FLEXIBLE AND UNIFIED AIR INTERFACE

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Co-funded by the European Union

6GSNS

General Task overview

Overall objectives

- Enhancement of the 3GPP-standarised air interface to support NTN in FR2 bands

Leverage on:

- Procedures specified in 3GPP Rel.17 & Rel. 18
- On-board processors, regenerative payloads and active antennas
- O-RAN Alliance approach to 5G RAN disaggregation

On-going activities

- Identify the modifications in the standard to supporting **beam hopping in NTN**
- Comparison of different **beam footprint layouts** in terms of EIRP, SNR and coverage ratio
- Analysis of different **mapping schemes between NTN beams and 5G NR cells**
- New **PRACH signal design and detection scheme** to increase the robustness to user positioning errors
- Comparison between NR OFDM and **OTFS**

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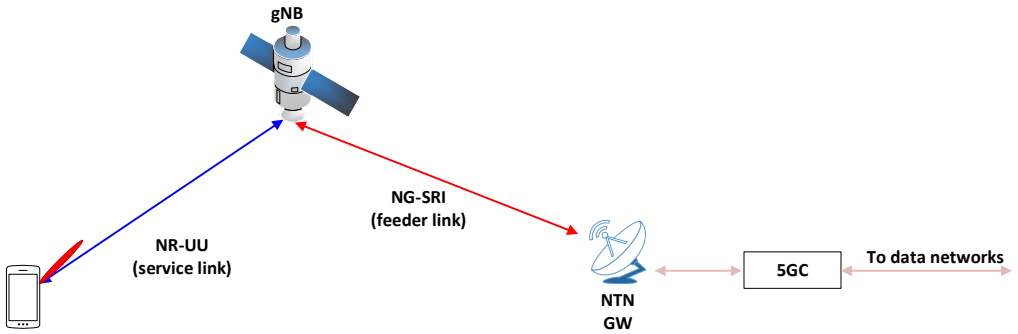
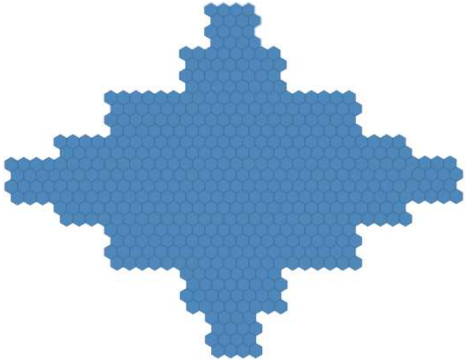
Reference satellite system

Regenerative architecture: The satellite hosts radio functions (full gNB or CU-DU split over feeder link)



Satellite antenna model

- DBF with 512 radiating elements
- 24 beams per antenna
- 200MHz per beam
- 65mW RF per radiating element on Tx
- The antenna spacing is 0.56λ



System and orbit parameters

Parameter	Inclined	Polar
Altitude	1300 km	1000km
Inclination	50°	99º
Number of planes	20	6
#sats per plane	11	13
Frequency band	Ka	
Satellite		
Max. sat antenna gain	31.76 dBi	
EIRP density	8.71 dBW/MHz	
Sat. G/T	13 dB/K	
UE	**Fixed**	**Mobile**
UE EIRP	60 dB	42 dB
UE G/T	8.8 dB/K	8.8 dB/K

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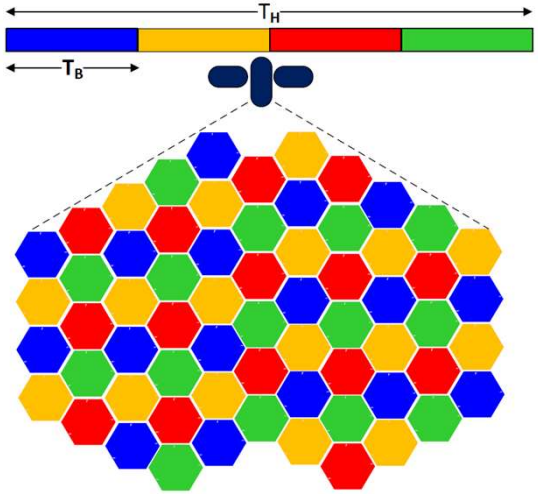
Beam hopping in NTN

Two management stages are defined:

- Transmission of information common to all users by **broadcast beams;**
- Transmission of user-specific information by data beams

Challenge: the satellite is not able to simultaneously illuminate all the broadcast beams. The need to cover the satellite file of view applies to:

- SSB, SIB1, other SIBs, paging and msg2/msg4 during the random access procedure (**DL**), the reception of msg1 during the random access procedure (**UL**)



Recommendation: Co-schedule signals to reduce the number of broadcast beams (e.g., SSB, SIB1) and select a beam illumination pattern that reduces co-channel interference

Impact on the standard:

- To enhance the coverage, the periodicity of DL and UL signals may need to be extended according to the hopping period

Open issues: adjust the periodicity according to the desired overhead and access delay

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Beam footprint layout

The reference satellite constellation deploys **Earth-fixed beams**:

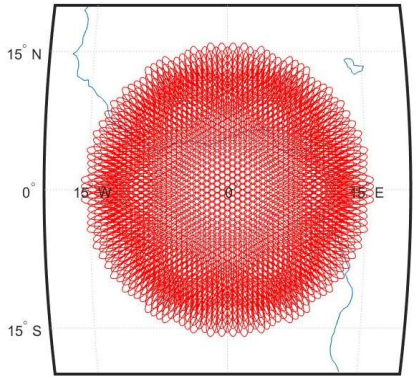
- A stationary user is served by the same beam during the satellite visibility window
- Mimic terrestrial deployments and reduce the number of HOs

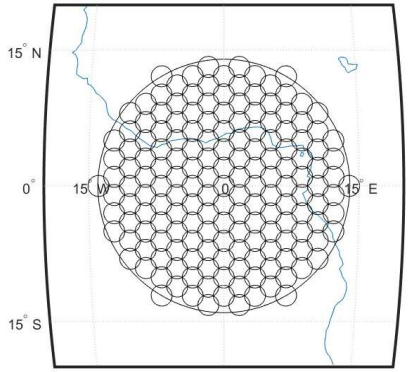
Based on the grid, different solutions are evaluated:

- **Maximum EIRP:** Dense homogenous grid according to footprint radius at Nadir
- **Uniform beams:** beam widening (aperture truncation keeping unchanged the Tx power)
- **Compromise solution:** tradeoff EIRP, number or beams and beam overlapping

Solution	Minimum beam radius (Km)	Minimum Beam Gain (dBi)	Number of beams	Simultaneous beams for reference SNR=3.3dB	Required resources for broadcast
Maximum EIRP beams	41.3	28.9	1723	24	72
Uniform beams	129	22.1	169	4	43
Compromise solution	64.6	28.2	703	12	59

Open issues: compute the optimal tradeoff implementing phase tapering solutions to widen the beams





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COVERAGE ENHANCEMENTS

Due satellite power and feeder-link bandwidth limitations, only a subset of beams in the satellite coverage can be illuminated simultaneously

	3GPP REFERENCE SCENARIO	MAX. EIRP	5G-STARDUST
Number of beams	800	1728	700-800
Active beams	12	24	10-12
Maximum BW	400 MHz	200 MHz	200 MHz
Coverage ratio	1.5%	1.39%	1.25%-1.7 %
SCS	120 KHz	120 KHz	120 KHz

Solutions:

- Option 1: SSB/SIBs periodicity extension -> Impact on the cell search time
- Option 2: Wider beam footprint and larger beam separation for SSB/SIBs -> Impact on EIRP
- Option 3: Combination of Options 1 and 2 (not mutually-exclusive)

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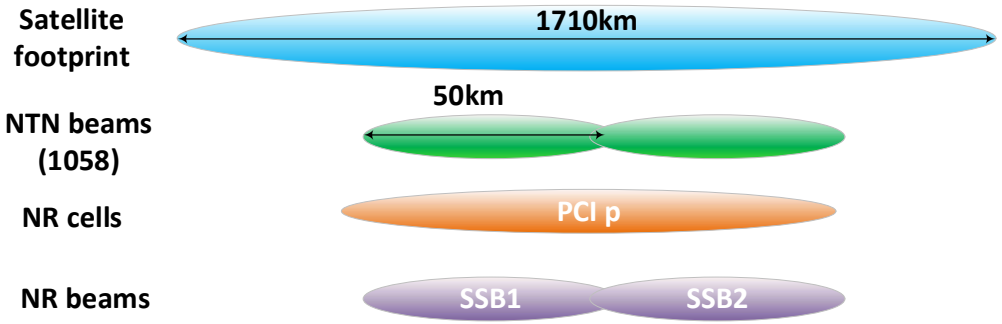
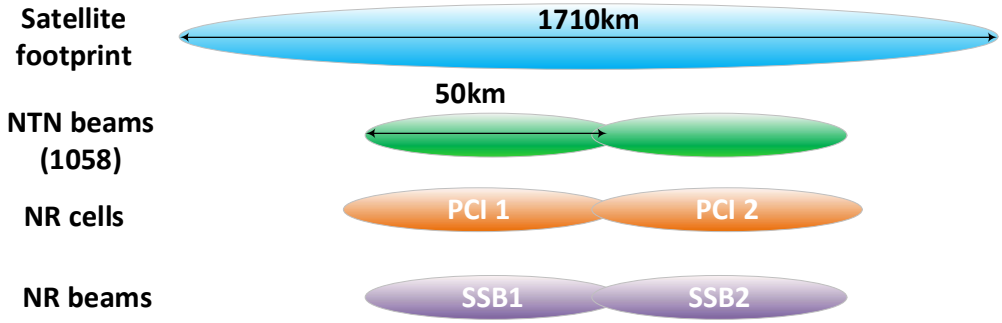
CELL MAPPING SCHEMES

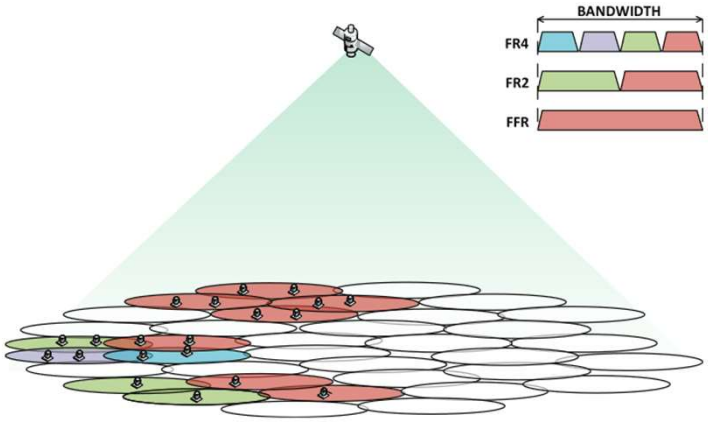
Multi-Satellite beam cell and multi NR beam cell



Single NR cell per satellite beam and single NR beam cell



- The satellite coverage area is divided into multiple beams
- Full frequency reuse setup would require all beams to operate on the same frequencies, leading to potential interference issues
- Adopting beam hopping or frequency reuse can minimize inter-beam interference



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Cell mapping and SSB multiplexing

Challenge:

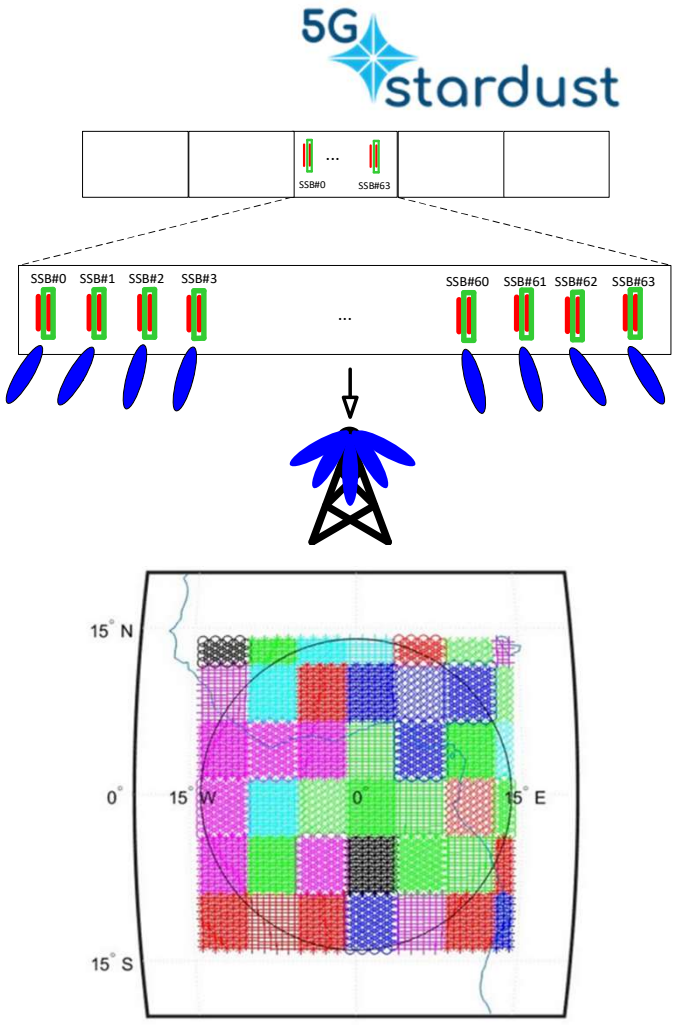
- The standard only considers 64 blocks per SSB burst (one per direction)
- Novel SSB multiplexing schemes are needed to serve more than 64 beams

Proposed Cell mapping and SSB multiplexing:

- Repeat the SSB index in latitude and longitude dimensions according to a rectangular pattern
- Create clusters of 64 beams and manage each cluster as a cell
- At the same dwell time, the satellite illuminates a beam from a different cell
- One beam active per cell to avoid cell DTX/DRX (clusters==active beams)
- Clusters can be allocated the same SSB pattern

Way forward:

- Beam size to SNR trade-off taking into account the SNR requirements of control signals
- Design number of clusters



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Random access

Motivation:

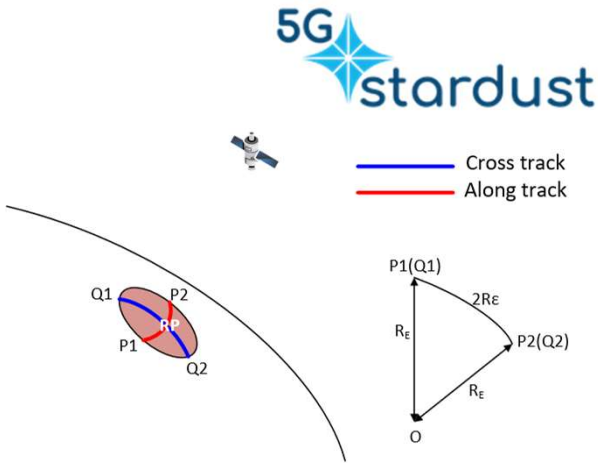
- In the basic configuration, UE exploits positioning capabilities and the satellite ephemeris to pre-compensate RTT delay and Doppler frequency shifts
- If GNSS is not available, alternative positioning methods based on the 5G-NR waveform shall be used. In some situations, UE positioning errors could be in the order of km

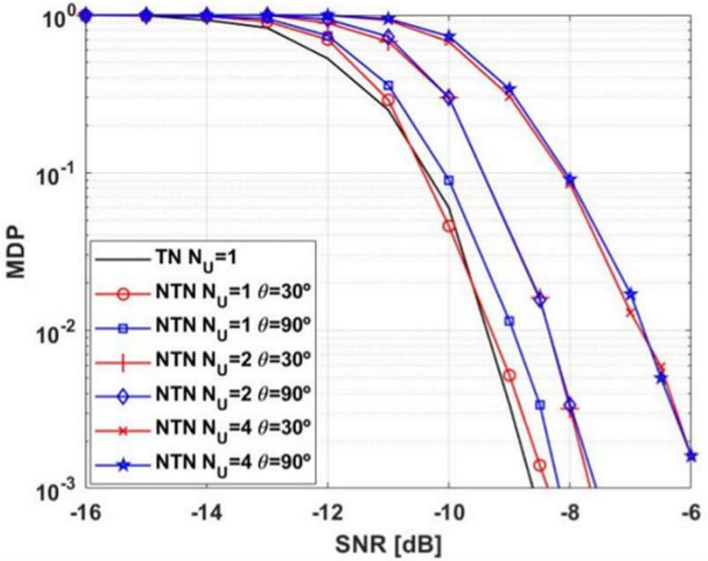
Challenge: In presence of UE positioning errors, attachment is not possible, as the random access procedure fails

Approach: New PRACH signal design and detection scheme is proposed to enhance the robustness to time and frequency misalignments

Results: MDP<1% for SNR>-8dB. LEO 1300 km operating at Ka band. UE positioning error up to 5 Km.

Impact on the standard: CP and GI need to be extended





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5G-STARDUST project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101096573. This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

MULTI-LINK AND NETWORK CONTROL ASPECTS IN AN INTEGRATED 5G/6G+NTN NETWORK ARCHITECTURE

Workshop Hexa-X-II and NTN related projects

Virtual, 7 November 2024

Daniele Tarchi

CNIT, Italy

TASK 5.2

AI Data Driven Network Management and Slicing

Lead: CNIT

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AI Data Driven Networking

D5.3: Preliminary report on AI-data driven networking and QoS management

- Submitted on 20/06/2024

Definintion a proper framework for the networking management of the 5G-STARDUST architecture.

O-RAN has been considered as the reference framework

- Proper elements have been defined by extending them to the case under study

End-to-End (E2E) Network Architecture definition considering the impact of the different elements in both direct and indirect connectivity scenarios.

Non-Real time and Near Real-time processes are taken into account

Controller definition with different possible options

- Impact of the ML blocks.

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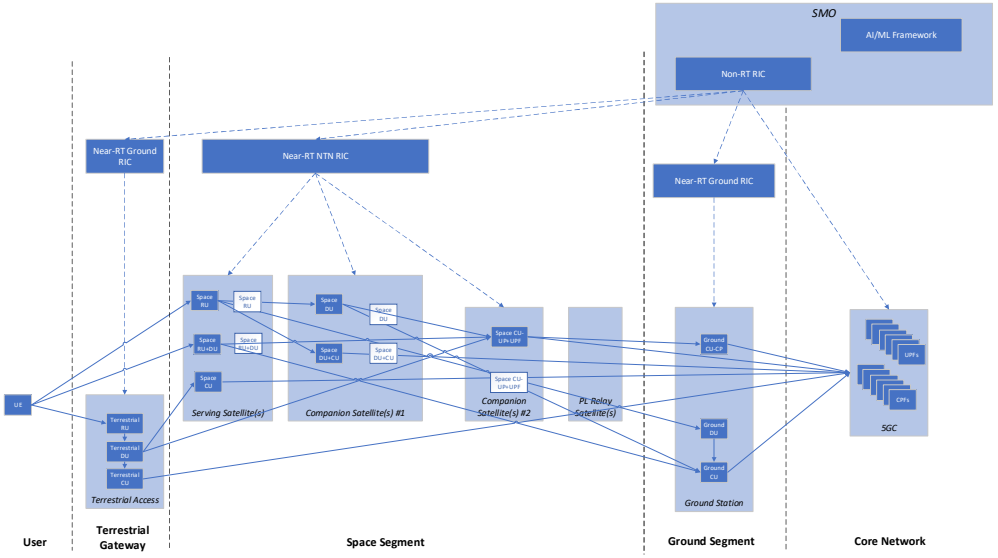
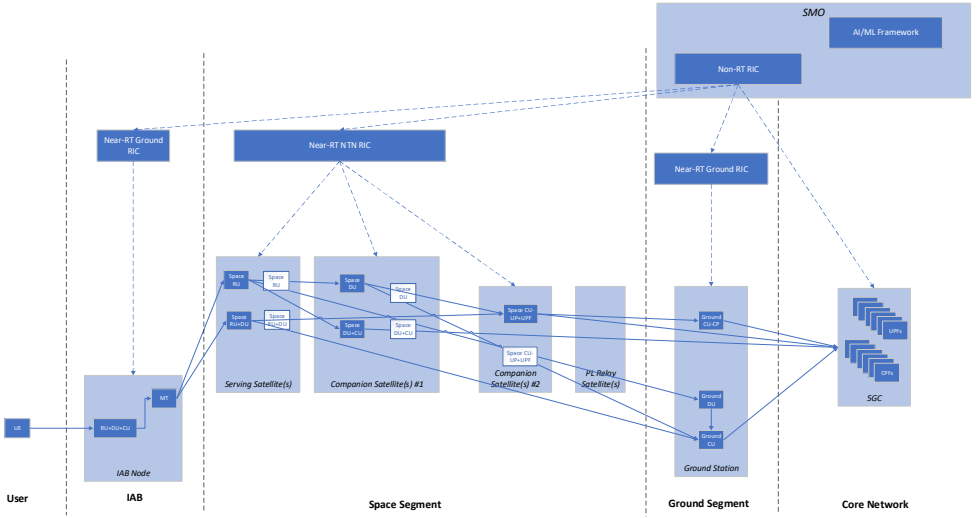
O-RAN based E2E Architecture

DIRECT CONNECTIVITY



INDIRECT CONNECTIVITY



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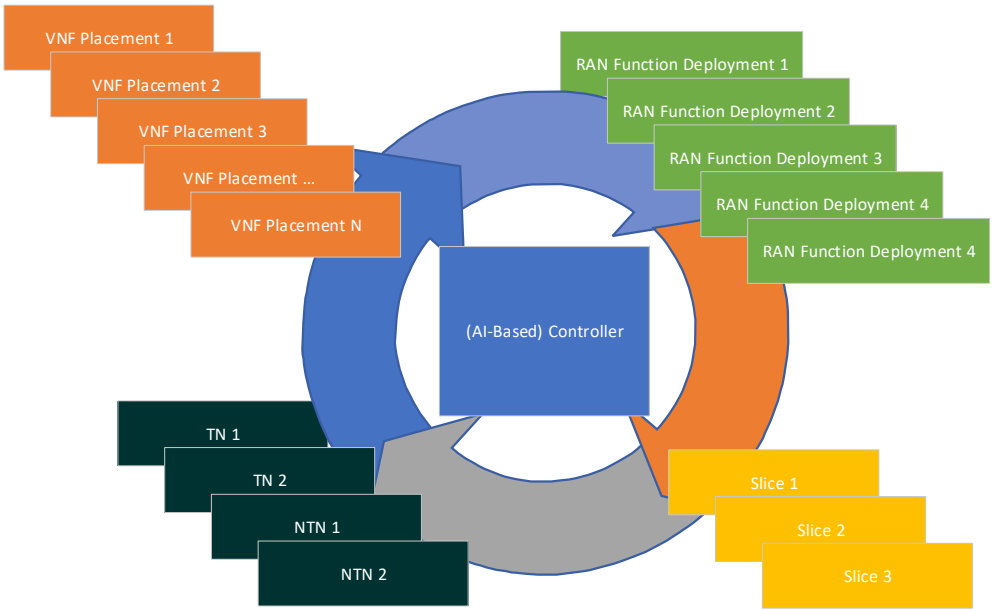
NETWORK CONTROLLER ACTIONS

The network elements to be managed/controlled/optimized are discussed.

The goal is to have an optimal placement of the VNFs, depending on their requirements, on the network configurations, and different slicing options.

The controller, eventually AI-based, works by managing four different elements



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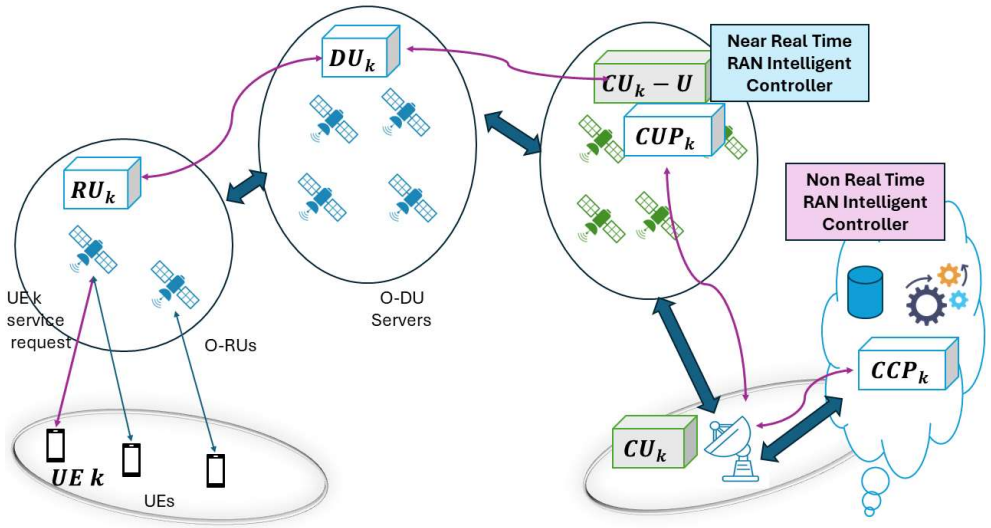
RAN Function Deployment

Several possible options for the deployment of the RAN functions

The possible set of RAN functions including RU, DU, and CU correspond to the set of stack function functions of the O-RAN protocol.

Core networking functions can be also deployed where the Core User Plane (CUP), and the Core Control Function (CCP) are considered

EXAMPLE: OPTION 7



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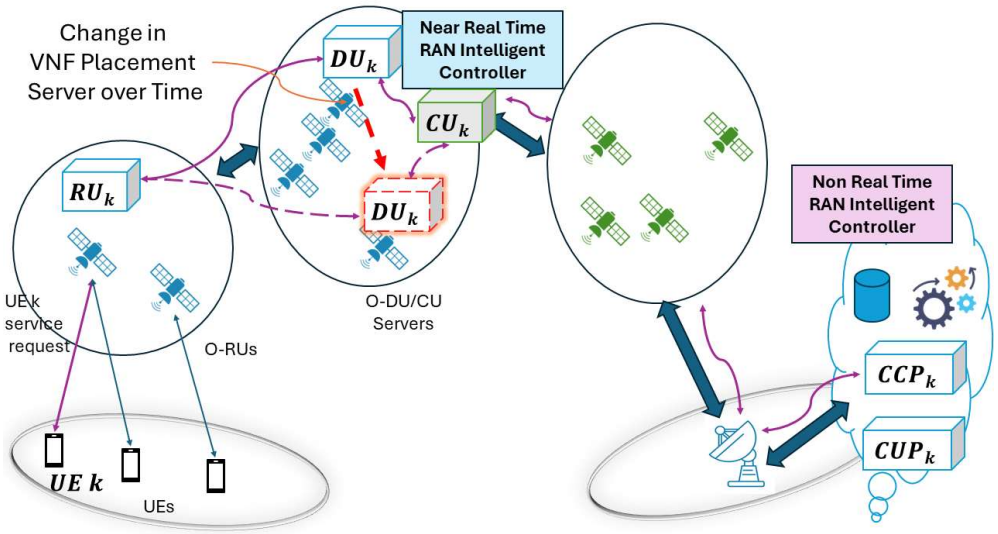
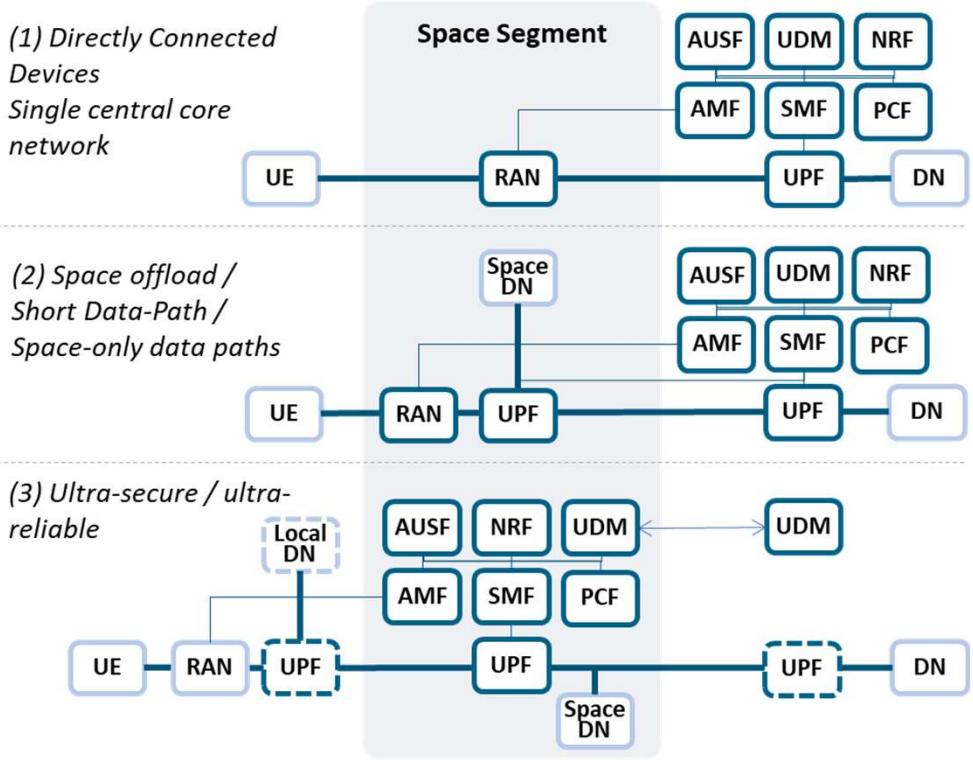
VNF Placement

RAN VNF PLACEMENT



CORE NF PLACEMENT



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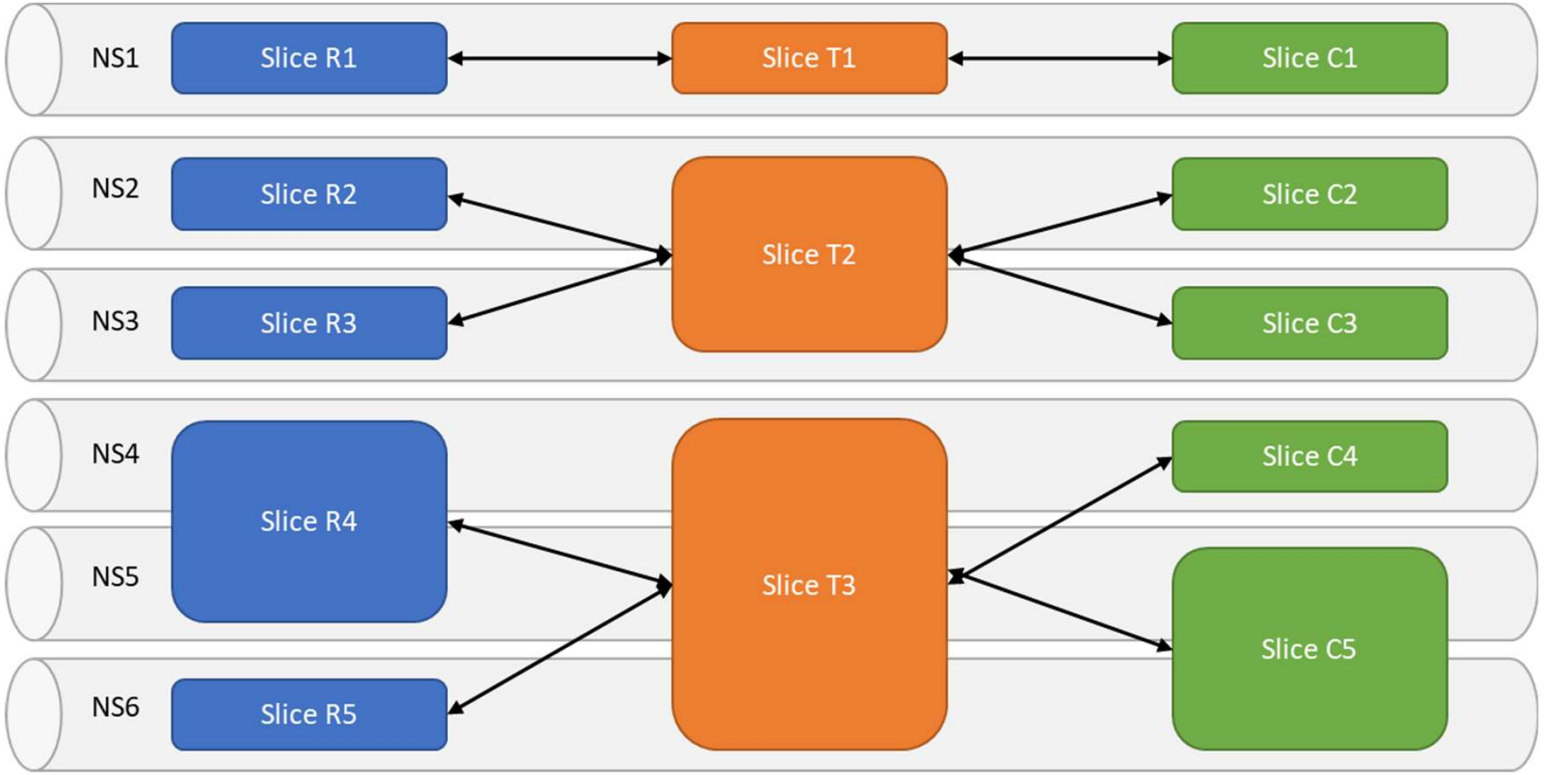
Network Slicing

END-TO-END NETWORK SLICES - DEDICATED AND SHARED



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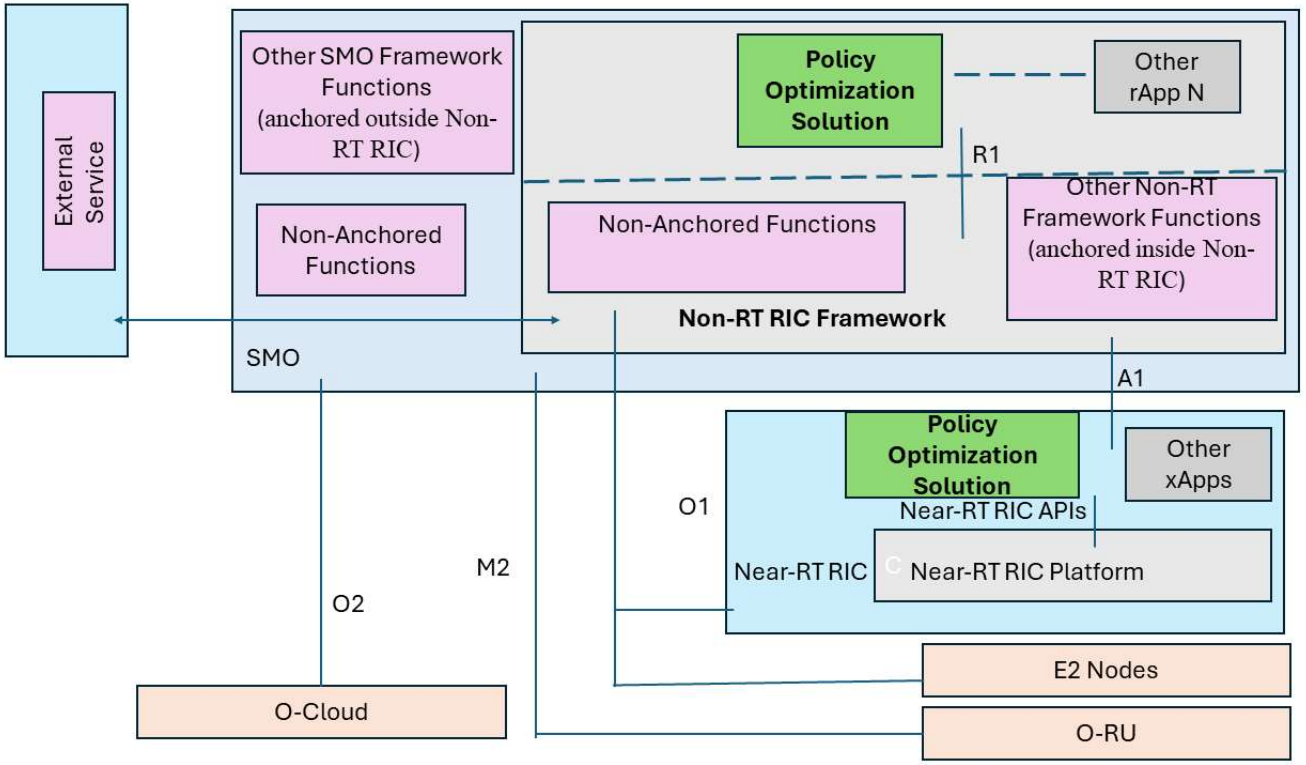
Controller Framework

TRADITIONAL OPTIMIZATION SOLUTIONS



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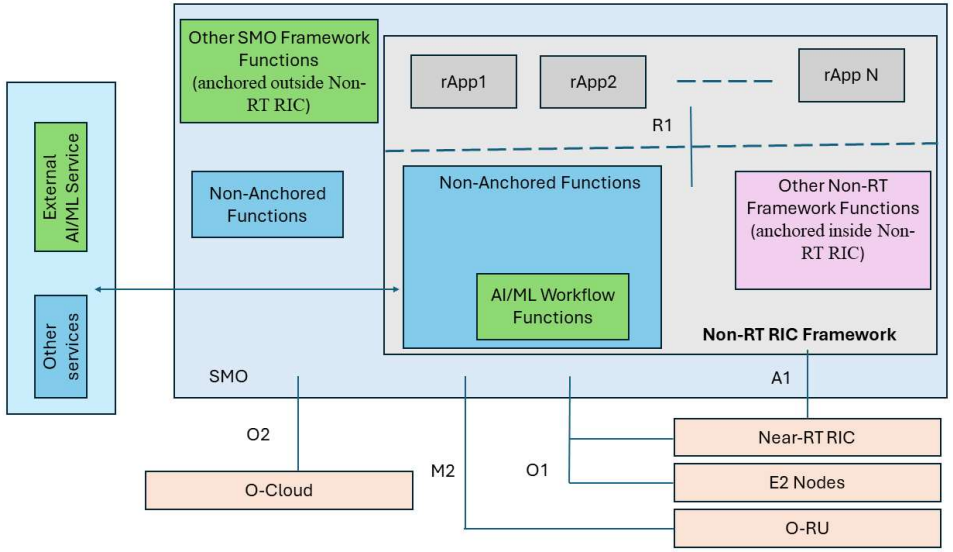
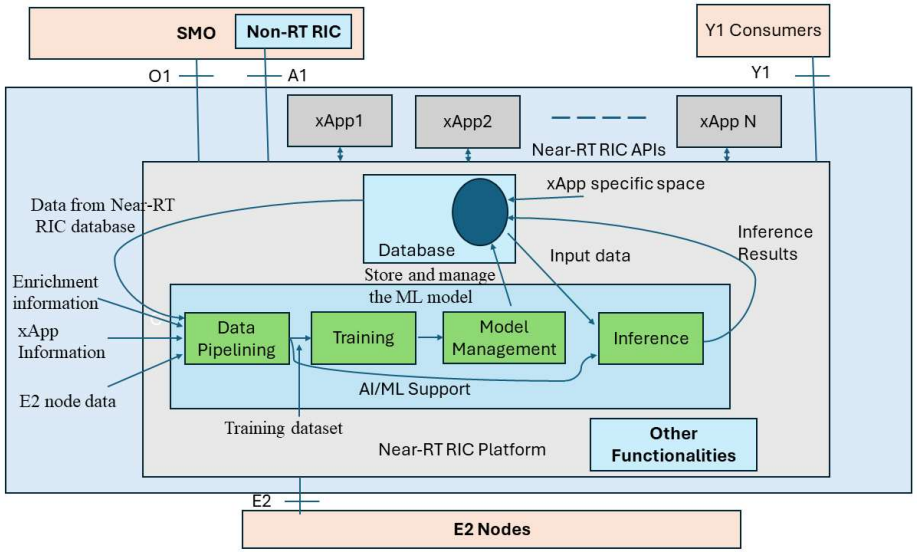
AI-based solutions

O-RAN NON-RT RIC ML FUNCTIONALITIES



O-RAN NEAR-RT RIC ML FUNCTIONALITIES



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