost IoT devices	1/0.1 Mbps (Outdoor only) @ up to 3 km/h	Outdoor conditions: Tens of Mbps @ up to 250 km/h Light indoor/in car conditions: At least Short Message Service capability
Peak data rate (DL/UL) wrt Vehicle or drone (flying and surface) mounted devices	[50/25] Mbps @ up to 250 km/h (with 60 cm aperture)	Hundreds of Mbps (Outdoor only) @ up to 250 km/h (with <20 cm equivalent aperture)
Peak data rate (DL/UL) wrt Large Aeronautic, maritime platforms mounted devices	[50/25] Mbps @ up to 1000 km/h	Thousands of Mbps (Outdoor only) @ up to 1200 km/h (with <60 cm equivalent aperture)
Location service (target accuracy and acquisition time) in outdoor conditions only	respectively 1 meter and < 100 seconds (reliability through Network verification)	respectively 1 meter and < few seconds (95% reliability through Network based positioning method)
Coverage	Outdoor only	Light indoor/In car
Reliability	up to 99.9% ($1-10^{-3}$)	up to 99.999% ($1-10^{-5}$)
Over the air Latency for eMBB-s and uRLLC-s	Control plane: 40 ms User plane: 10 ms	Control plane (propagation delay excluded): same as IMT-2030 terrestrial Radio Interface User plane (propagation delay excluded): same as IMT-2030 terrestrial Radio Interface
Connection density	Up to 500 per km2	>1000 per km2

NTN Architecture: Design Drivers

- 3D multi-layered architecture with inter-node links (both RF and optical)
  - Innovative LEO constellation design
- Software defined payloads embarking required RAN and CN functionalities based on component virtualization, and including edge computing resources
- Access protocol enhancements to optimize mobility (zero-time interruption under high hand-over rate) of terminals combined with simultaneous multi connectivity between the various components (terrestrial and non-terrestrial)
- Interference mitigation through AI driven RRM
- Dynamic orchestration of VNF, smart routing and edge-based service provisioning in a dynamic network topology
- Cyber and physical layer security
  - based on a thorough assessment of the vulnerabilities and threats introduced by the proposed 6G architecture for NTN
- Affordability and sustainability constraints
  - sustainability metrics and target values for carbon foot print and overall energy consumption

NTN Architecture: 3D Network Concept



NTN radio interface: design drivers (1/2)

Spectrum efficient and flexible waveform optimized for both terrestrial and non-terrestrial network components

Candidate radio interface features	Rationale
Multi carrier waveform enhancements	▪ OFDM evolution offering relaxed synchronization requirements. ▪ Supporting UE without GNSS capabilities (also referred as « GNSS free operation ». ▪ Mitigating specific satellite constraints: Reduce the Peak-to-Average Power Ratio (PAPR) on the downlink to maximize the spectral efficiency in case of reduced number of channels in a single on board amplifier.
Advanced modulation, coding and multiple access schemes	▪ Minimizing error rate performance under low SNR conditions. ▪ Enabling the support high link margin to mitigate challenging radio link conditions (e.g. to overcome building penetration loss).
Design flexible UL/DL framing structure	▪ Adapt the frame structure to satellite Orbit, frequency range etc… ▪ Reduce the overhead penalty since there are quasi no multi-paths in satellite propagation channel.

NTN radio interface: design drivers (2/2)

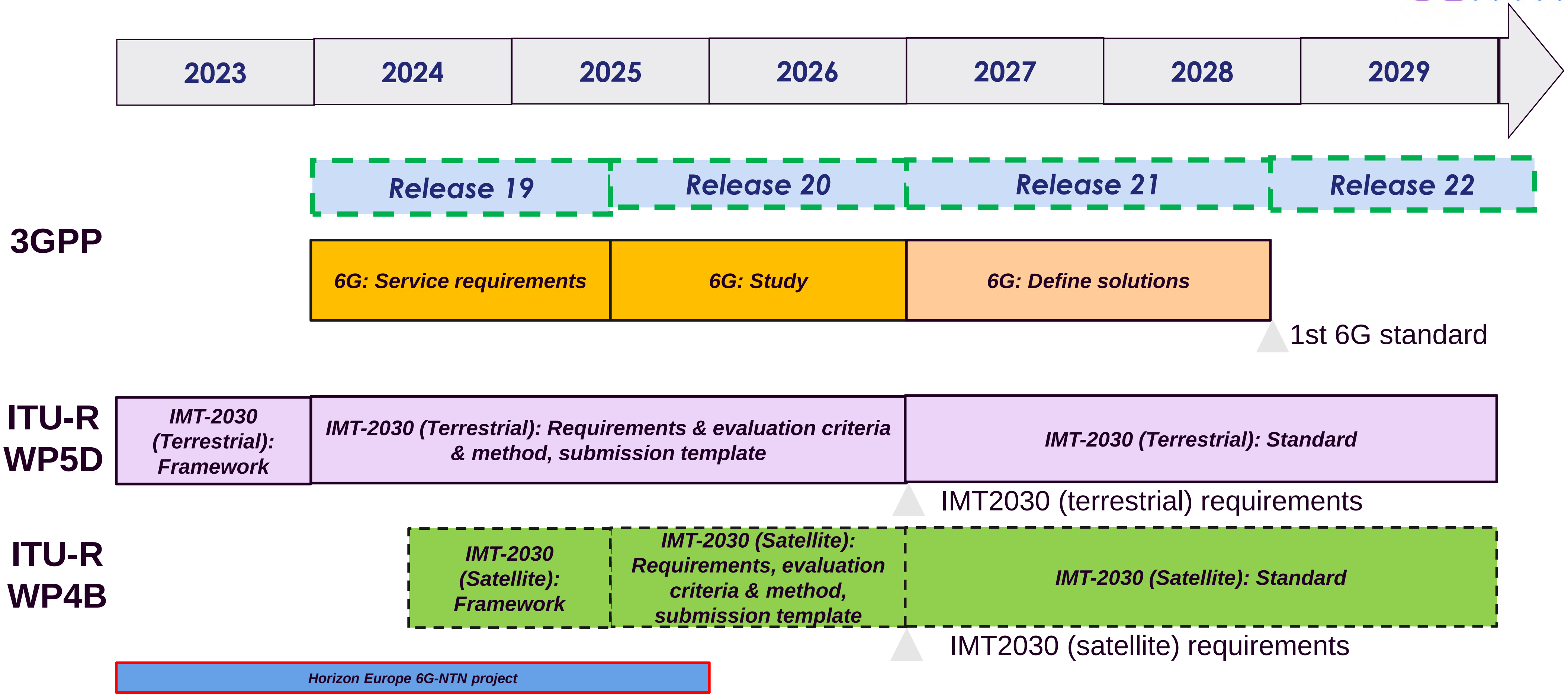
Candidate radio interface features	Rationale
Design appropriate robust reference signals for enhanced positioning	▪ Support reliable (i.e. trusted) network based solution for accurate and fast response Positioning, Navigation and Timing (PNT) service. ▪ Potential narrow-band synchronization signals could be also designed, where the PRS resources could be defined over multiple slots.
Joint communication and sensing	▪ Provide low to medium resolution sensing capabilities with sensing capability directly integrated/embedded into the design of the waveform.
Support of broadcast and multicast	▪ Leverage the large coverage area of satellites
Enablers for Artificial Intelligence driven radio resource control	▪ Increase the “goodput” of a radio link through dynamic optimisation of the radio interface configuration (e.g. Modulation, coding, power, signal occupancy, interleaving depth, HARQ) according to the radio link conditions
Spectrum sharing between TN and NTN	▪ Revise the methodology of coexistence study and RF/RRM specification, and potentially consider co-channel spectrum sharing between TN and NTN.
New spectrum	▪ Some additional MSS allocations may be granted at the WRC-2027 as per agenda items 1.12, 1.13 and 1.14. Moreover, some additional bands such as Q/V bands should be considered for broadband connectivity.
TDD support	▪ Unpaired spectrum may be allocated to NTN in selected bands, e.g. in order to support TDD operation in some frequency bands for NTN nodes at 800 km altitude and lower.

Spectrum Usage

Here under frequency bands that may be considered for respectively 5G and 6G non-terrestrial networks:

Services	NTN in 5G (Currently)	NTN in 6G
Narrow/Wideband connectivity to smartphones, vehicle/drone mounted & low cost IoT devices	FR1: MSS allocations in L & S bands (e.g. see Rel-17 work).	FR1: same as 5G NTN and additional Satellite service allocations in bands up to 7.125 GHz.
Broadband connectivity to vehicle/drone mounted devices and to large Aeronautic, maritime platforms	Above 10 GHz: FSS and MSS allocations in Ka band (e.g. see Rel-18 work).	Above 10 GHz: same as 5G NTN + Satellite service allocations in Ku and Q/V bands.

Standardisation Approach: 3GPP, ITU-R



Proposed way forward

POSSIBLE TOPICS FOR DISCUSSION BETWEEN 6G RELATED SNS-JU PROJECTS

- Use cases and families
- Radio interface & Architecture: necessary enablers/enhancements for the various targeted deployment scenarios
- Sustainability metrics and target values for energy consumption and carbon foot print ?

ANNEX

NTN Development/Deployment Wrt Reference Scenarios

Solutions	Narrow band connectivity to IoT devices		Narrow to wideband connectivity to handheld devices	Broadband connectivity to non-handheld devices	
Spectrum	< 7 GHz			Above 10 GHz	
Service	Up to hundreds of kbps		Up to few Mbps	Up to hundred Mbps	
3GPP radio interface	**4G NB-IoT/eMTC**		**5G New Radio**		
Example of applications	*Verticals (smart grids, water distribution, oil & gas), agriculture)*		*Consumers + Verticals (Automotive, public safety, utilities, agriculture ..)*	*Verticals: Telco (e.g. Backhaul), IPTV service providers, Satellite News Gathering, Transport (aeronautical, maritime, railway), public safety,*	
Space segment	**GSO**	**NGSO**	**NGSO**	**GSO**	**NGSO**
Timeline indication (NOTE 1)	**2023-2025**	**2024-2029**	**2026-2029**	**2026-2029**	**2026-2029**

NOTE 1: Sources: 3GPP RP-232732 (source: GSOA)

Some References

- « 3GPP Non-Terrestrial Network: A Global Standard for Satellite Communication Systems », Special Issue of the International Journal of Satellite Communications and Networking, Pages: 217-301, Edited by Mohamed El Jaafari and Nicolas Chuberre, published by Wiley, May/June 2023,
  - https://onlinelibrary.wiley.com/toc/15420981/2023/41/3
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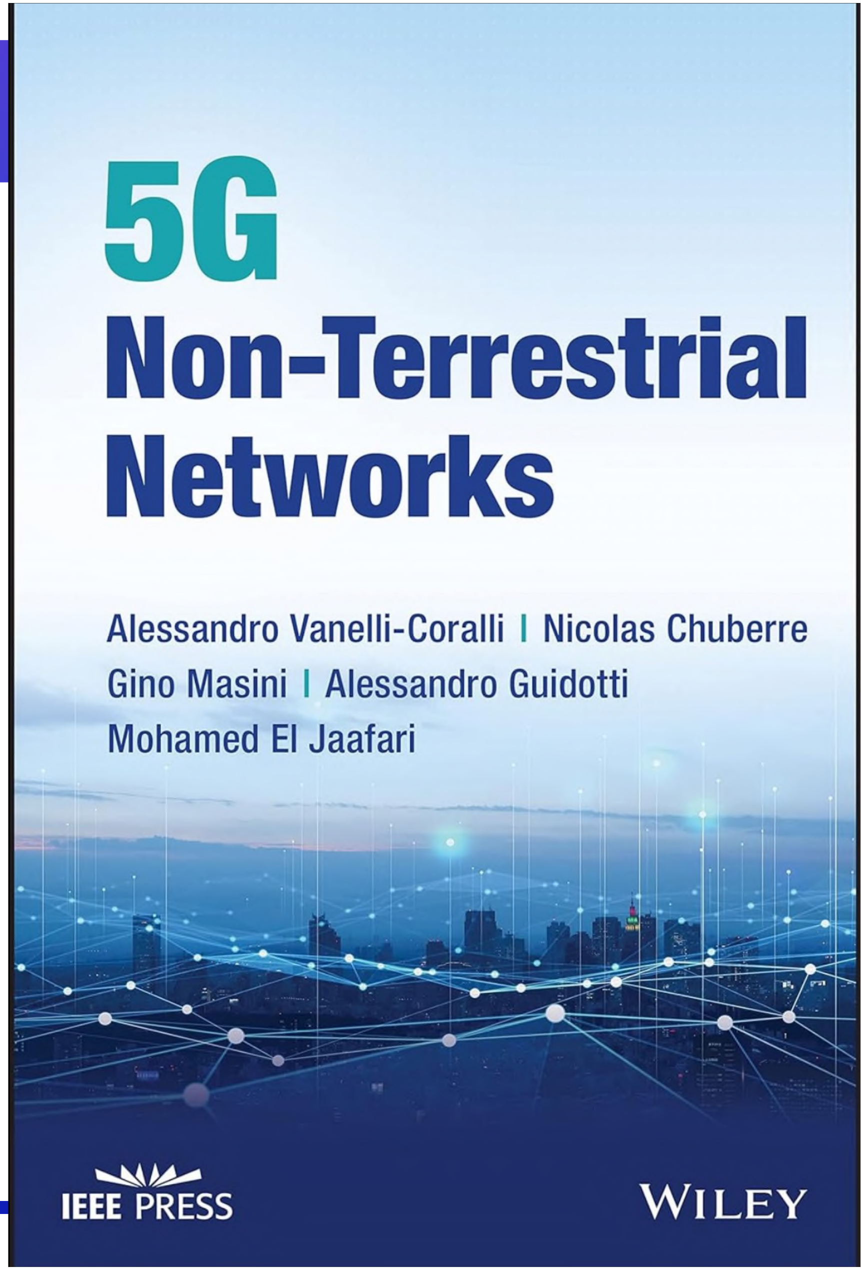
  - https://www.amazon.co.uk/5G-Non-Terrestrial-Networks-Vanelli-Coralli/dp/1119891159

Horizon Europe R&D « 6G-NTN » project: https://www.6g-ntn.eu



The Consortium

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THANKS