



ALMA MATER STUDIORUM  
UNIVERSITÀ DI BOLOGNA

# Evolution of Non-Terrestrial Networks towards 6G Systems

**Towards 6G - Drivers and State of Play**

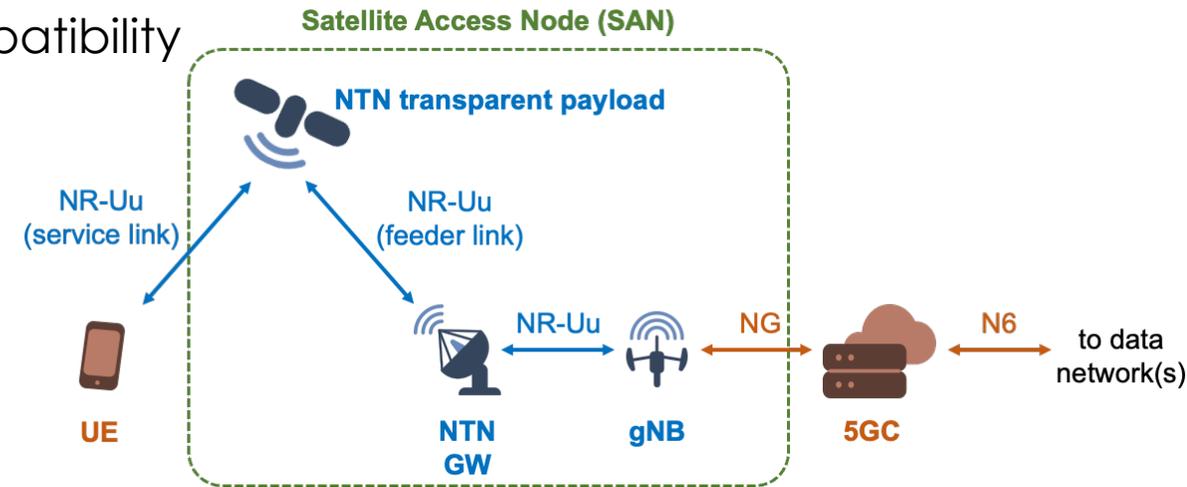
*11th FOKUS FUSECO Forum  
Berlin, September 15, 2023*

Dr. Alessandro Guidotti, CNIT



# 3GPP NTN in Rel. 17

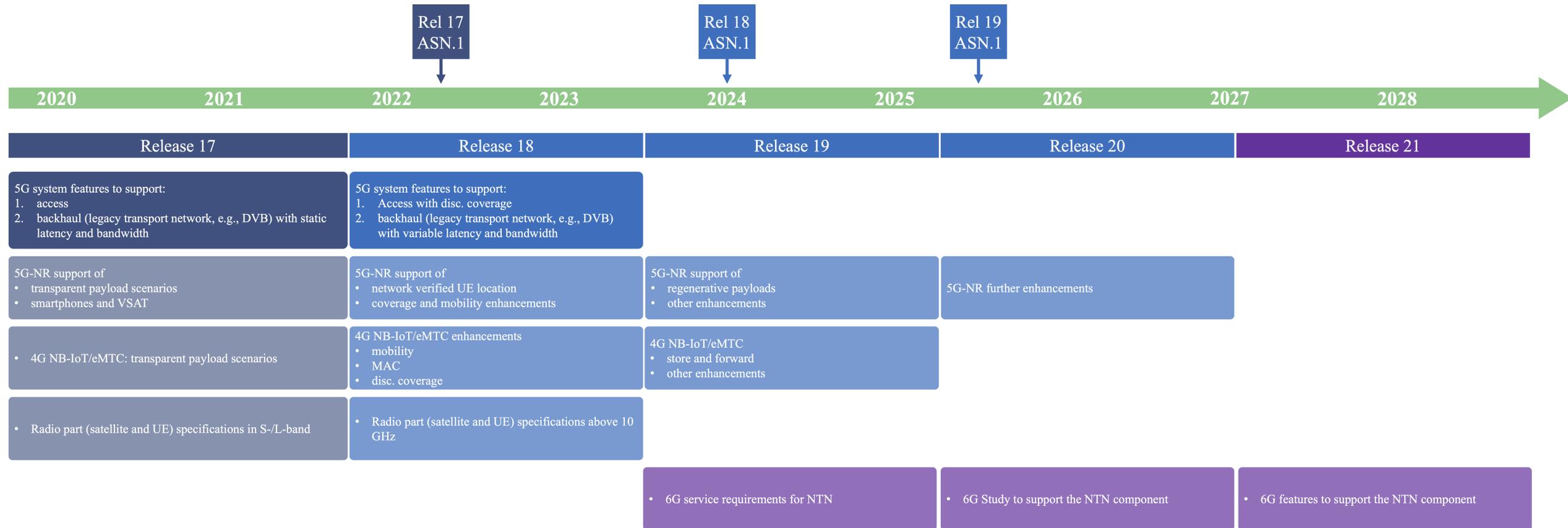
- NTN-based GEO/LEO with implicit HAPS/ATG compatibility
- Main characteristics
  - **transparent payload architecture**
  - coverage type
    - **Earth-fixed**
    - **Quasi-Earth-fixed**
    - **Earth-moving**
  - **FR1**: S-band and L-band
  - **handheld** terminals **with GNSS** capabilities
  - **FDD**
  - **Earth-fixed tracking**
- **Massive normative work to adapt** the NR system to the **NTN characteristics**



RAN1: Physical layer	RAN3: Access network architecture	SA2: System level
<ul style="list-style-type: none"> <li>• Timing relationship</li> <li>• UL time and frequency synchronization</li> <li>• Enhancements on HARQ</li> <li>• Polarization signaling for VSAT/ESIM</li> </ul>	<ul style="list-style-type: none"> <li>• Network Identity handling</li> <li>• Registration Update and Paging Handling</li> <li>• Cell Relation Handling</li> <li>• Feeder Link Switch-Over (NGSO)</li> <li>• Aspects Related to Country-Specific Routing</li> </ul>	<ul style="list-style-type: none"> <li>• Mobility management with huge cell size</li> <li>• UE location and support of regulated service</li> <li>• QoS class for GEO satellite links</li> <li>• Impact of satellite backhauling</li> </ul>
RAN2: Access layer	RAN4: RF & RRM performance	CT1: Network protocols
<ul style="list-style-type: none"> <li>• User Plane: RACH aspects, Other MAC aspects (e.g. HARQ), UP: RLC, PDCP</li> <li>• System information broadcast</li> <li>• Control Plane: Tracking Area Management, Idle/connected mode mobility, UE Location Service</li> </ul>	<ul style="list-style-type: none"> <li>• New bands               <ul style="list-style-type: none"> <li>• TN/NTN coexistence</li> <li>• Satellite Access Node, UE</li> </ul> </li> <li>• RRM: e.g. timing compensation (idle, connected mode), GNSS accuracy</li> </ul>	<ul style="list-style-type: none"> <li>• PLMN (re)selection</li> <li>• NAS timers</li> </ul>

Source: Mohamed El Jaafari, "3GPP NTN standardization: status and prospect," ASMS/SPSC conference, September 2022.

# 3GPP NTN beyond Rel. 17



Source: A. Guidotti et al., "Role and Evolution of Non-Terrestrial Networks towards 6G systems," submitted to IEEE Access, 2023



# 3GPP NTN Rel. 18-19

- **NR radio protocols** enhancements
  - **support FR2** and mobile/nomadic **VSAT**
    - transparent payloads
    - co-existence analysis on-going (adjacent channel)
  - **network verification of the GNSS** coordinates determined by the UE
  - optimise **mobility procedures** in idle/connected modes
- **NB-IoT/eMTC radio protocols** enhancements
  - optimise **mobility procedures**
  - improve the support of small constellations providing **discontinuous service** over a given area

2022	2023	2024	2025
Release 18		Release 19	
5G system features to support: <ol style="list-style-type: none"> <li>1. Access with disc. coverage</li> <li>2. backhaul (legacy transport network, e.g., DVB) with variable latency and bandwidth</li> </ol>			
5G-NR support of <ul style="list-style-type: none"> <li>• network verified UE location</li> <li>• coverage and mobility enhancements</li> </ul>		5G-NR support of <ul style="list-style-type: none"> <li>• regenerative payloads</li> <li>• other enhancements</li> </ul>	
4G NB-IoT/eMTC enhancements <ul style="list-style-type: none"> <li>• mobility</li> <li>• MAC</li> <li>• disc. coverage</li> </ul>		4G NB-IoT/eMTC <ul style="list-style-type: none"> <li>• store and forward</li> <li>• other enhancements</li> </ul>	
<ul style="list-style-type: none"> <li>• Radio part (satellite and UE) specifications above 10 GHz</li> </ul>			

- **NR-NTN**
  - **coverage** enhancements (DL and possibly UL)
  - NTN/TN **mobility** enhancement in connected mode (e.g., CHO)
  - support of HD mode **RedCAP** UE (Reduce Capabilities) in FR1
  - support of **regenerative** payloads (i.e., with ISL)
  - support of UE with **GNSS independent** operation for UL time and frequency synchronization in NTN based access (idle/connected modes)
- **IoT-NTN**
  - **regenerative** payload = Store and Forward (i.e., eNB + ePC network elements)

n512, n511, n510

n512  
n510 n511

Region 1, Region 3, and Region 2 countries except US  
US market and countries with the same assignments

n258  
n261  
n257

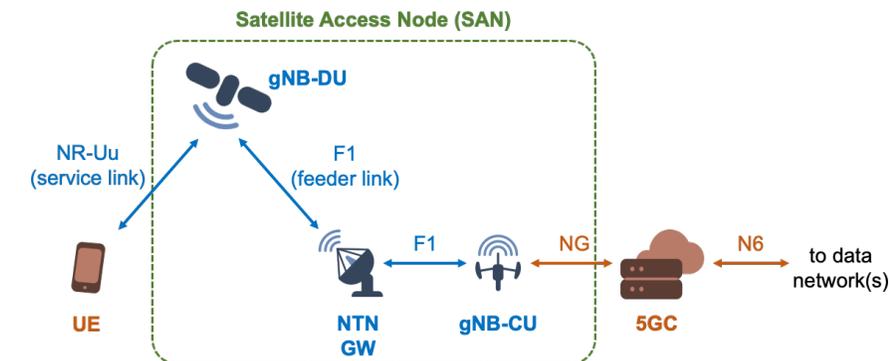
3GPP TDD bands for TN



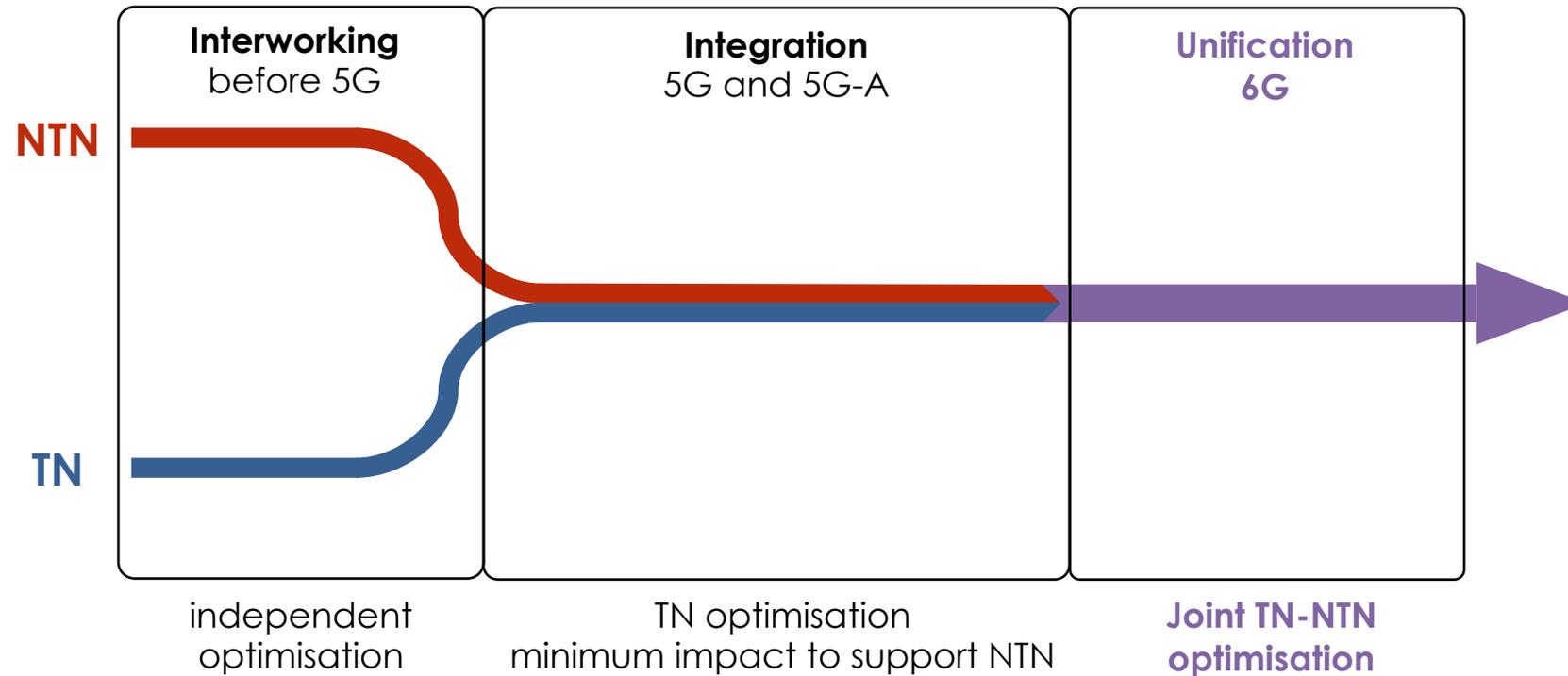
Source: ESA EAGER Project, White Paper, "Architectures, services, and technologies towards 6G Non-Terrestrial Networks," February 2023.

Source: EC HORIZON-JU-SNS-2022 Project 5G-STARBUCK, D3.1 "System Requirements Analysis and Specifications," July 2023.

**A. Guidotti - The evolution of NTN from 5G to 5G-Advanced and the path to 6G**



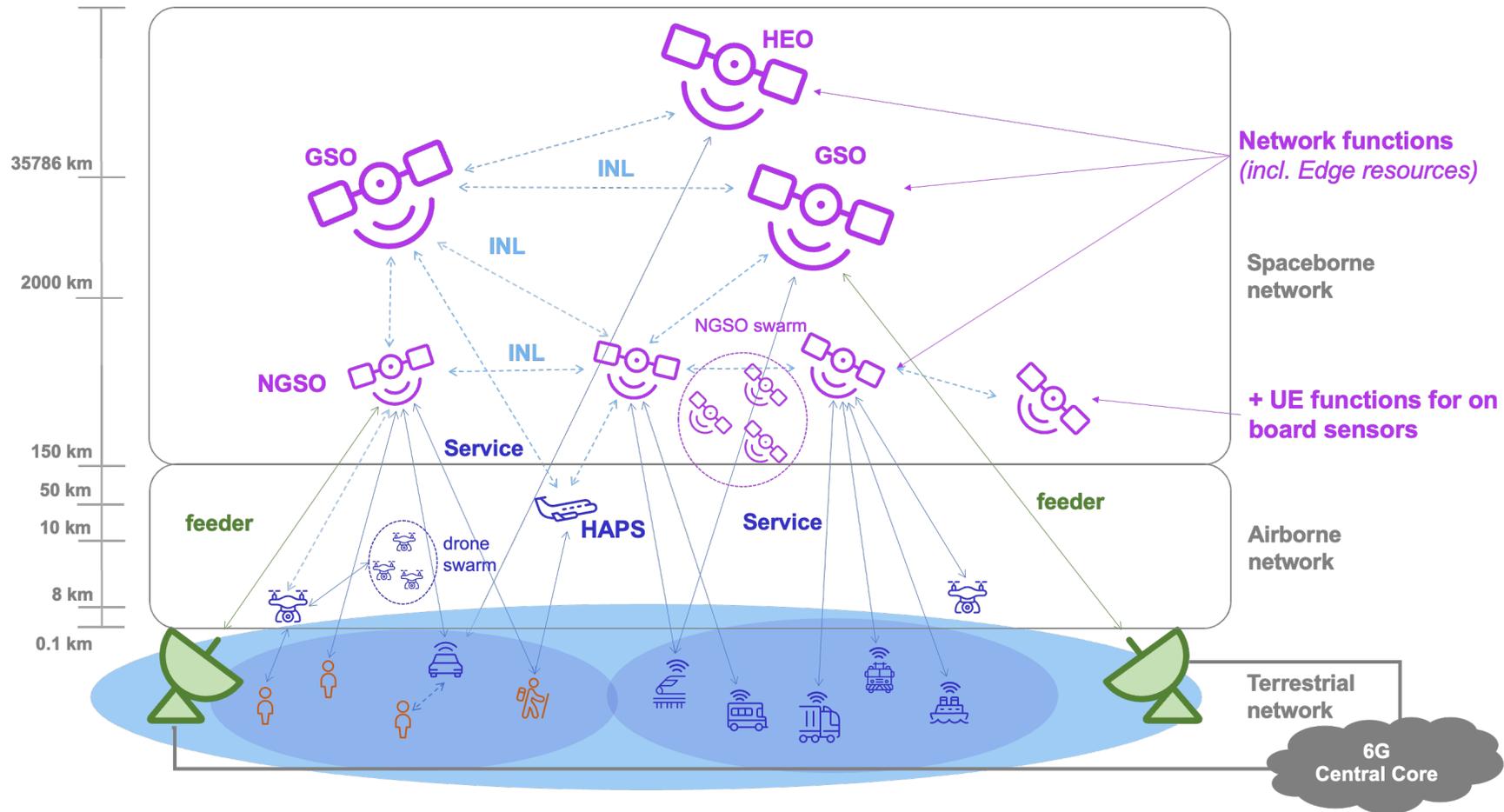
# The role of Non-Terrestrial Networks in 6G



- **6G will target a fully unified T-NT infrastructure based on multi-dimensional multilayer architecture**



# The role of Non-Terrestrial Networks in 6G



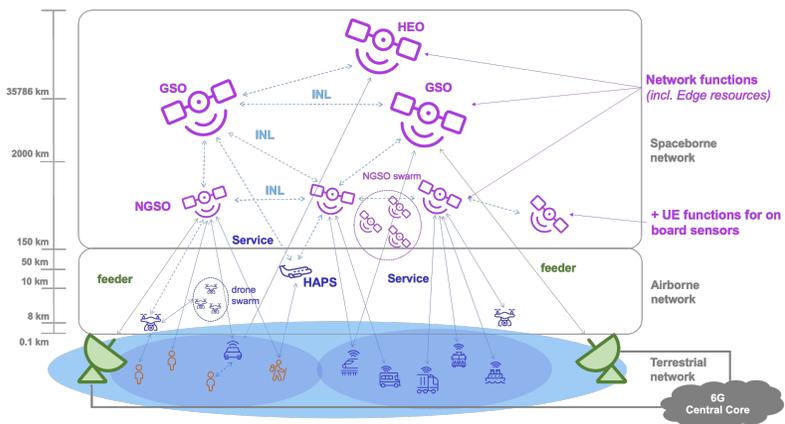
- No distinction between TN and NTN nodes: they are all nodes of the same infrastructure, to be jointly optimised and exploited

Source: A. Guidotti et al., "Role and Evolution of Non-Terrestrial Networks towards 6G systems," submitted to IEEE Access, 2023

A. Guidotti - The evolution of NTN from 5G to 5G-Advanced and the path to 6G



# The role of Non-Terrestrial Networks in 6G



## Architecture and system design

Multi-layered 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 OOB 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

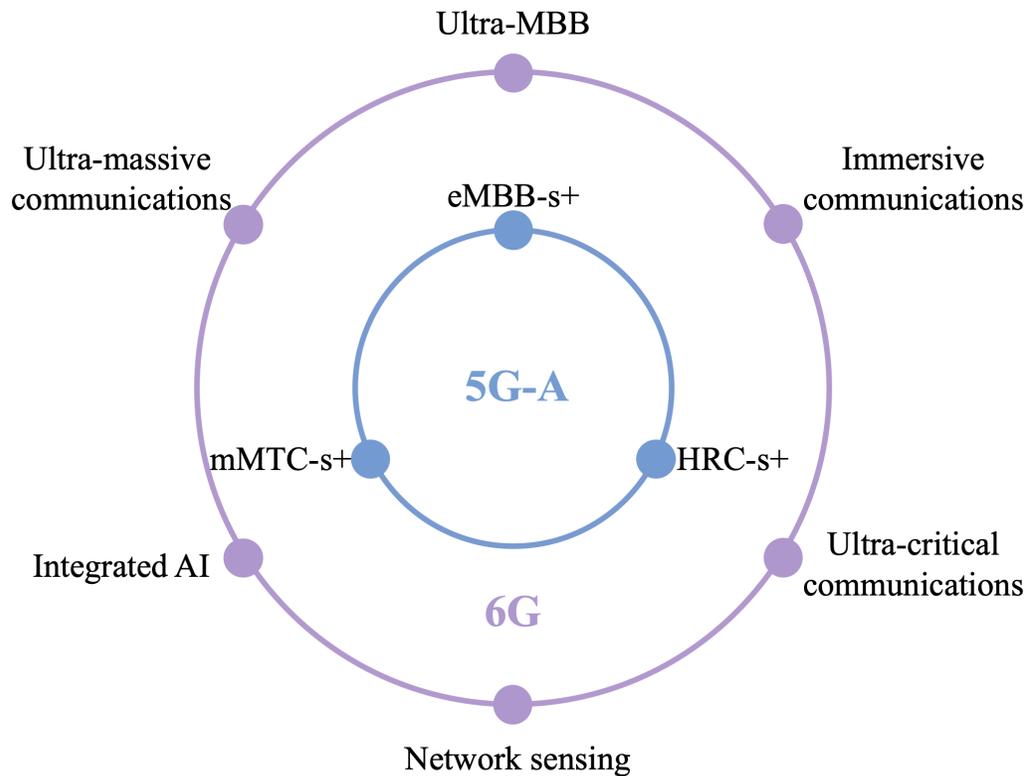
Network and system orchestration, Radio Resource Management, Network traffic forecasting, Physical layer management, Channel estimation

## Antennas and components

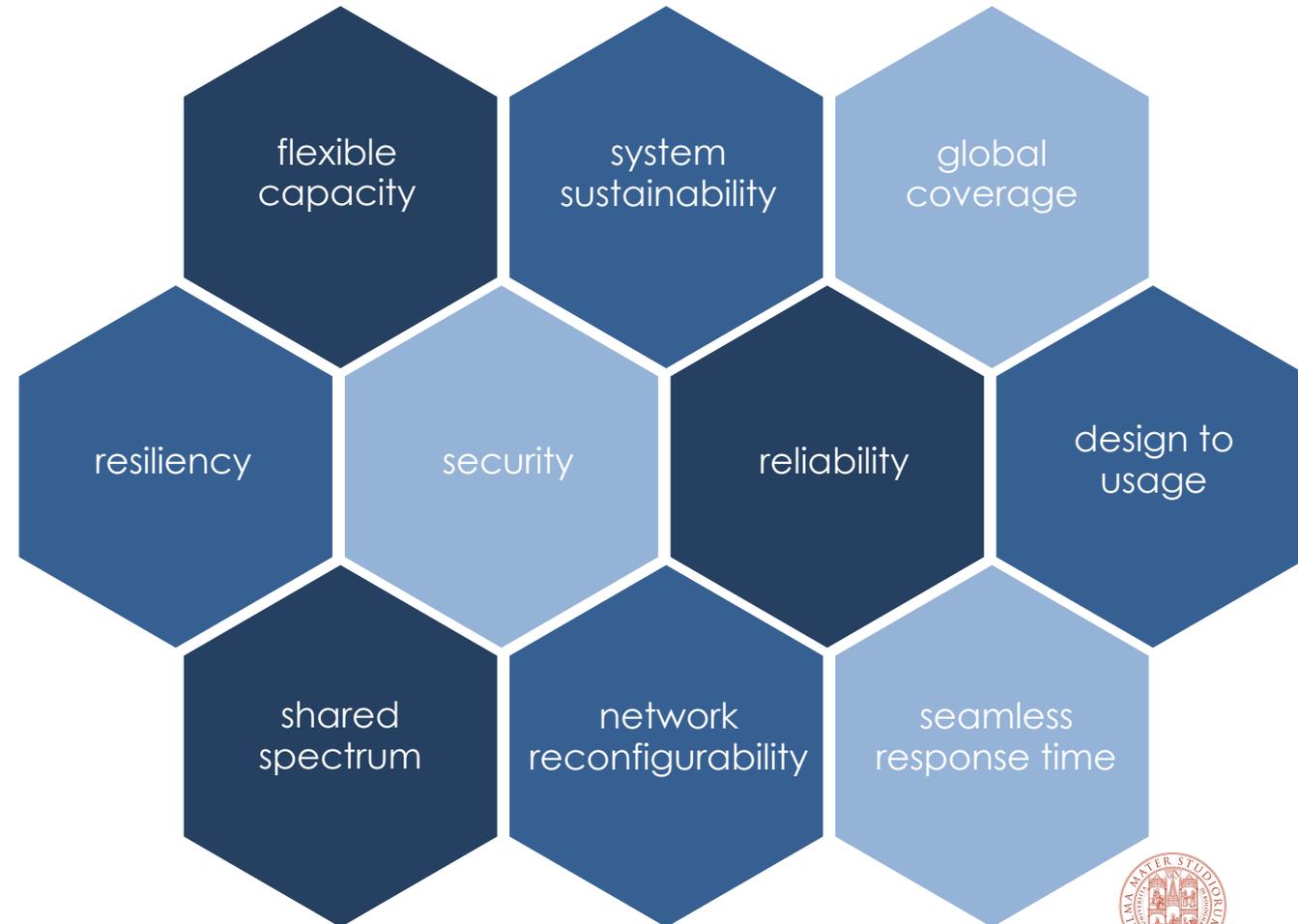
Active antennas for link budget and flexible coverage, Refracting RIS for indoor coverage, regenerative payload, high-parallel energy efficient HW, Optical devices



# The role of Non-Terrestrial Networks in 6G



## 6G NTN key elements



# Conclusions

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- The integration of an NTN component into 5G is a reality since Rel. 17
- However, both **evolutionary and revolutionary technologies** are needed towards a true fully integrated NT-T system infrastructure for 5G-Advanced and 6G communication systems
- **NTN** will play a **pivotal** role in future fully unified systems, leading to a **ML-MO-MB 6G NTN**

**For future NTN systems, we need to make a further technology leap now!**



# Current funded projects on NTN...

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<https://www.6g-ntn.eu/>



<https://www.linkedin.com/company/6g-ntn/>



<https://twitter.com/6Gntn>



<https://www.eagerproject.eu>



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



<https://twitter.com/eagersatcom>

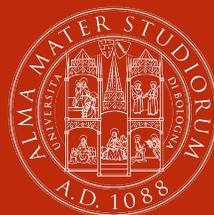


<https://www.5g-stardust.eu>



<https://www.linkedin.com/company/5g-stardust/>





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