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6GNTN

O-RAN based Non-Terrestrial Networks: Trends and Challenges

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  - research and develop the **innovative technical, regulatory, and standardization enablers** needed to ensure the **full-fledge integration of the NTN component** into the 6G system to meet **vertical industries and consumer market** expectations

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

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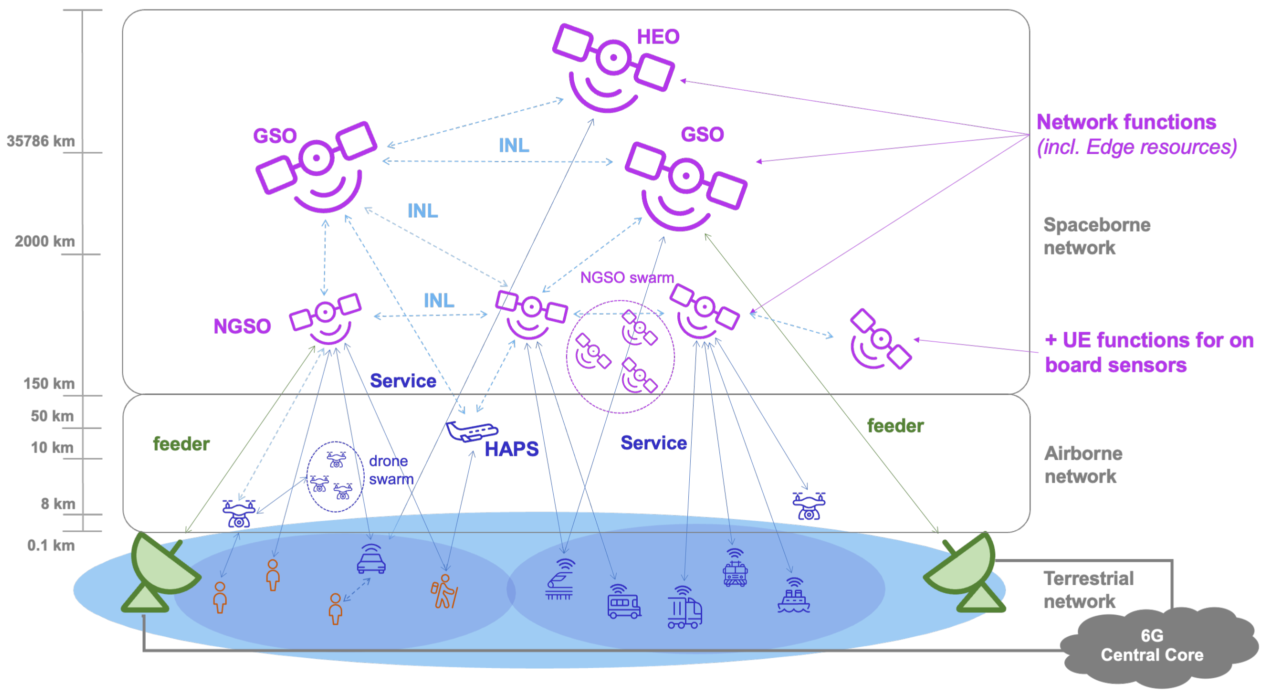
Introduction

- One of the enabling elements of B5G and 6G system will be the integration of Non-Terrestrial Networks (NTN) into terrestrial ones.
- To ensure a proper integration it is required:
  - autonomous network monitoring and management
  - *data-driven optimization of network functions enabled by AI*
- This concepts are enforced by the Open RAN paradigm (O-RAN).
- Extension of O-RAN to the NTN component.



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

Objective

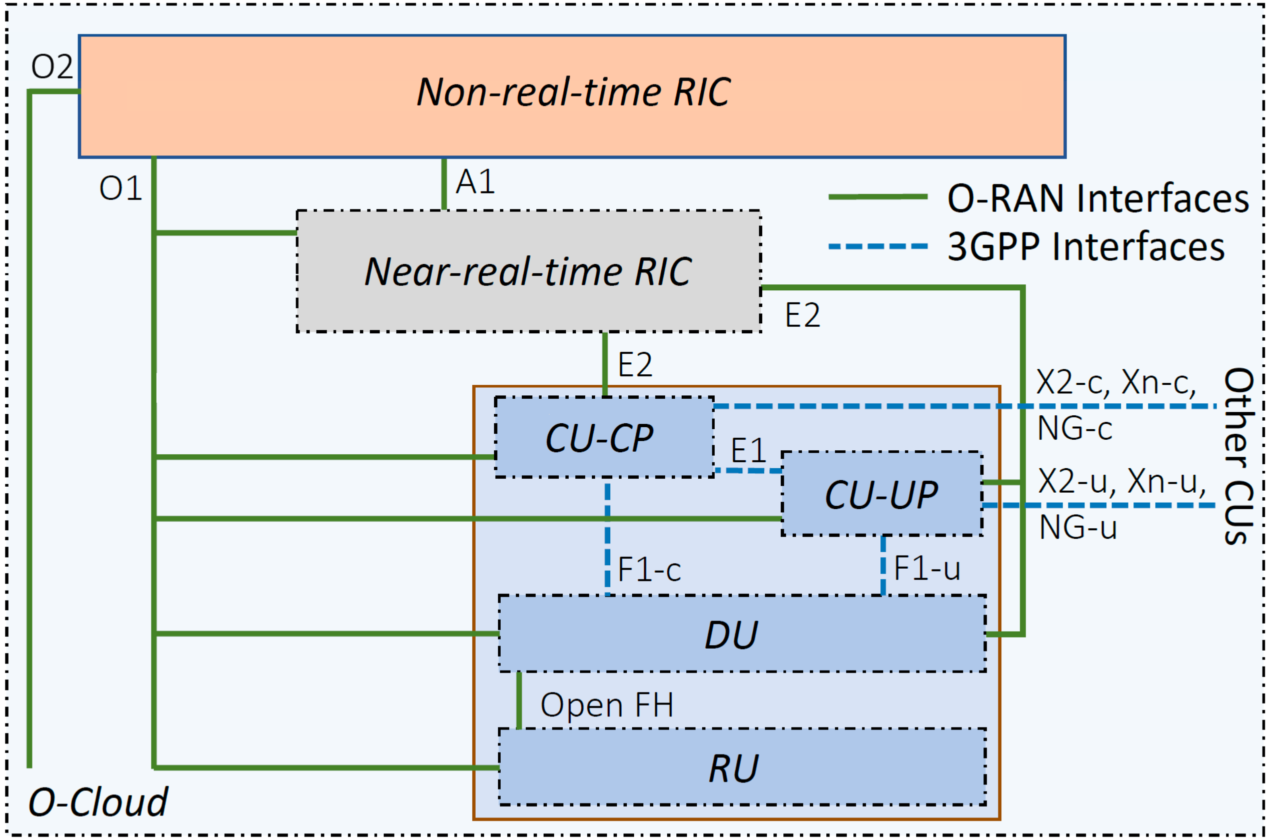
In this paper, we *identify a possible* ***architecture solution for an O-RAN-based NTN*** *system and we highlight the O-RAN implementation trends with the potentiality of increasing the NTN system efficiency.*

- *We identify the functions of the NTN system that can be optimized and enhanced by fully exploiting the O-RAN concept*
- *An analysis of the O-RAN implementation trends is provided highlighting their advantages along with the brought challenges*

Open RAN Architecture

It is based on the concepts of:

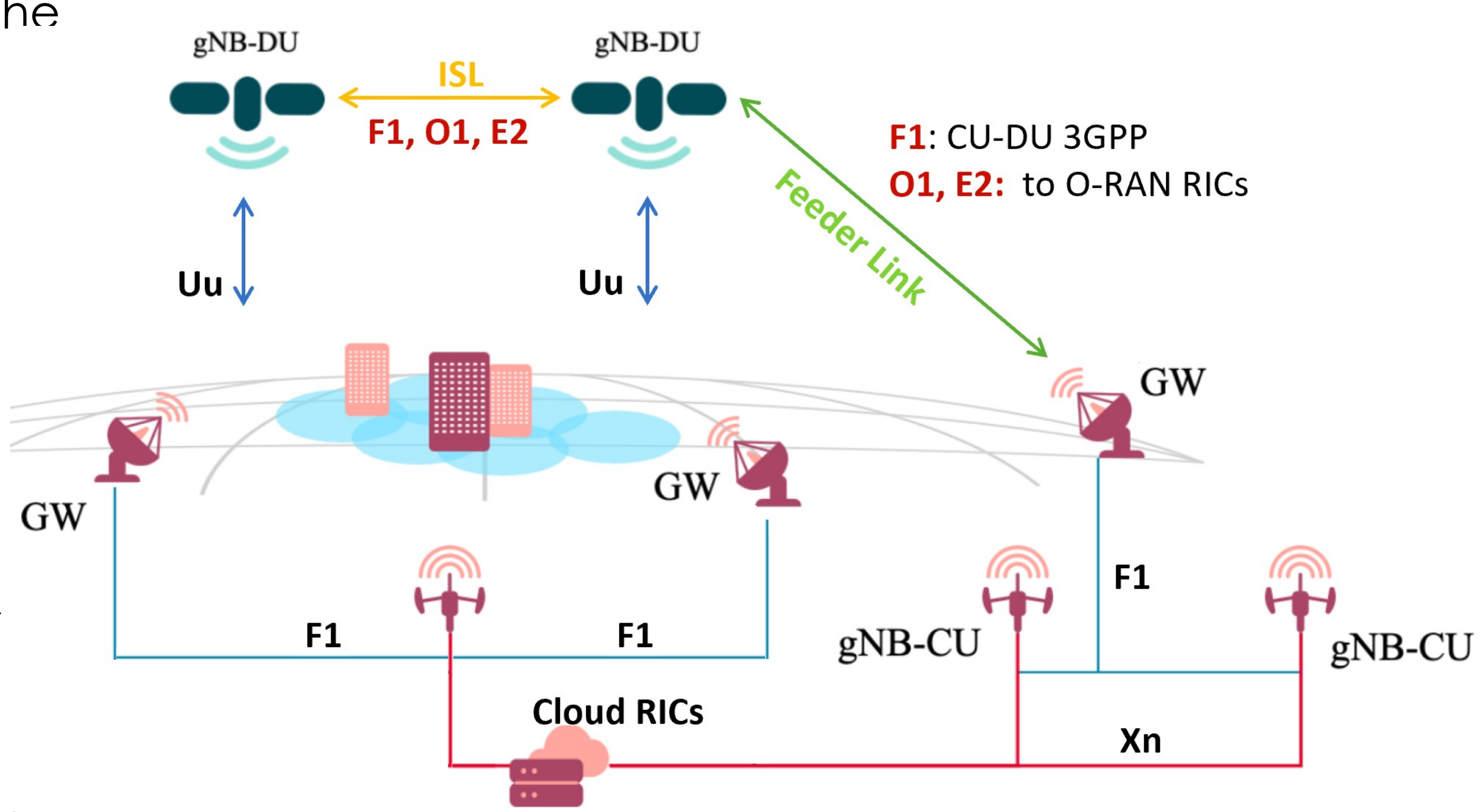
- Disaggregation
- Virtualization
- RAN Intelligent Controllers (RIC)
- Open Interfaces



M. Polese et al., "Understanding O-RAN: Architecture, Interfaces, Algorithms, Security, and Research Challenges," Aug. 2022, arXiv:2202.01032

NTN System Architecture

- **Terrestrial Segment**: interconnects the gNB-CUs with the 5GC and the GWs
- **User segment**: potentially massive number of UEs
- **Access segment**:
  - Regenerative nodes
  - The node embarks the full gNB or part of it (Functional split)
  - The nodes are connected to the terrestrial segment trough the GWs or ISLs



O-RAN in NTN: Architectural design aspects

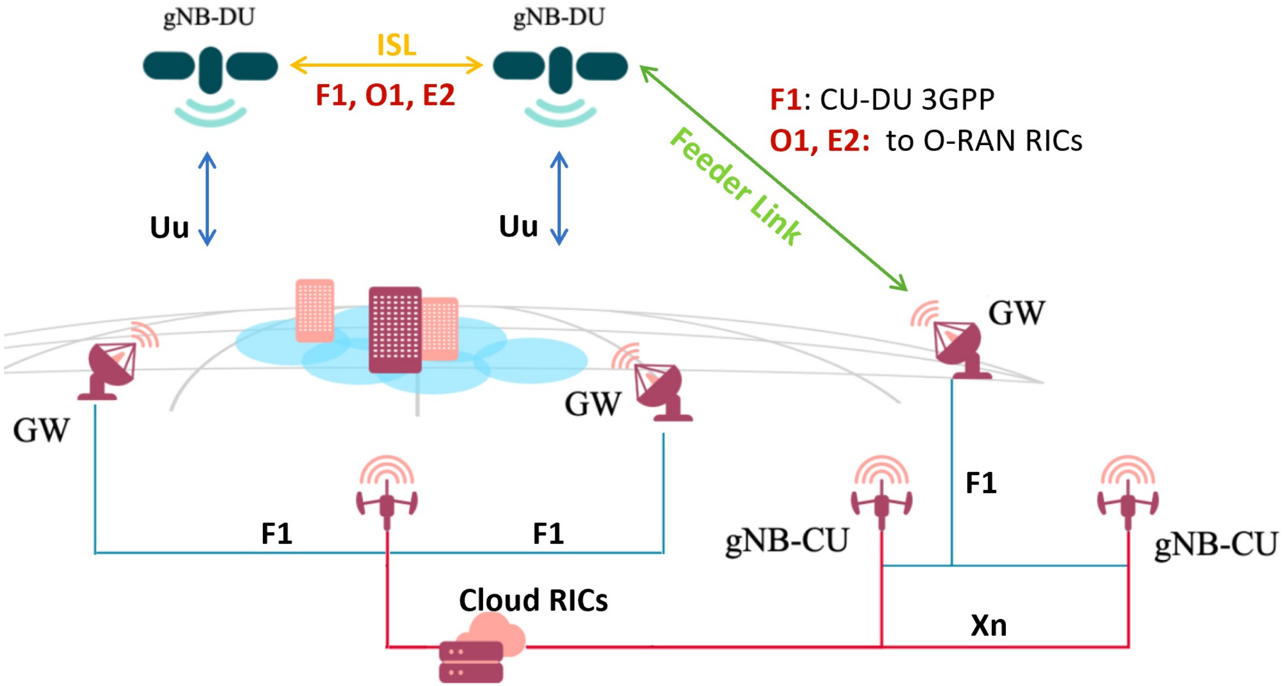
While adapting the O-RAN concept to NTN, we focused on:

- the network entity in which the O-RAN components are implemented;
- the physical links to which the O-RAN interfaces are mapped.

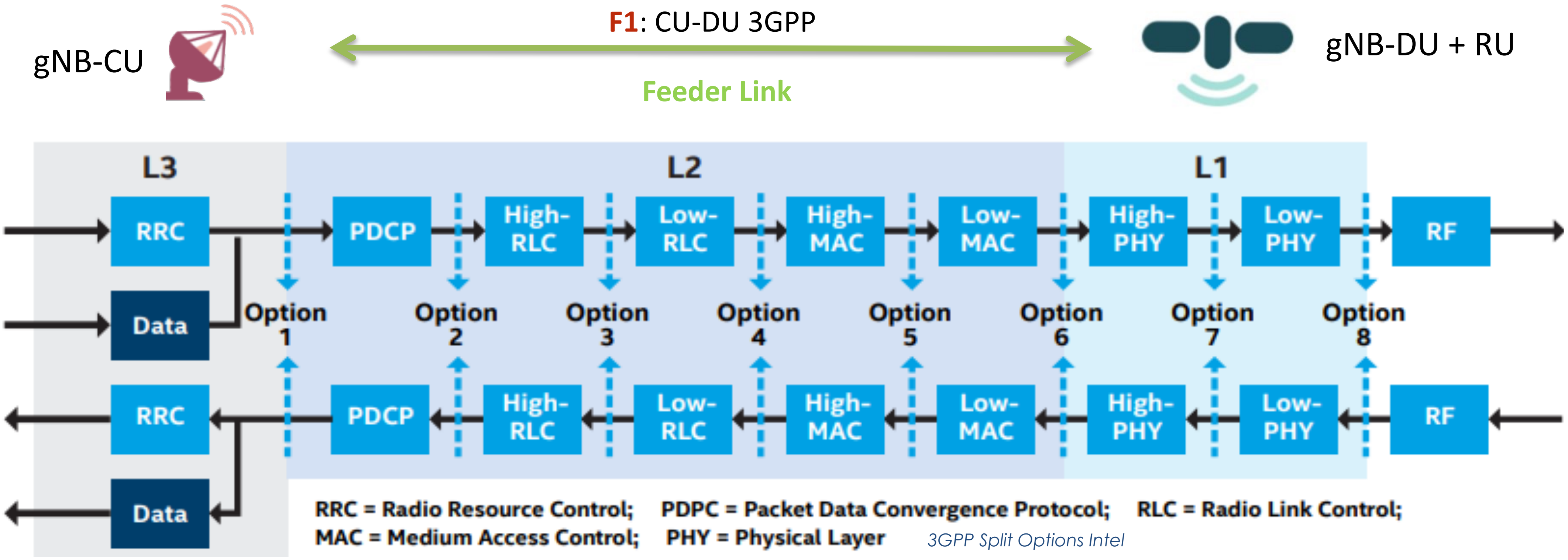
The **RICs are implemented in the cloud**, interconnected through the ground distribution network.

3GPP and O-RAN interfaces mapping:

- **NR-Uu** air interface is mapped on the **user access link**.
- **3GPP F1 and O-RAN O1 and E2** interfaces are mapped on the **Feeder Link and Inter Node Links**.



gNB Functional Split in NTN



Increase interface required performances

Increase NTN node required computational power

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Future Trends

Future Trend: Dynamic Functional Split Optimization

The **near-RT RIC** will be in charge of:

- **computing the optimal functional split** based on the collected network status data;
- **redeploying the network functions** in the CU and DU according to it.

the near-RT RIC application will need to be an **AI algorithm**, in order to:

- foresee the future behaviours and needs of the network;
- optimize the functional split in advance.

Functional Split Optimization: *onboard payload energy consumption*

The comm. payload **power is a scarce resource**, and it is **not constant in time.**

This AI operates by **collecting data from the network** about:

- Type and volume of requested user traffic;
- Payloads computational power capabilities;
- Payloads instantaneous available power;
- CU-DU physical feeder link instantaneous throughput and latency.

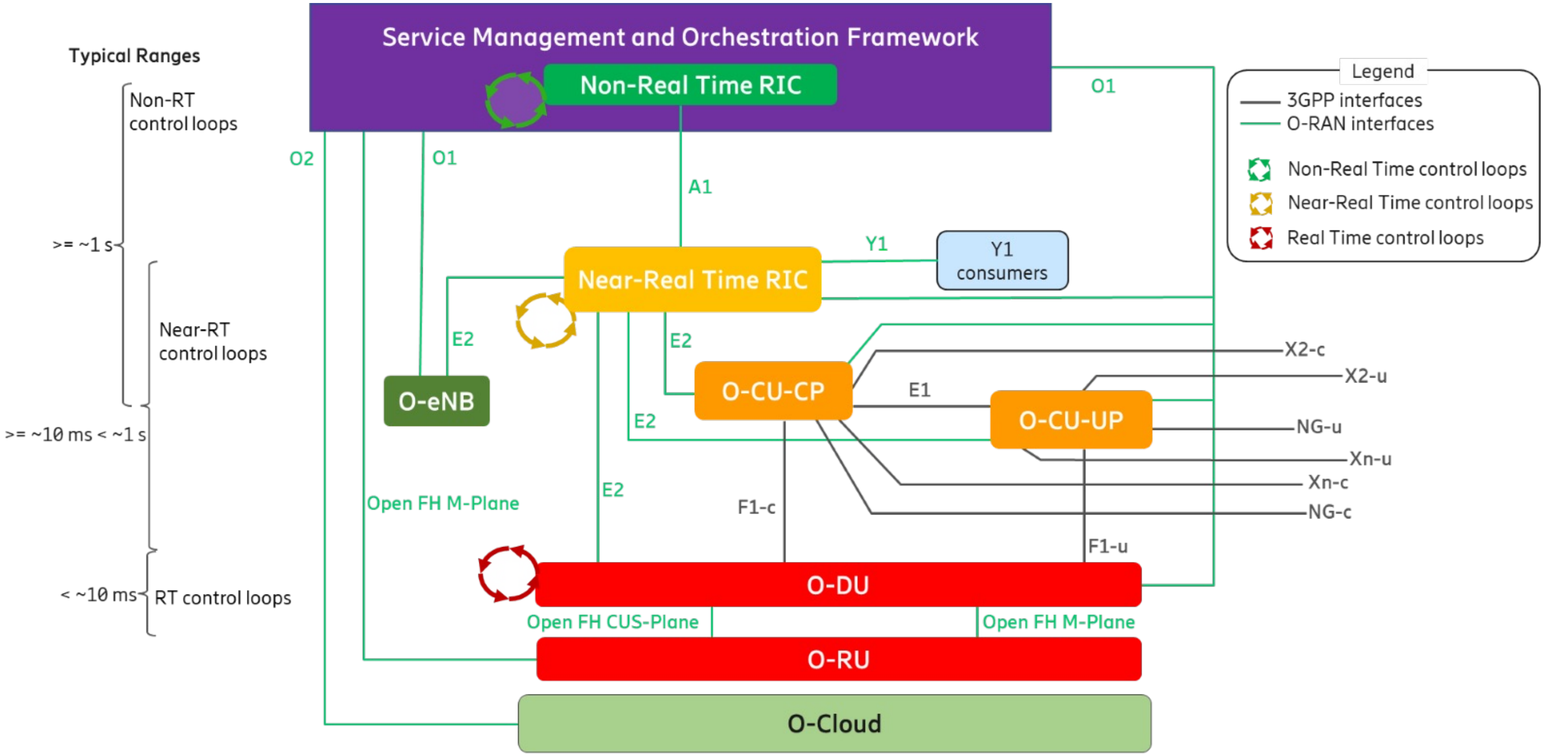
An **AI app** in the near-RT RIC will be able to select and implement the optimal functional split that allows to:

- Minimize the payload energy consumption;
- guaranteeing an appropriate Quality of Service (QoS).

Future Trend: Data-driven Optimization of NTN RAN

The O-RAN based NTN architecture enables:

- The **collection of KPIs from the network** nodes (E2 and O1) through the open interfaces;
- The exploitation of the collected data to **train the AI/ML models in the RICs**;
- The exploitation of the input KPI data and trained AI/ML models to **optimize the RAN configuration parameters**.



O-RAN architecture description 5.00, O-RAN, Alfter, Germany, Jul. 2021.

Data-driven Optimization: Wide-Scale Radio Resource Management

Current NTN architecture:

- RRM optimization is restricted to the **point of view of a single satellite**

O-RAN enabled NTN architecture:

- Dynamic RRM performed **at constellation scale**.

The AI app in the near-RT RIC will need to **collect information about:**

  - The area traffic demands and user locations;
  - The satellite ephemeris to identify the best scheduling options based on ancillary information.

The RIC based approach to RRM will introduce:

- **Longer latency in the scheduling computation** compared to on-board AI solution; but
- A **comprehensive optimization** of the resources.

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Challenges

Challenge: Onboard gNB Functional Flexibility

The dynamic functional split requires an **high functional flexibility on the payload**.

That grade of flexibility can be met by:

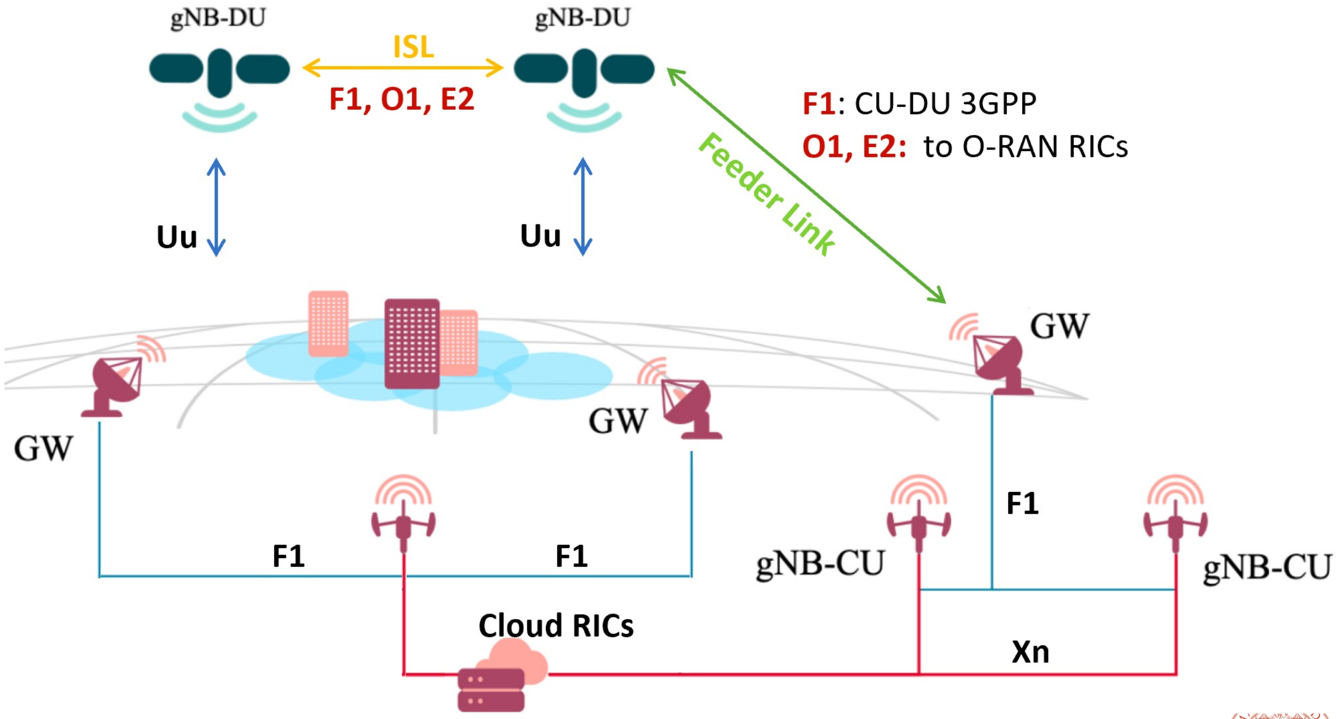
- Relying on **general-purpose computing** processors.
  - Computing technology currently available is **not fully compliant with NGSO**.
- Implementing the single RAN functions on **specialized and isolated hardware** that can be individually activated.
  - Implies high complexity design and **poorly exploited payload** hardware.

→ Currently applicable to low-capacity services

Challenge: Reliable Delivery of F1 Interface PDUs

- The **F1 interface is a constantly available logical link** between the CU and the DUs.
- In NGSO constellations there is the need for **feeder link and INL handovers**.

- The **F1 is made logically always available** adding a layer of abstraction.
- This can cause late **delivery or loss of a consistent number of PDUs**, currently not foreseen by 3GPP.
- introduction of **near-RT RIC to route the F1 PDUs** towards an active link



Challenge: Global Distribution of the RAN Optimization Functions

- The near-RT RIC has not a global view of the network.

- It is challenging to **serve the DUs from different RICs while orbiting** around the earth

- This is can be addressed in two ways:

  – **Implementing over-dimensioned near-RT RICs** to keep in memory the data and applications of all the RAN elements, even the ones not in visibility; or

  – **Exchanging the data and applications between the near-RT RICs** when it is needed, causing an increased load on the non-RT RIC in charge of managing the near-RT RICs.

Conclusion

Leveraging O-RAN is possible to **enhance the performance of NTNs** by means of:

- The full exploitation of AI relying on data-collection pipelines and centralized intelligence
- The optimal allocation of RAN functions to the different network nodes;

In order to meet this ambitious goal it is necessary to address the following **challenges**:

- Onboard gNB Functional Flexibility;
- Reliable Delivery of F1 Interface PDUs;
- Global Distribution of the RAN Optimization Functions.

Future works foresee the **evaluation of these use cases** through system simulators.

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