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6G-NTN

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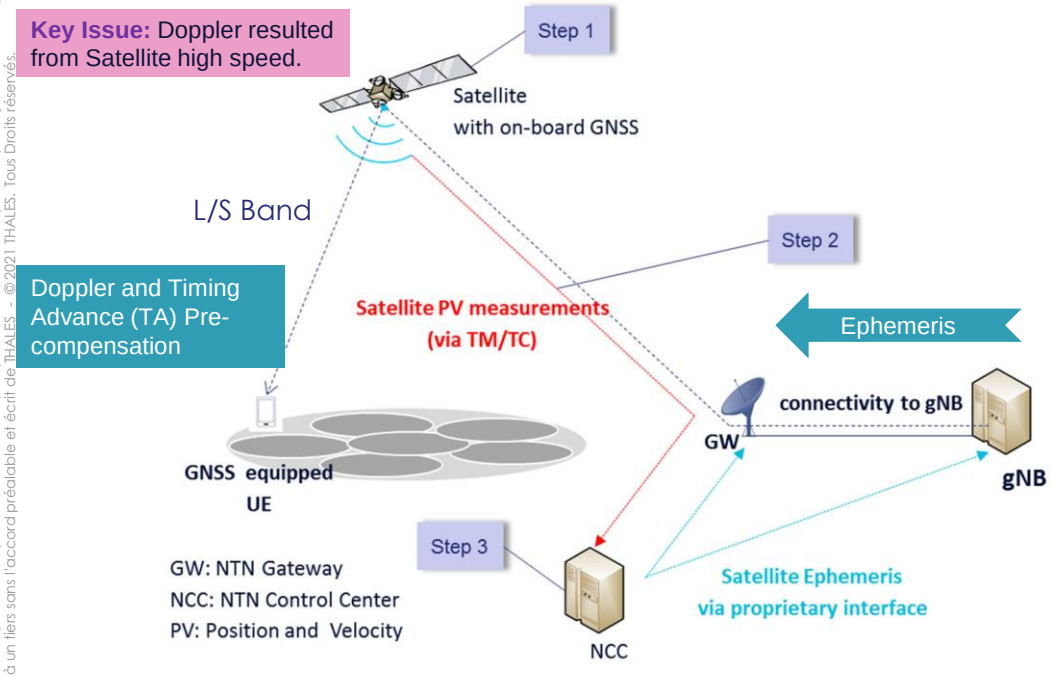
5G NR NTN in Release-17 (5G NR Direct Smartphone Access)

Key Issue: Doppler resulted from Satellite high speed.



General Hypothesis:

- UE (User Equipment) with GNSS;
- Ephemeris data send through satellite to UE (broadcast SIB19);

UE is using GNSS and Ephemeris data to pre-compensate Doppler and Timing Advance;

Transparent satellite configuration with:

- Earth Fixed or Earth Moving Cells;

Considered constellation types:

- LEO@600km (worst case, higher Doppler);
- LEO@1200km;
- GEO.

Intermediate constellations are also possible.

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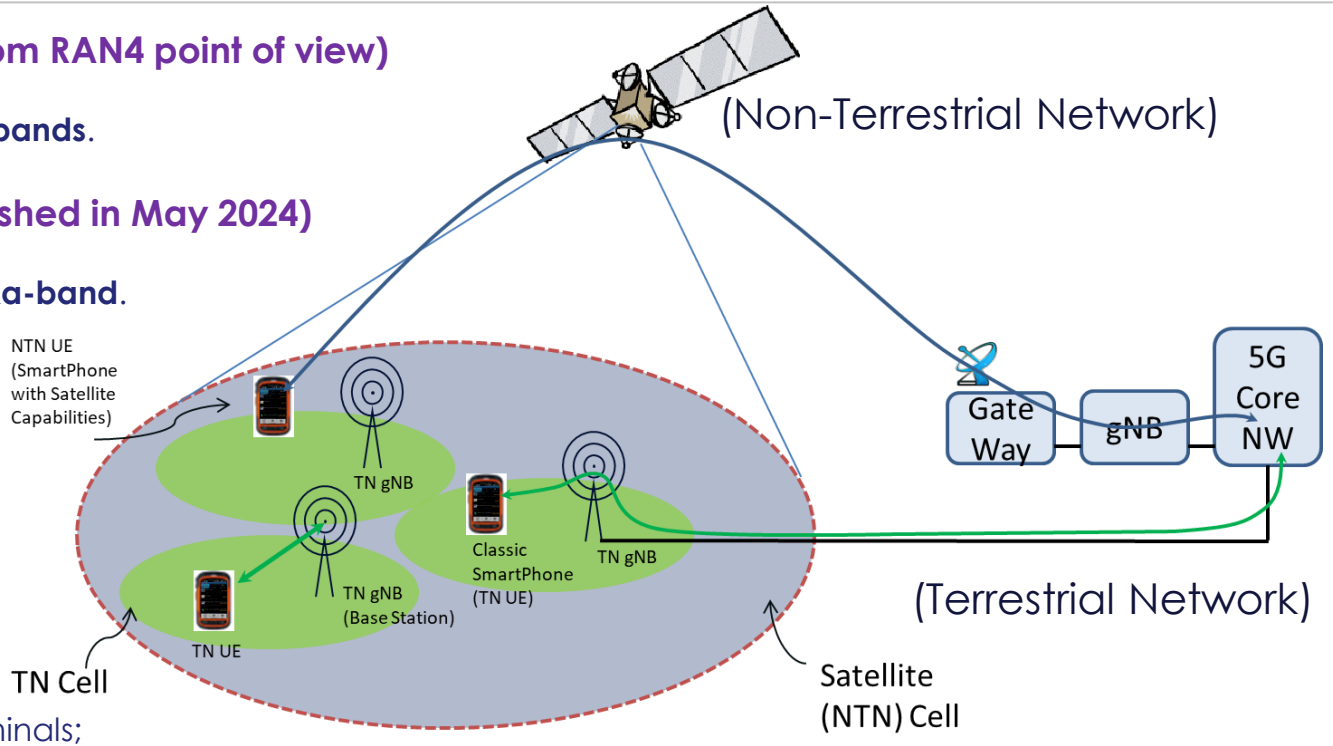
5G NR Satellite NTN integration with 5G NR TN – Short View

Rel-17: Ended (March 2023 from RAN4 point of view)
- **Transparent Satellite**;
- NTN UE is a **Smartphone** in **L/S-bands**.

Rel-18: Ended (RAN4 work finished in May 2024)
- **Transparent Satellite**;
- NTN UE is a **VSAT** operating in **Ka-band**.

Rel-19: TBC end-2025?
- **Regenerative Satellite;**
- **DL coverage enhancements;**
- Other bands: **Ku-band**;
- Other **FR1-NTN UE types: HPUE**.

Rel-20/Rel-21:
- **GNSS-free operation**;
- Other bands: **Q/V-band**;
- **Lower form factor** for VSAT terminals;
- **Enhanced (broadband)** services.



5G NR NTN 3GPP bands in Rel-17 and Rel-18 (as for now)

"Exotic" Satellite frequency ranges compared with TN.

NTN operating bands in FR1 for satellite networks (FR1-NTN[4])

NTN satellite operating band	UpLink (UL) operating band SAN receive / UE transmit F_{UL_low} – F_{UL_high}	DownLink (DL) operating band SAN transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex mode	Applicability (starting with)
n256	1980 MHz – 2010 MHz	2170 MHz – 2200 MHz	FDD	5G NR Release-17
n255	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD	
n254	1610 MHz – 1626.5 MHz	2483.5 MHz – 2500 MHz	FDD	5G NR Release-18

NOTE: NTN satellite bands are numbered in descending order from n256.

Technical, regulatory & sometimes political **challenges to introduce new bands.**

NTN operating bands in above 10 GHz for satellite networks (FR2-NTN[5])

NTN satellite operating band	UpLink (UL) operating band SAN receive / UE transmit F_{UL_low} – F_{UL_high}	DownLink (DL) operating band SAN transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex mode	Applicability (starting with)
n512[1]	27500 MHz – 30000 MHz	17300 MHz – 20200 MHz	FDD	5G NR Release-18
n511[2]	28350 MHz – 30000 MHz	17300 MHz – 20200 MHz	FDD	
n510[3]	27500 MHz – 28350 MHz	17300 MHz – 20200 MHz	FDD	

NOTE 1: This band is applicable in the countries subject to CEPT ECC Decision(05)01 and ECC Decision (13)01.
NOTE 2: This band is applicable in the USA subject to FCC 47 CFR part 25.
NOTE 3: This band is applicable for Earth Station operations in the USA subject to FCC 47 CFR part 25. FCC rules currently do not include ESIM operations in this band (47 CFR 25.202).

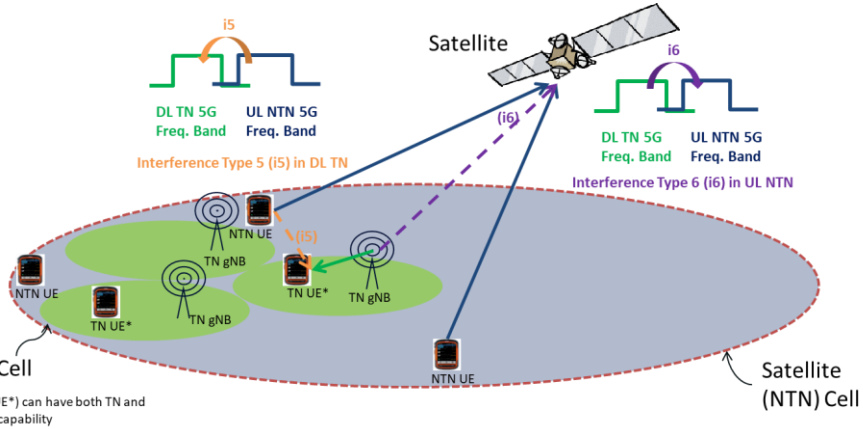
Difficult Satellite **radio channel propagation**, with relatively **low Spectral Efficiency** per end user.

FR1-NTN[4]: 410 MHz – 7125 MHz
FR2-NTN[5]: 17300 MHz – 30000 MHz

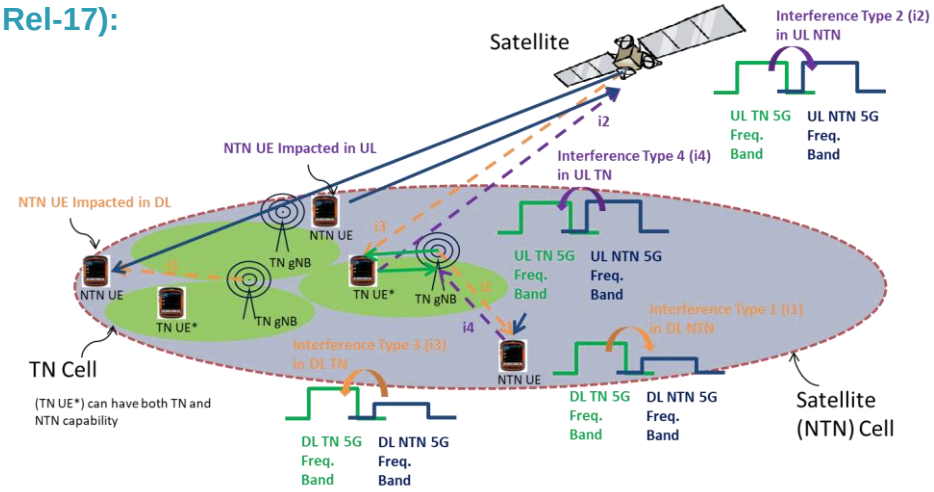
5G NR NTN Context in 3GPP RAN4 Work Group – RF & Radio Resource Management

NTN-TN adjacent band coexistence analysis (examples Rel-17):

- n256 (FDD NTN) with n1 (FDD TN) – top figure
- n256 (FDD NTN) with n34 (TDD TN) – bottom figure



S-band NTN-TN adjacent band coexistence scenarios with TN in TDD mode (e.g. n34)



S-band NTN-TN adjacent band coexistence scenarios with TN in FDD mode (e.g. n1)

NTN-TN adjacent band coexistence analysis is essential for:

- Definition of **RF core requirements**;
- Introduction of **new NTN bands**.

5G NR NTN Bandwidth Configuration (as for now, see TS 38.101-5/38.108)

Maximum transmission bandwidth configuration N_{RB} for FR1-NTN

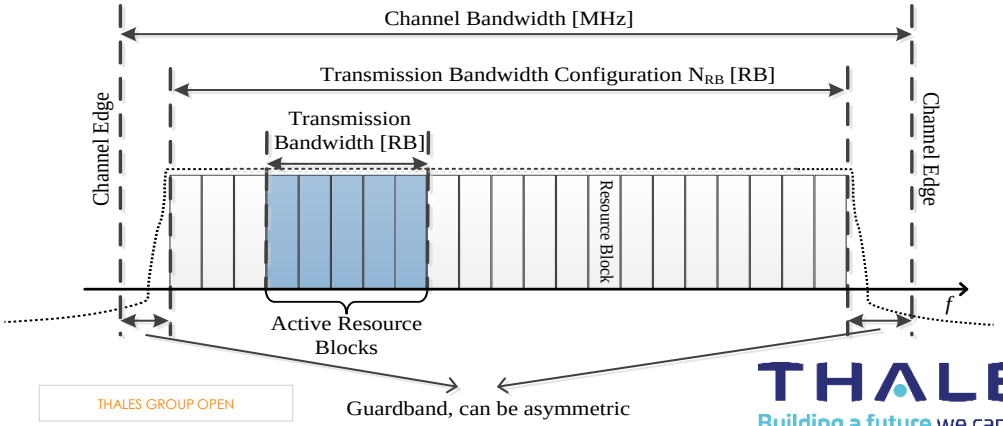
SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}	N_{RB}
15	25	52	79	106	160
30	11	24	38	51	78
60	N/A	11	18	24	38

Maximum transmission bandwidth configuration N_{RB} for FR2-NTN

SCS (kHz)	50 MHz	100 MHz	200 MHz	400 MHz
	N_{RB}	N_{RB}	N_{RB}	N_{RB}
60	66	132	264	N/A
120	32	66	132	264

SCS: Sub-Carrier Spacing

1 RB (Resource Block):
12 Sub-Carriers



NB-IoT NTN 3GPP bands in Rel-18 (as for now, see TS 36.108/36.102)

E-UTRA operating bands for satellite access

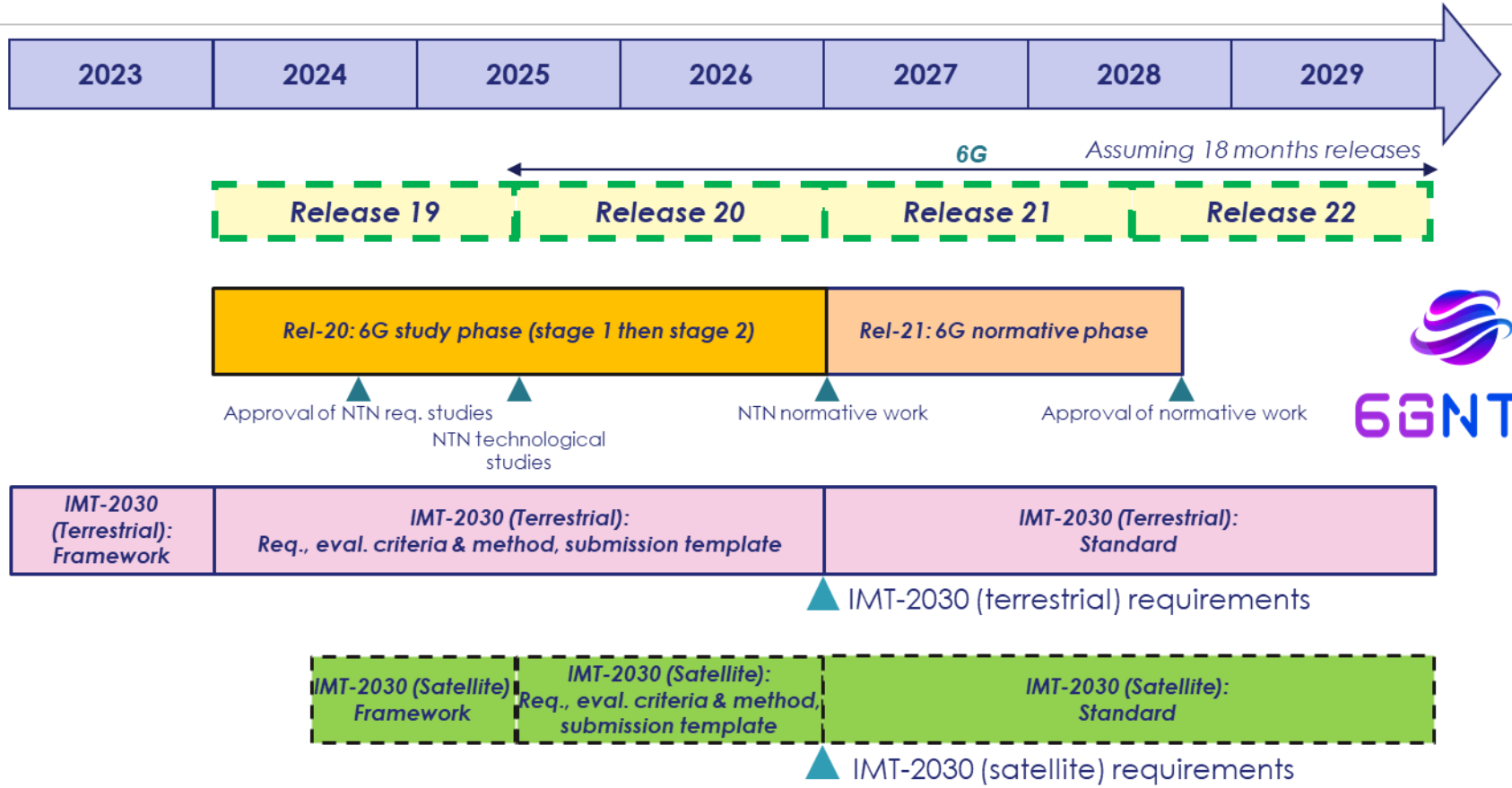
E-UTRA operating band	UpLink (UL) operating band SAN receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$	DownLink (DL) operating band SAN transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$	Duplex mode	Applicability
256	1980 MHz – 2010 MHz	2170 MHz – 2200 MHz	FDD	Starting with 5G LTE Release-18
255	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD	
254	1610 MHz – 1626.5 MHz	2483.5 MHz – 2500 MHz	FDD	
253	1668 MHz – 1675 MHz	1518 MHz – 1525 MHz	FDD	
NOTE 1: NTN satellite bands are numbered in descending order from 256. NOTE 2: UE assigned to channels and allocated frequency resources in the lower portion of Band 253 may experience blocking or harmful interference from terrestrial networks in adjacent or nearby frequencies when operating in the proximity with terrestrial base stations.				

NTN 3GPP Rel-19 ongoing work for both 5G NR and NB-IoT (as for now)

Current targeted NTN frequency bands under Rel-19

UpLink (UL) operating band SAN receive / UE transmit F_{UL_low} – F_{UL_high}	DownLink (DL) operating band SAN transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex mode	Applicability (target)
1668 MHz – 1675 MHz	1518 MHz – 1525 MHz	FDD	5G NR starting with Release-19 n253 frequency band definition
2000 MHz – 2020 MHz	2180 MHz – 2200 MHz	FDD	5G NR and 5G LTE starting with Release-19 n252 and 252 frequency band definitions
1626.5 MHz – 1660.5 MHz	1518 MHz – 1559 MHz	FDD	5G NR starting with Release-19 n251 frequency band definition
1668 MHz – 1675 MHz	1518 MHz – 1559 MHz	FDD	5G NR starting with Release-19 n250 frequency band definition
14000 MHz – 14500 MHz	10700 MHz – 12750 MHz	FDD	5G NR starting with Release-19 [n509] frequency band definition
…	…	…	…

6G-NTN standardization timeline: 3GPP and ITU-R



NTN targeted market segments (see S1-241041)

Consumer market:

- Includes connectivity to smartphones or wearable devices & cars;
- Need for guaranteed coverage;
- By 2030, at least:
  - 7.5% of the total number of mobile subscribers (5.2Bn) expected to be NTN;
  - 5% of the new cars (~75 million per year) are expected to be NTN capable.

Enterprise market:

- Need for services in rural areas or less developed areas and moving platforms;
- Unique UE for both NTN/TN;
- Similar use cases to today (e.g. office, media & entertainment);
- As the technology becomes cheaper and compact and easier to access, the adoption is expected to rise.

Vertical markets:

- Utilities, agriculture (e.g. sensors), governmental users (e.g. broadband communication);
- Specific requirements: e.g. sensor data collection over a wide area, autonomy, security, resilience and mobility;
- Several millions of users are expected to require satellite connectivity.

Proposed Topics *for* Rel-20 SA1 6G SID (see S1-241041)

- **Ubiquitous and resilient connectivity, including:**
  - Enhanced NTN:
    - e.g. GNSS-free operation;
    - 3D NTN;
    - Use of AI/ML for NTN;
  - Unified TN+NTN:
    - e.g. NTN-friendly radio interface from the day 1 (unified radio interface)
    - Enhanced TN/NTN selection..

- **Focusing in priority on NTN related mass market use cases (consumer & enterprise):**
  - Enhanced direct connectivity to smartphones/wearable devices;
  - Enhanced Broadband connectivity to:
    - Land vehicles;
    - Drones (or UxV);
    - Homes/small offices;
    - Public transportation platforms (Aircraft, Railway, Maritime, ..);
  - Public Safety/Mission Critical applications with fast connectivity setup.

Trends: Standardization, Implementation and Research (takeaways)

IRIS² (approach under construction):

Support implementation of **5G NTN standards** defined in 3GPP domain
- to the maximum extent possible and
- through a gradual implementation approach

Future roadmap, in order to support 5G/6G NTN-TN convergence:

- Satellite with **regenerative** payload: starting from **Rel-19**;
- Evolution towards **6G New Radio:**
  - **Increasing Non-Terrestrial Network (NTN) capacity**:
    - Introducing **more Satellite** frequency **bands for increased capacity;**
    - **Integration of TN and NTN 5G/6G towards 3D (mesh) communications.**
  - **Simulation and testing capabilities:**
    - **6G WaveForm (WF)** abstraction **toolbox;**
    - **Channel Model** for satellite communication;
    - Evaluate **PAPR**, **resilience to Doppler & timing errors** of various WaveForms.

Some on-going work in 6G-NTN SNS R&D project.

6G-NTN SNS Architecture: Design Drivers

- Resilient 3D multi-layered architecture with Inter-Node Links (both RF and Optical) for ubiquitous coverage & affordable end-user connectivity;
- Interference mitigation through AI/ML driven RRM, possibility for spectrum sharing;
- System affordability (e.g. in terms of computational complexity, cost) and sustainability constraints;
- Reduced carbon footprint and overall energy consumption;
- Dynamic orchestration of VNF, smart routing and edge-based service provisioning in a dynamic network topology;
- Support of accurate network-based positioning;
- Software defined payloads embarking RAN & CN functionalities, edge computing resources;
- Cyber and physical layer security.

Target features for research

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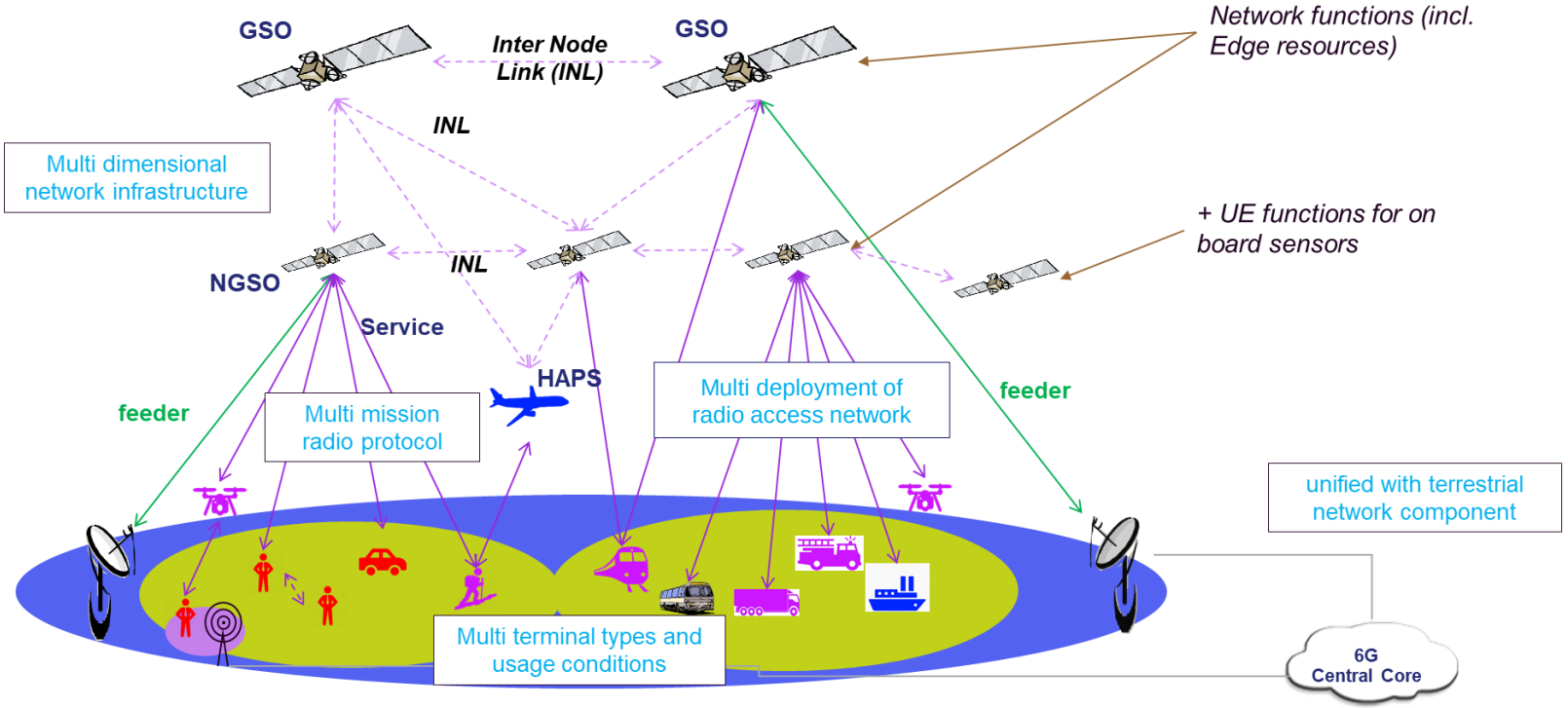
6G-NTN SNS Radio Interface: Design Drivers

Enabling features for a spectrum efficient and flexible radio interface optimized for both TN and NTN components

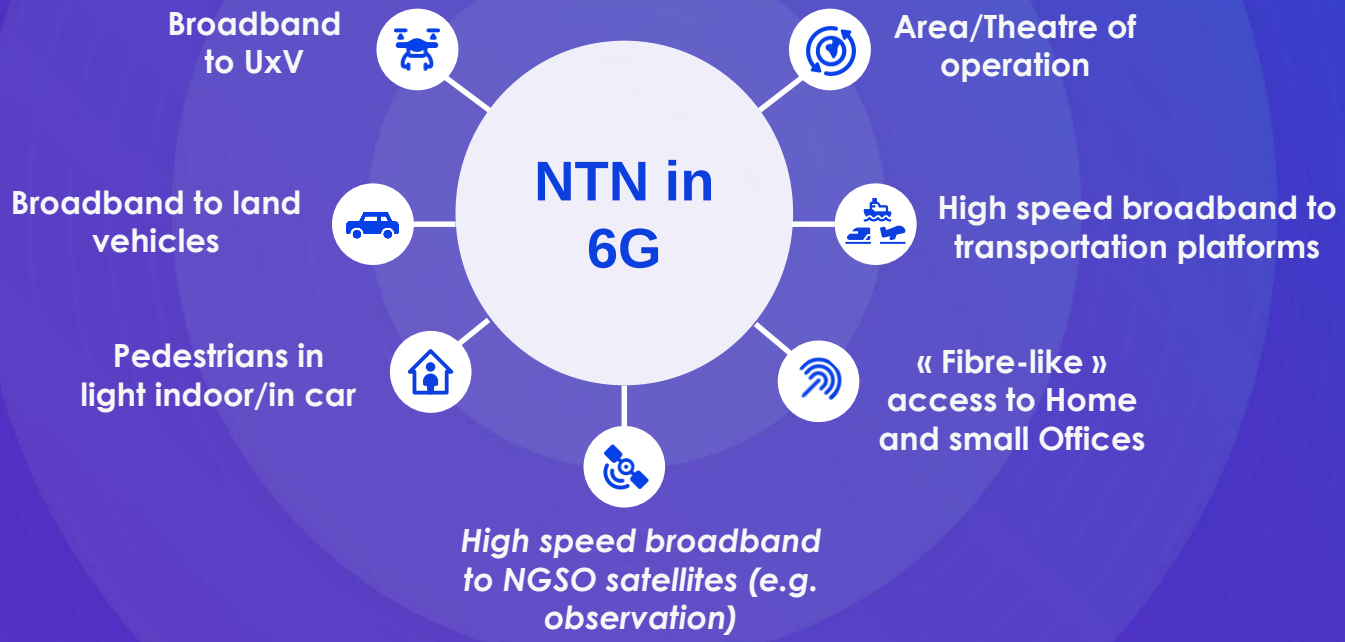
- Compatibility with terrestrial networks;
- Multicarrier waveform enhancements (GNSS-free, PAPR reduction);
- Advanced modulation, coding and multiple access schemes;
- Design of flexible UL/DL frame structure;
- Robust reference signals for enhanced positioning;
- Support of broadcast and multicast;
- Backward compatibility with 5G NR;
- Enablers for AI/ML-driven radio resource control and AI-enhanced waveforms;
- Enablers for optimized Spectrum coexistence between TN and NTN;
- Support of FDD and TDD;
- Integrated communication and sensing for NTN;
- New spectrum (e.g. Q/V-band, C-band).

Target features for research

6G-NTN SNS Project: Key Design Principles



NTN in 6G: an evolution of NTN in 5G enabling new roles / capabilities / connectivity scenarios



- NTN contribution to 6G: ubiquitous and resilient service
- From service to user centric design approach
- Star & Mesh NTN topologies (with/without feeder)
- Sustainability

Enabling FEATURES for NTN in 6G

- Compact and self-tracking FPA for vehicle/UxV mounted devices
- GNSS free operation
- Seamless NTN/TN service continuity
- Reliable determination of UE location
- UE-NTN-UE (without feeder) for local access
- Autonomous private network (NTN+TN) operation over a specific area
- Smart NTN/TN combination for sustainability and resilience
- Multi-tenant NTN infrastructure
- NTN/TN spectrum coexistence optimization
- Integrated sensing

6G drivers proposed by associations/organizations (both TN and NTN): Table based on 6G Workshop (Rotterdam, May 2024) – see S1-241041

Big Ambitions Make the World Go Round

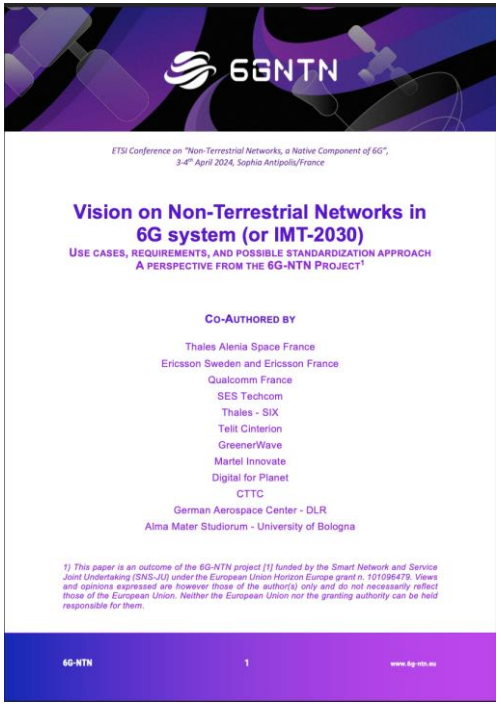
6G-NTN White Paper (2nd of April, 2024)

On 2nd of April 2024, the 6G-NTN SNS project released a white paper entitled:

"Vision on Non-Terrestrial Networks in 6G system (or IMT-2030): Use cases, requirements, and possible standardization approach – A perspective from the 6G-NTN project"

The white paper presents:

- The use cases for NTN connectivity by 2030 and beyond
- 6G and drivers for native integration of satellite components
- The 6G NTN standardization approach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ETSI Conference on "Non-Terrestrial Networks, a Native Component of 6G", 3-4th April 2024, Sophia Antipolis/France

Vision on Non-Terrestrial Networks in 6G system (or IMT-2030)

USE CASES, REQUIREMENTS, AND POSSIBLE STANDARDIZATION APPROACH A PERSPECTIVE FROM THE 6G-NTN PROJECT[1]

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