



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

The path to 5G-Advanced and 6G Non-Terrestrial Network systems

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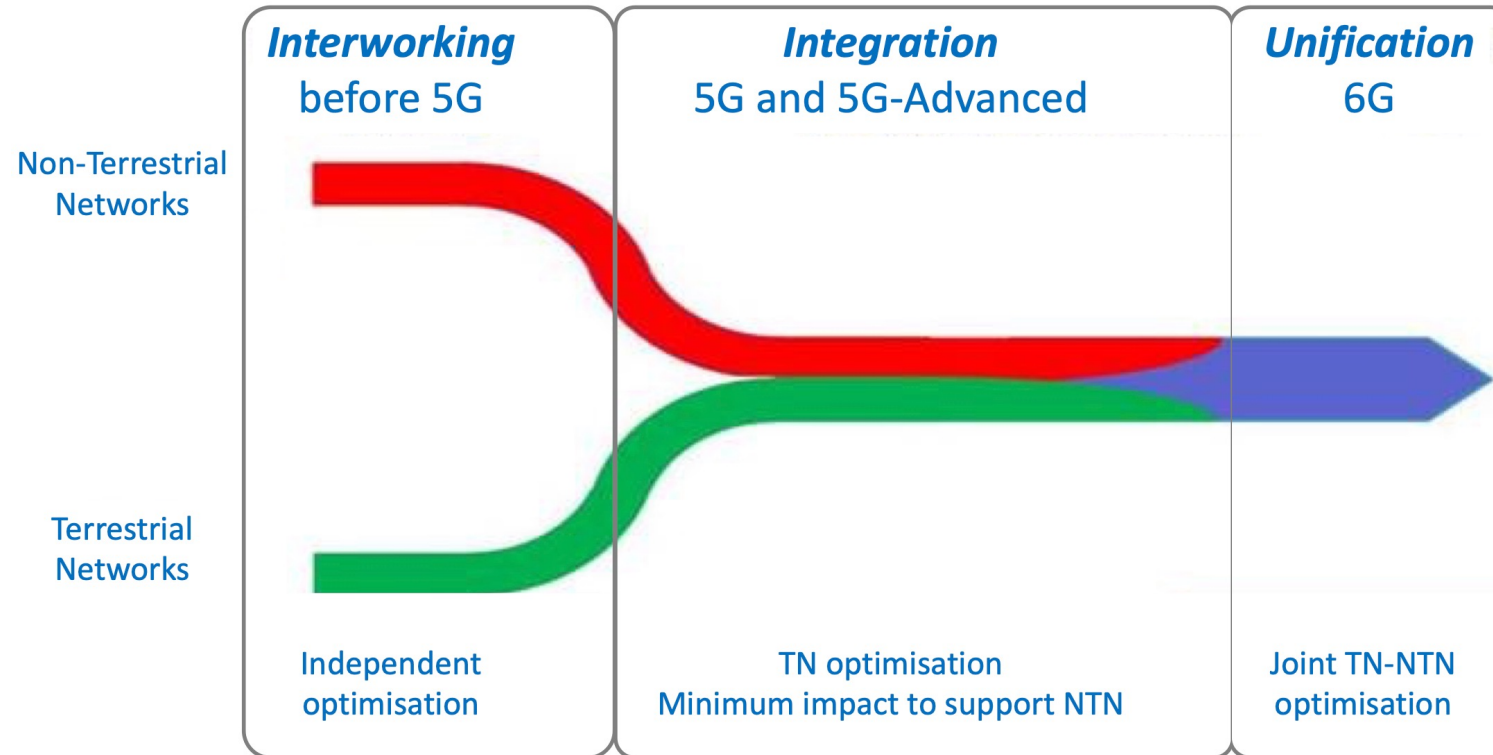
Introduction



- 5G systems are now bringing benefits to all sectors of our economy and society...
- ...but we are all already looking into the future
- **5G-Advanced** (5G-A): unleash the full potential of 5G systems
 - Strengthen the network performance
 - Provide connectivity to all devices in all scenarios
- **6G**: 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
- A **significant innovation breakthrough** is now required to define **future NTN systems** (Rel. 18+)
- To achieve a ubiquitous, continuous, flexible, and resilient infrastructure, a **unified TN-NTN network** is fundamental



Interaction between TN and NTN

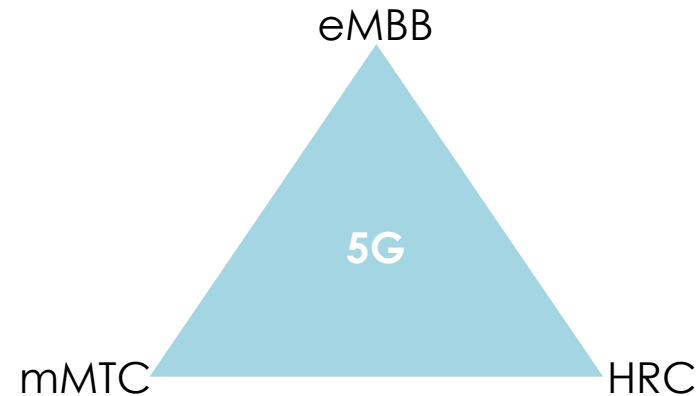


- great opportunity to optimize the 6G service performances over the NTN component taking into account its peculiarities
- native support of MC and mobility across TN/NTN access technologies → improved QoE

Potential services via NTN: 5G



- mass-market consumers
- complementing the TN in un-/under-served areas

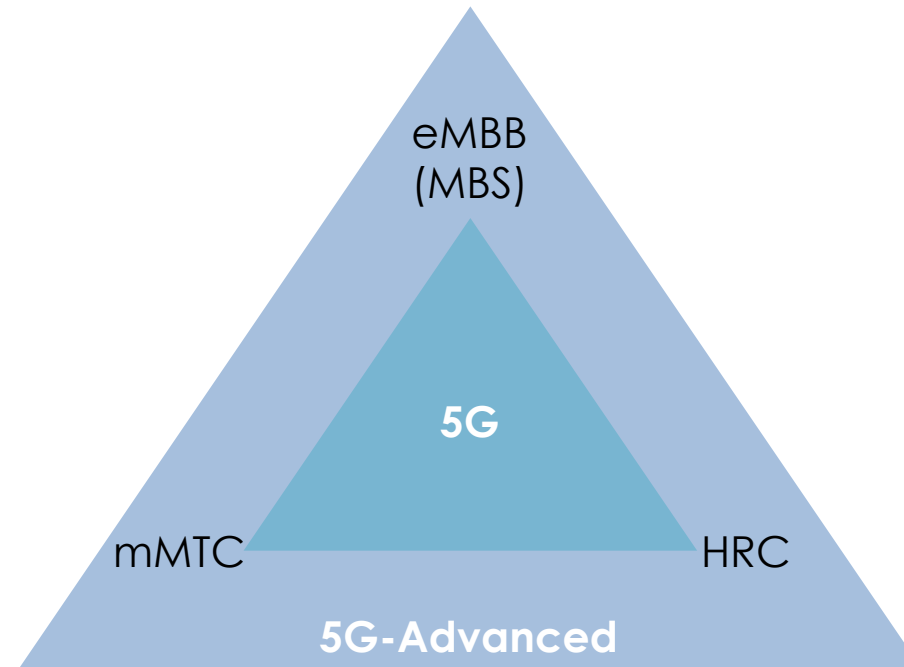


- Global NB-IoT/mMTC coverage
- Remote control/monitoring of critical infrastructures
- Smart good tracking

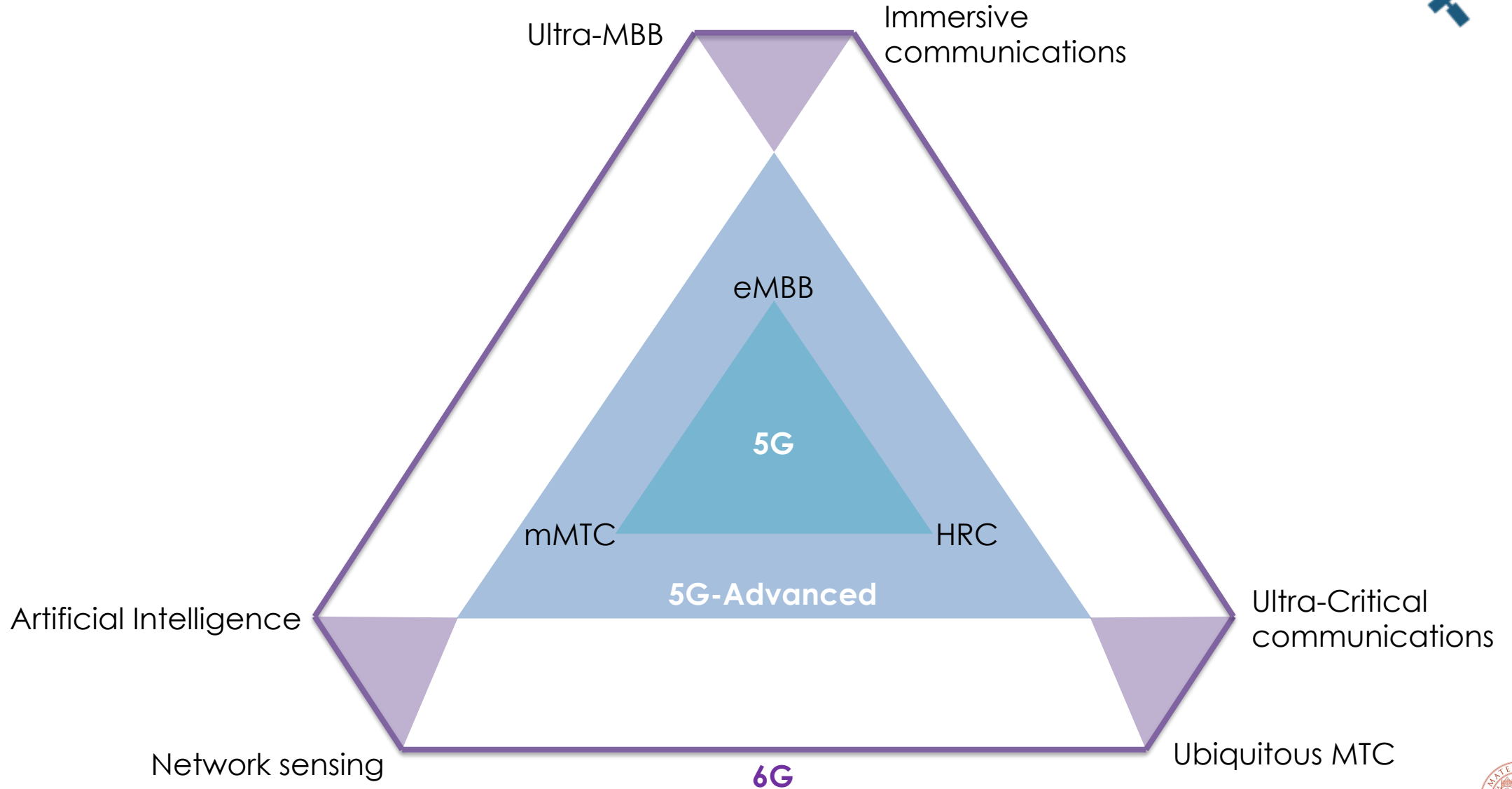
- Governmental services
- Emergency management



Potential services via NTN: 5G-Advanced



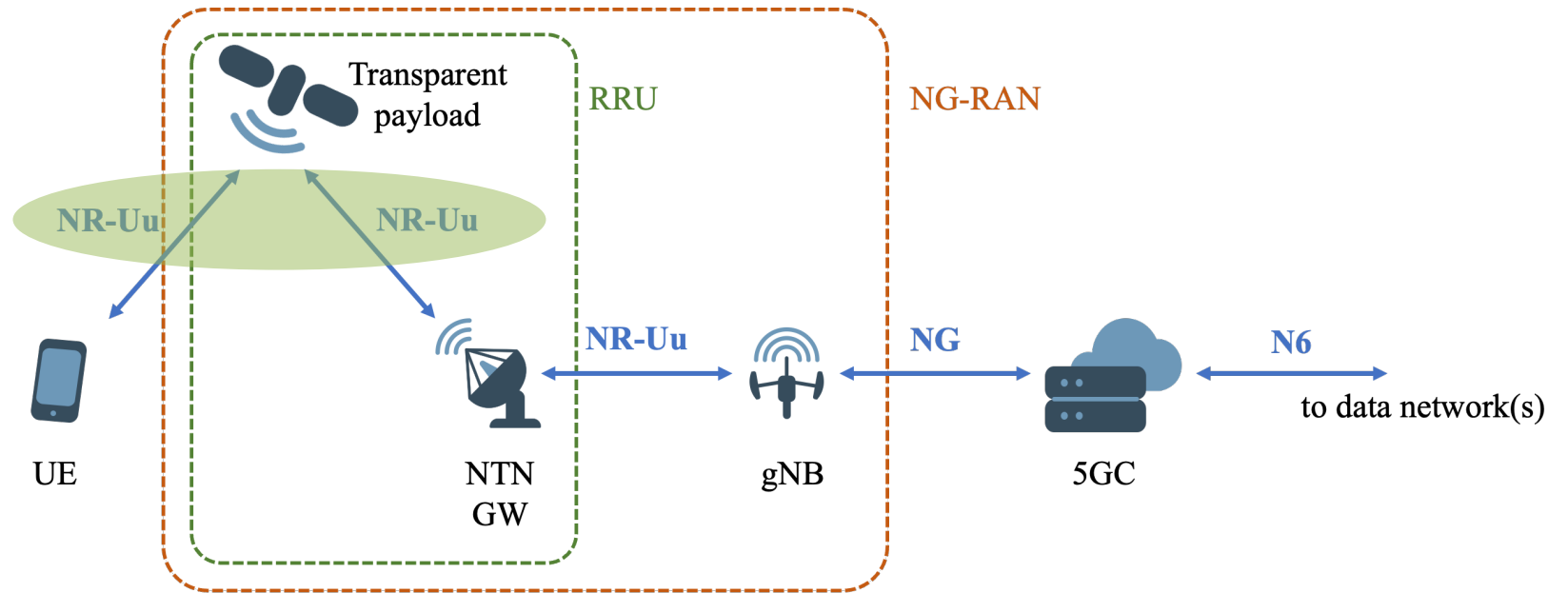
Potential services via NTN: 6G



Architecture evolution: 5G

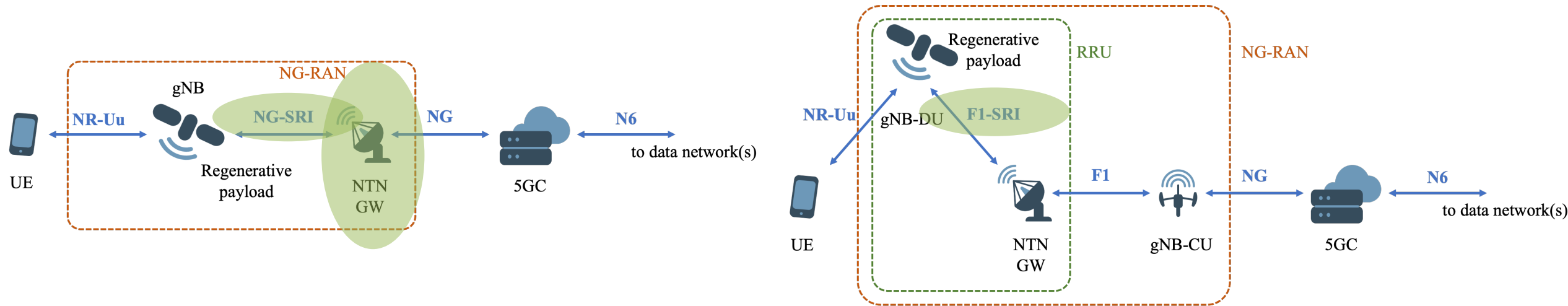
- 5G NTN (Rel. 17) focused on direct access via transparent payload satellites
 - GEO/LEO with fixed or moving beams

The transparent payload does not terminate the NR-Uu procedures nor it manages the QoS flows



Architecture evolution: 5G-A

- 5G-Advanced enhancements: regenerative payload, relay-based access, Multi-Connectivity

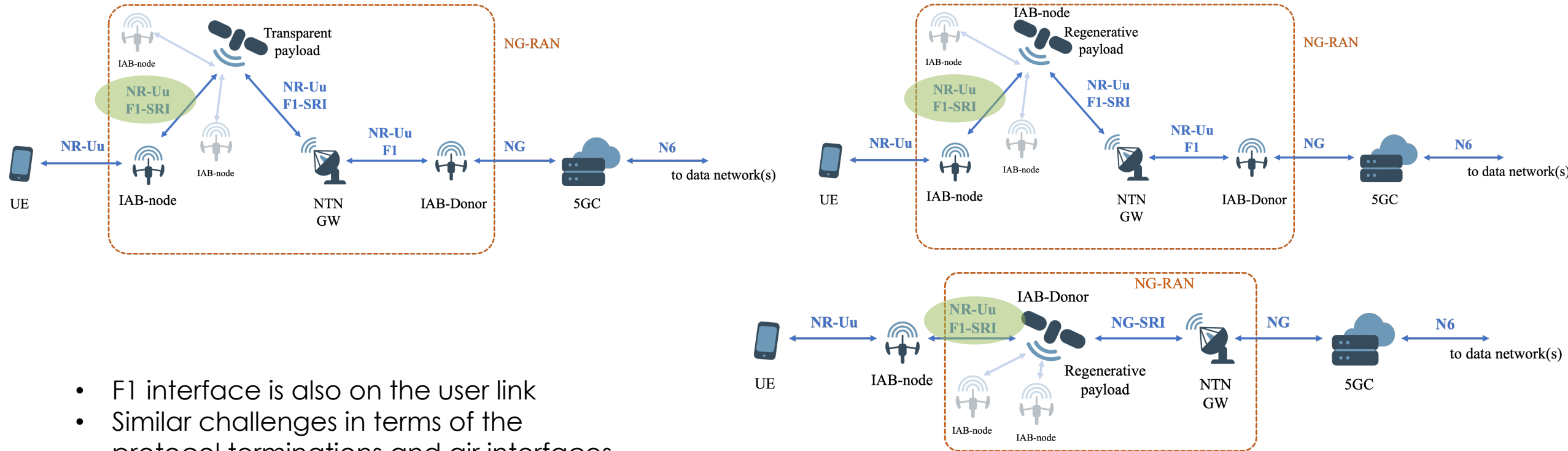


- The GW terminates all transport protocols
- The NG Air Interface is logical

- Scalable solution based on NFV/SDN for system tailoring
- Challenges related to F1
- Only opt.2 split is full-3GPP

Architecture evolution: 5G-A

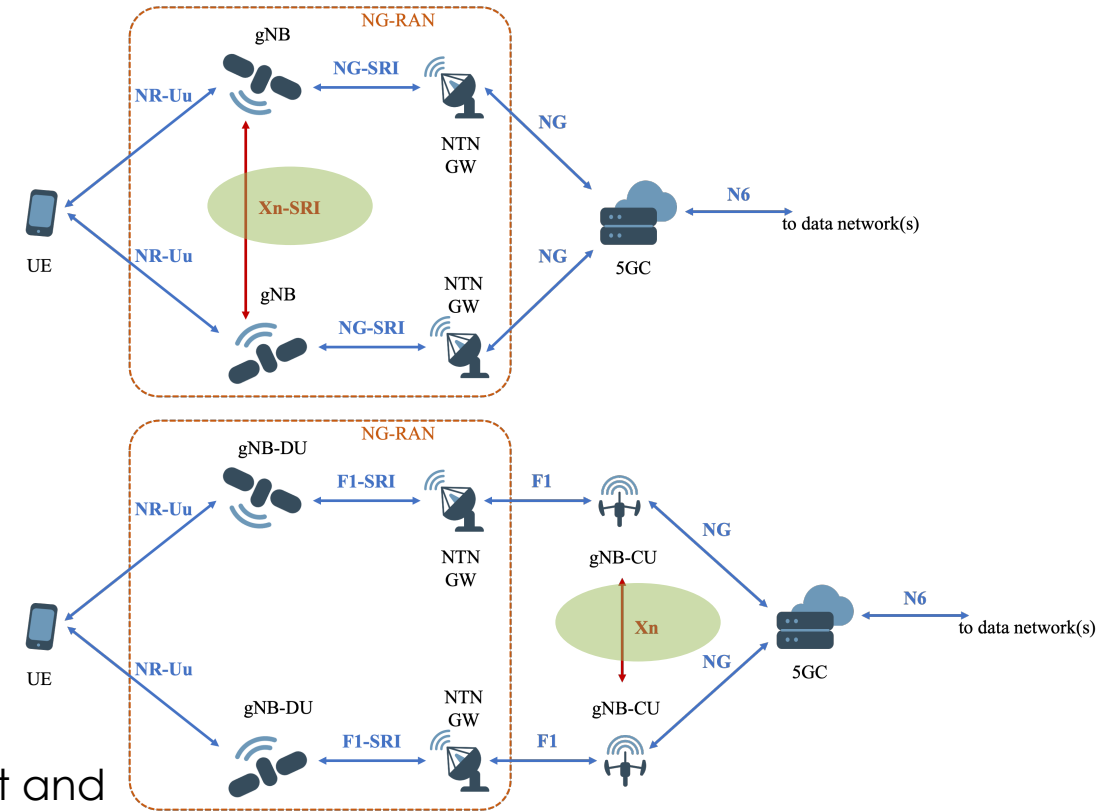
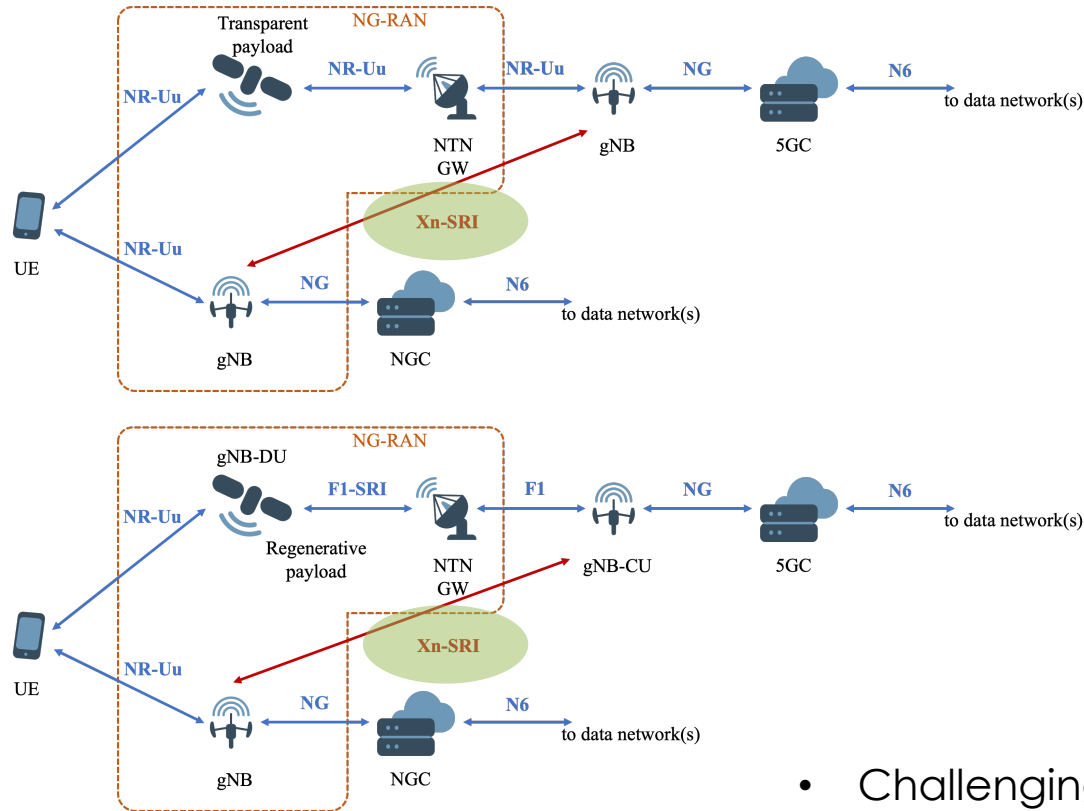
- 5G-Advanced enhancements: regenerative payload, relay-based access, Multi-Connectivity



- F1 interface is also on the user link
- Similar challenges in terms of the protocol terminations and air interfaces

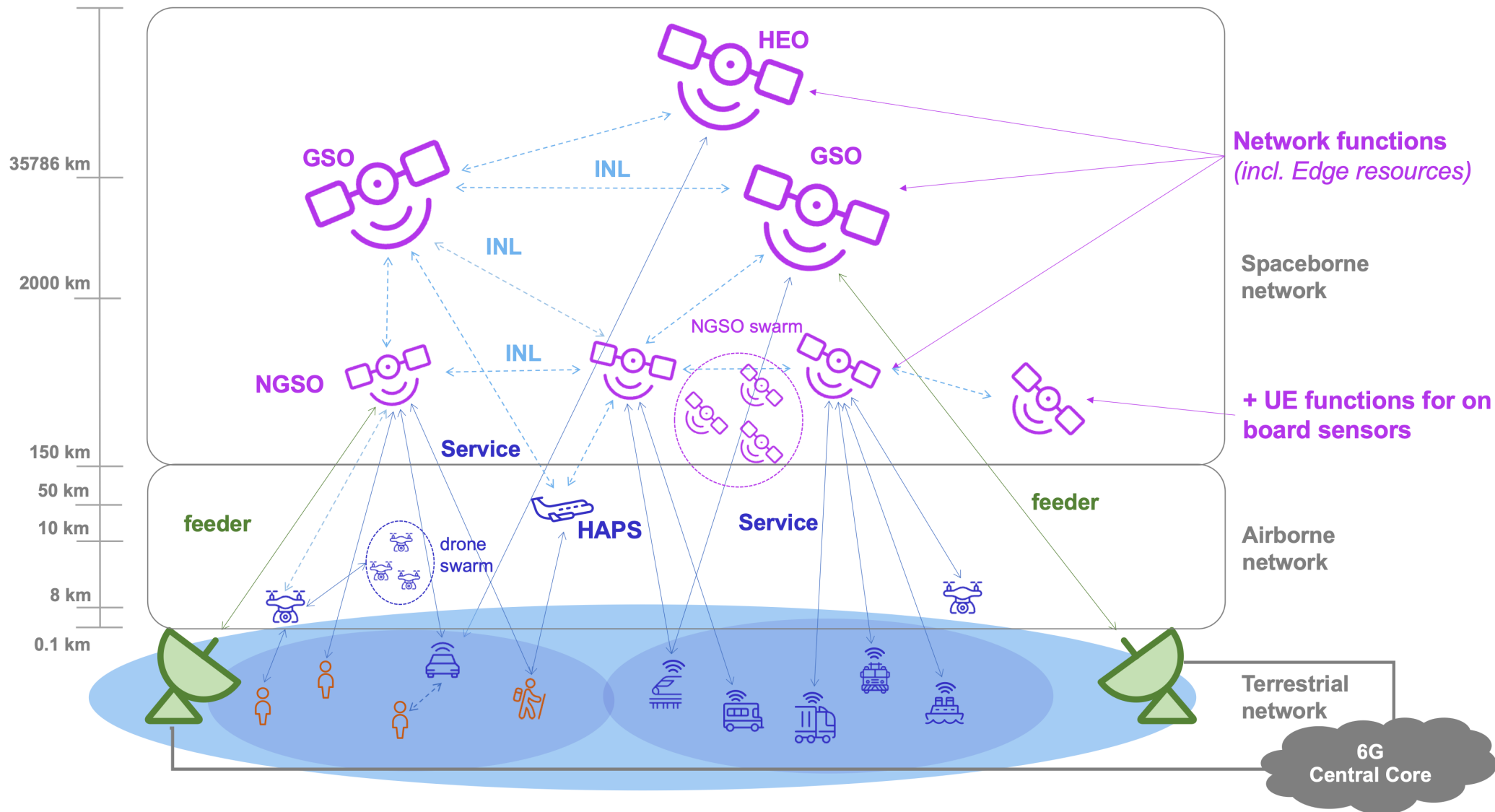
Architecture evolution: 5G-A

- 5G-Advanced enhancements: regenerative payload, relay-based access, Multi-Connectivity

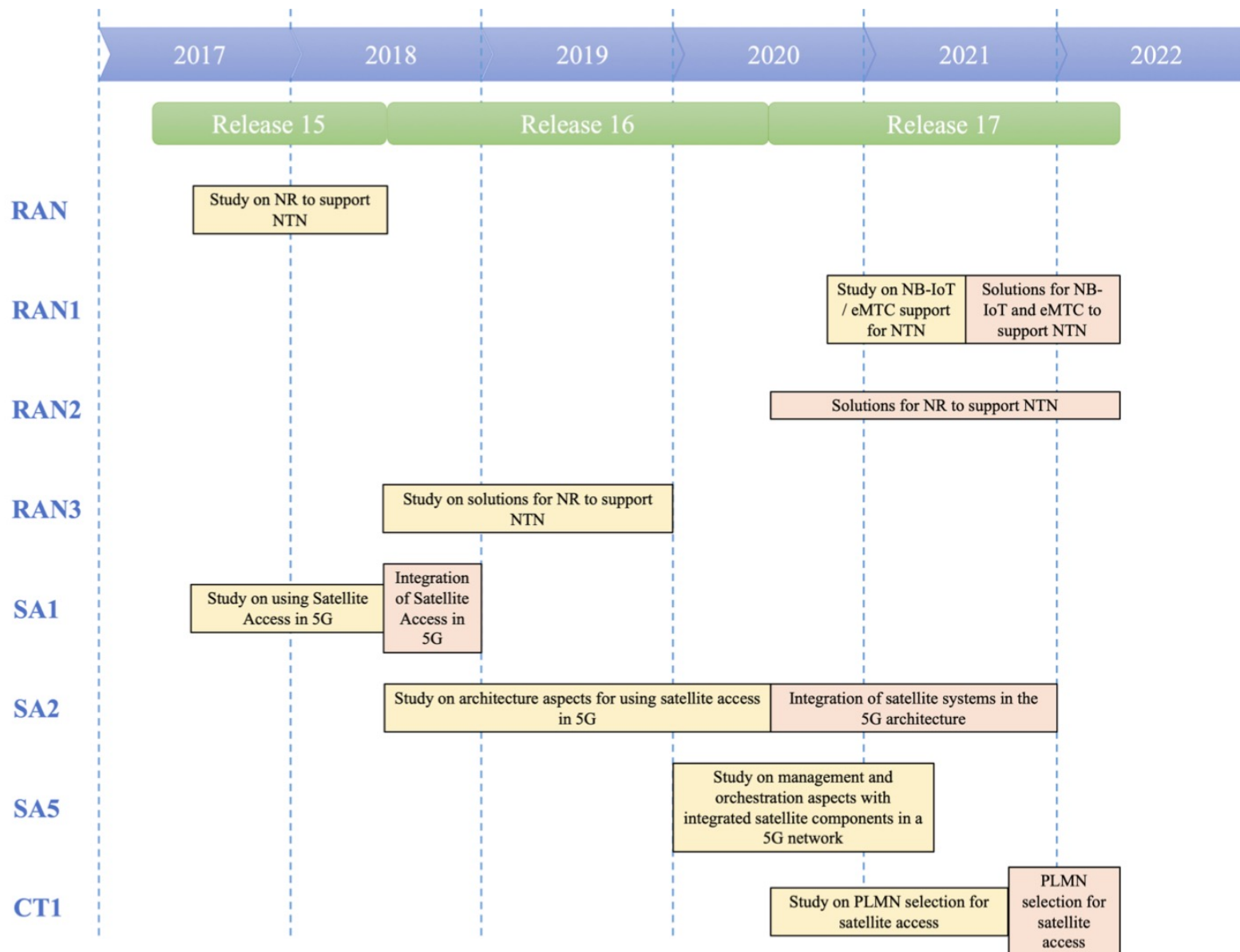


- Challenging for alignment and synchronisation aspects
- Xn over SRI to tightly coordinate the access characteristics
- Intra-satellite Multi-Connectivity

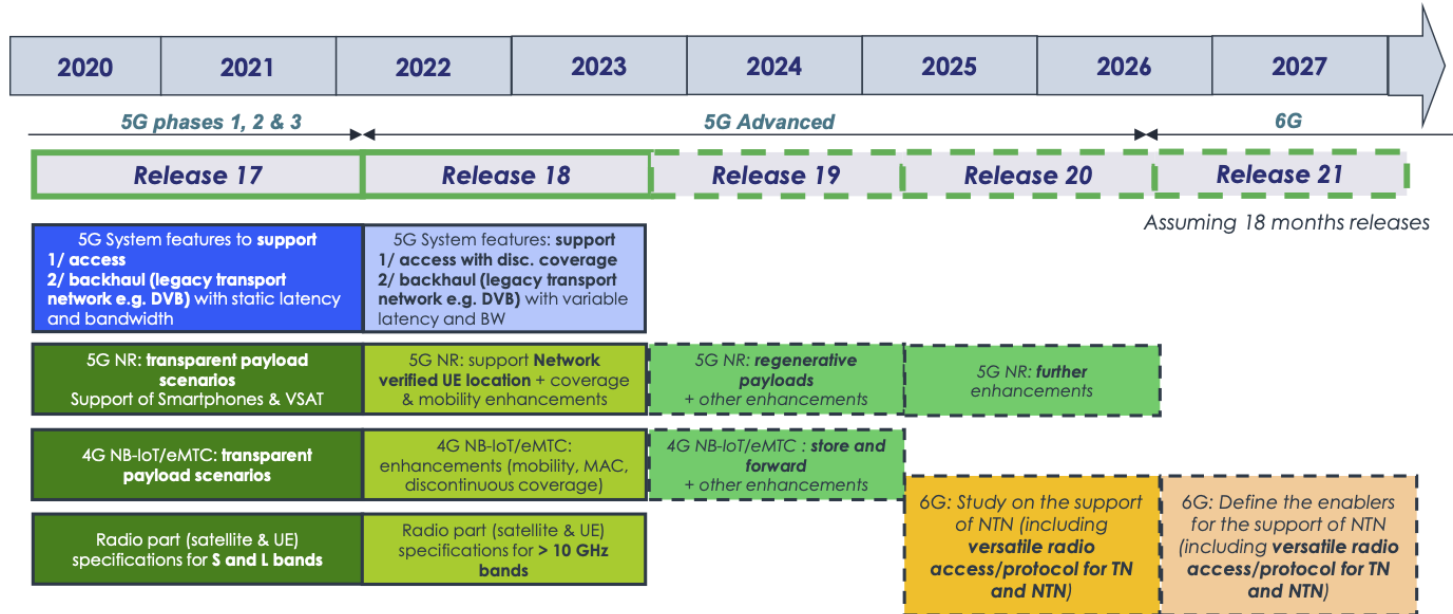
Architecture evolution: Multi-Layer Multi-Orbit Multi-Band 6G NTN



Standardisation roadmap up to Rel. 17



Technologies and standardisation roadmap: Rel. 18



- Rel. 18
 - mMTC: improving the performance in discontinuous coverage and deal with terminal mobility
 - eMBB
 - network-based UE location determination
 - coverage enhancements
 - NR- NTN deployment above 10 GHz and support for VSAT/ESIM terminals
 - NTN-TN and NTN-NTN mobility and service continuity enhancements

Item	Lead	Title	Completion
FS_5GET “Extra territoriality”	SA1	Guidelines for extra-territorial 5G Systems (5GS)	Dec. 2021
WI “NR_NTN-enh”	RAN2	Enhancements to Solutions for NR to support non-terrestrial networks (NTN)	Dec. 2023
WI “IOT_NTN-enh”	RAN2	Enhancements to Solutions for NB-IoT & eMTC to support non-terrestrial networks (NTN)	Dec. 2023
SI “FS_5GSAT_ARCH_Ph2”	SA2	5GC enhancement for satellite access Phase 2	Jun. 2023
SI “FS_5GSATB”	SA2	Study on satellite backhauling	Jun. 2023
SI “FS_eLCS_ph3”	SA2	Enhanced location services	Jun. 2023

Technologies and standardisation roadmap: Rel. 19+

- NTN-NTN asynchronous MC and CA
 - Beam management and Bandwidth Part (BWP) association enhancements
 - Complete support for HEO and MEO and hybrid multi-orbit architectures
 - Support of eMBMS
 - UE without GNSS
 - Relay-based architecture for NTN
 - MU-MIMO
- AI and ML
 - Next generation waveforms for PAPR reduction
 - NOMA and OTFS
 - Reflecting Intelligent Surfaces

5G-Advanced

6G

Conclusions



- The integration of a 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**
 - **Architecture evolution**
 - Regenerative payloads, relay-based access, MC
 - **Technology evolution**
 - Many technologies are candidate to be key enablers for 5G-A/6G NTN
 - NTN-NTN asynchronous MC and CA
 - UE without GNSS
 - Relay-based architecture for NTN
 - MU-MIMO
 - AI and ML
 - Next generation waveforms for PAPR reduction
 - Reflecting Intelligent Surfaces
 - ...
- For **future** NTN systems, we need to make a further technology leap **now**





- **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/>



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