5G-STARDUST: The Role of AI to Boost NTN to Next Level

5th NTN Workshop: Towards a unified TN-NTN system

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Tomaso de Cola

German Aerospace Center (DLR)

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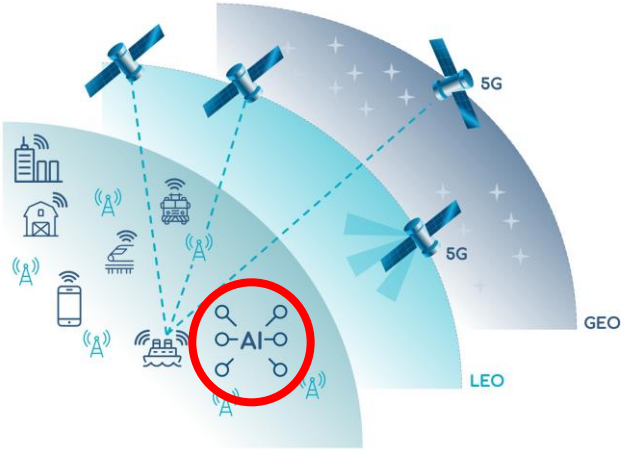
6GSNS

PROJECT AMBITION

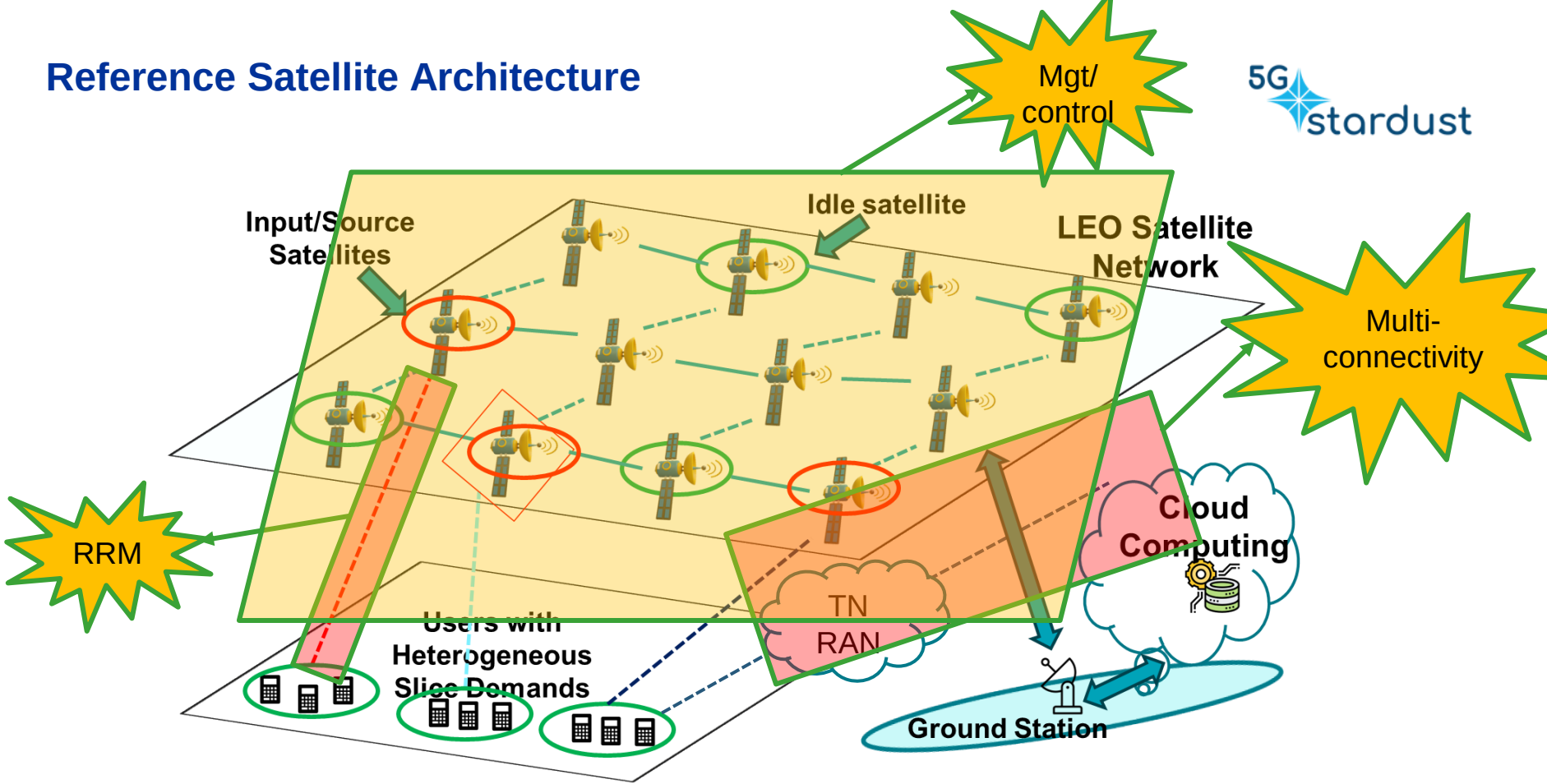
Design, develop and demonstrate a deeper integration of TN and NTN:
Deliver a fully integrated 5G-NTN autonomous system with novel self-adapting end-to-end connectivity models for enabling ubiquitous radio access.

KEY TECHNOLOGIES



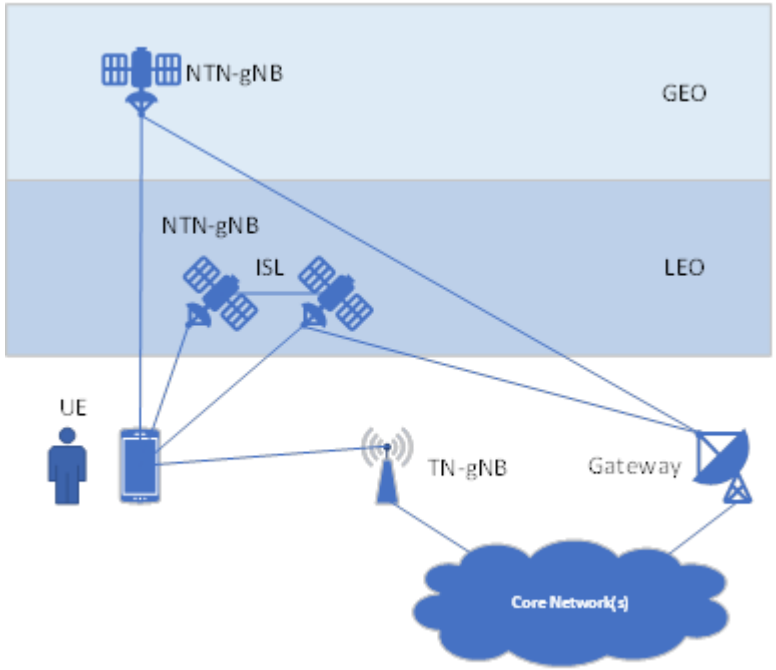
- *Regenerative payloads for GEO and NGSO systems*
- *Unified radio interface for cost-effective converged TN/NTN multi-tenant networks*
- *Softwarised self-organised network architecture*
- *E2E AI-Driven Network Design*

Reference Satellite Architecture

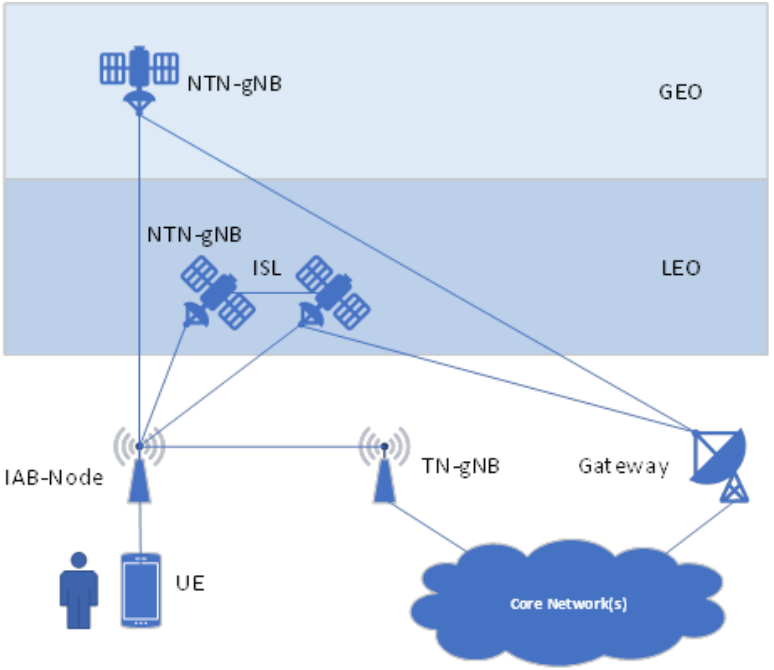


Multi-Link Connectivity Scenarios

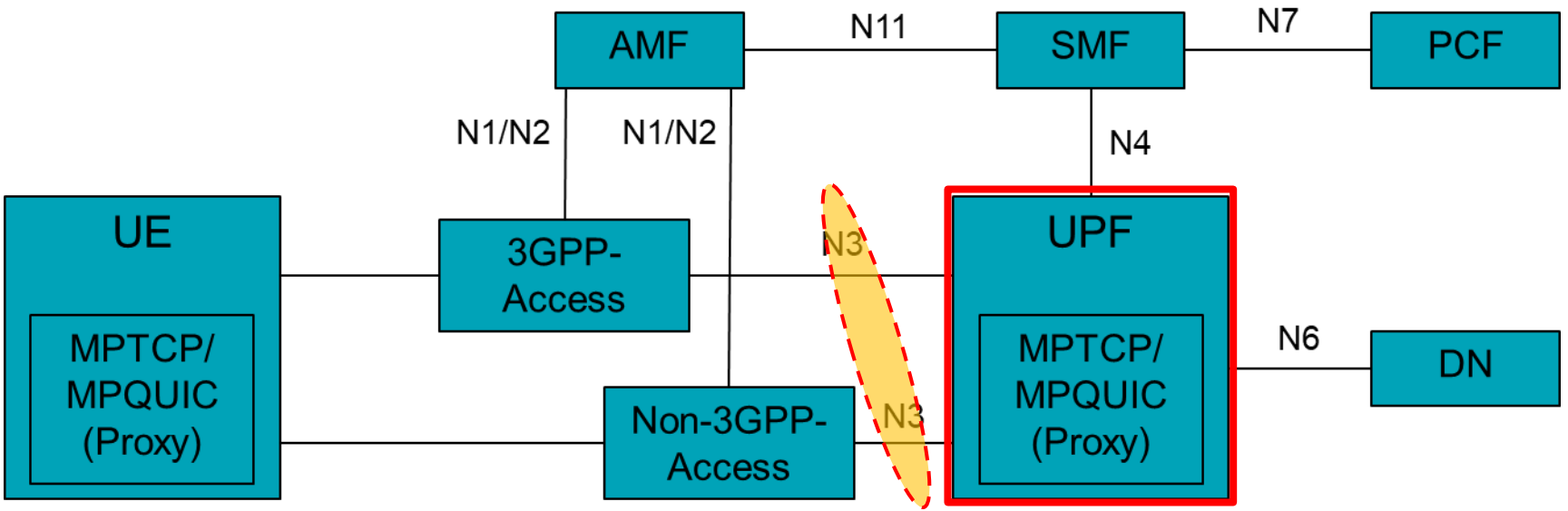
DIRECT ACCESS



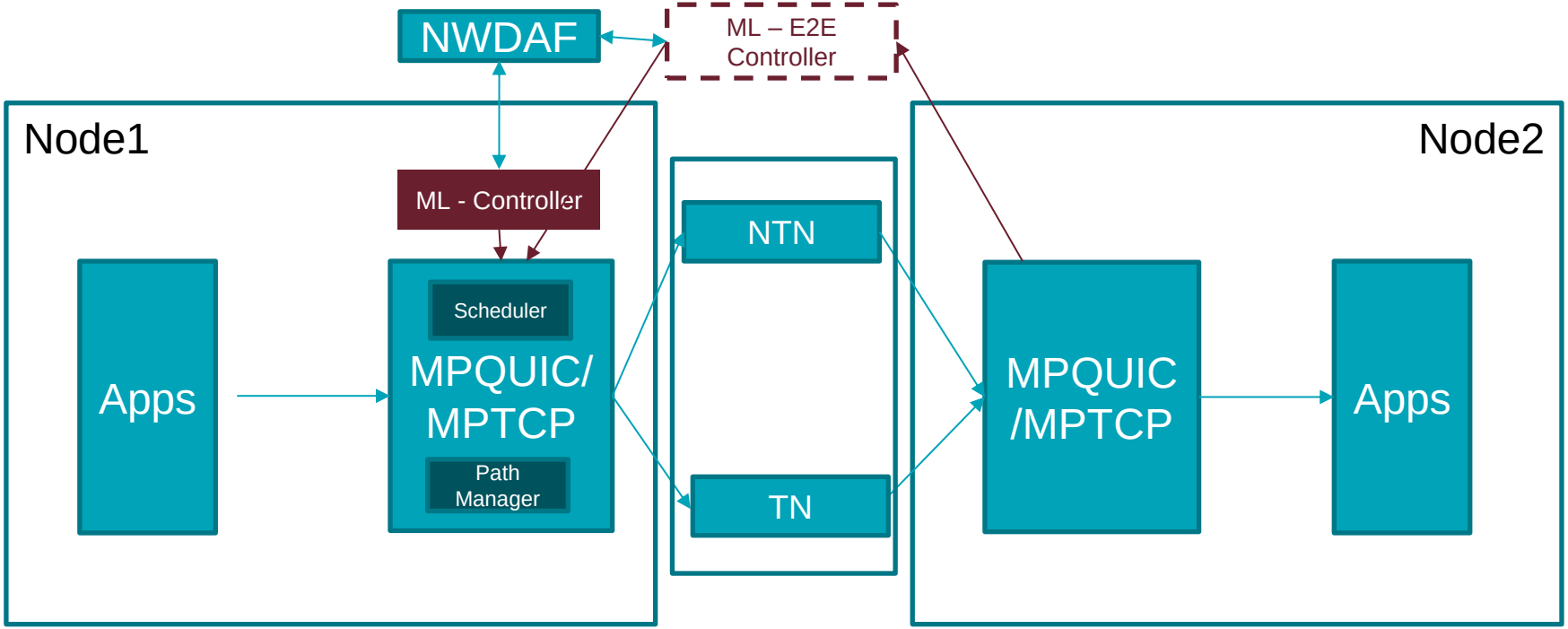
INDIRECT ACCESS



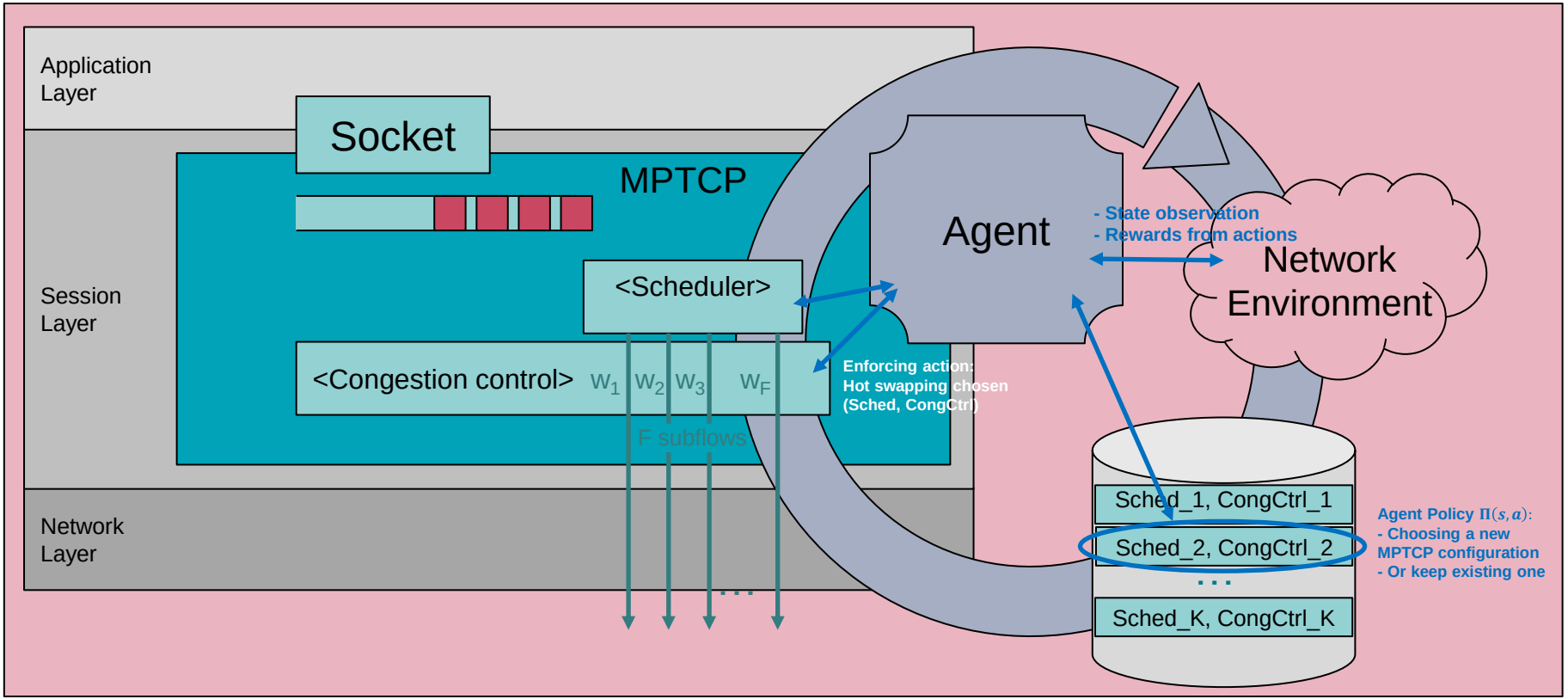
ATSSS in the Overall 5GS Architecture



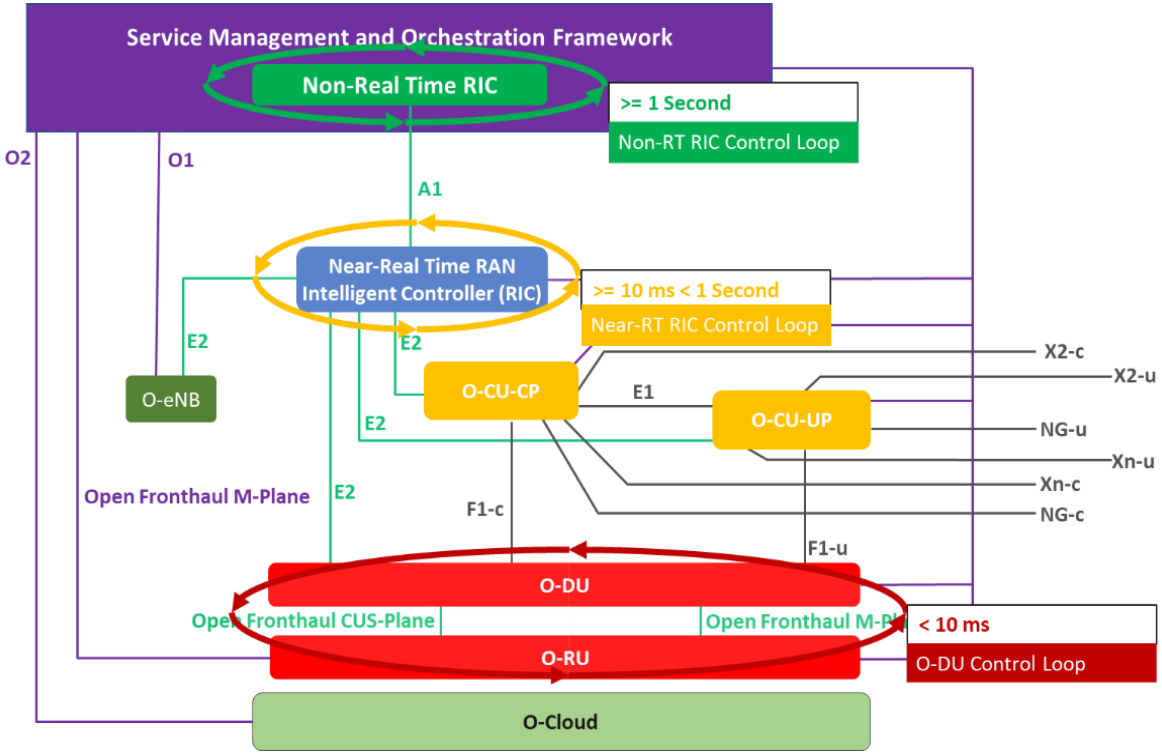
A Simple Implementation



Multi-Path Scheduling Optimisation via AI



Power is nothing without control…



Identified Non-real time RIC problems

- **DATA-DRIVEN BANDWIDTH ALLOCATION**
  - Data-driven bandwidth allocation for the aggregated traffic.
  - The aim is **to decide the number of PRBs that are needed among multiple NTN beams to serve all the users**.
  - **rApps can pre-allocate PRBs on a large timescale** based on the traffic demand.
  - Traffic forecasting is in the core of the problem.

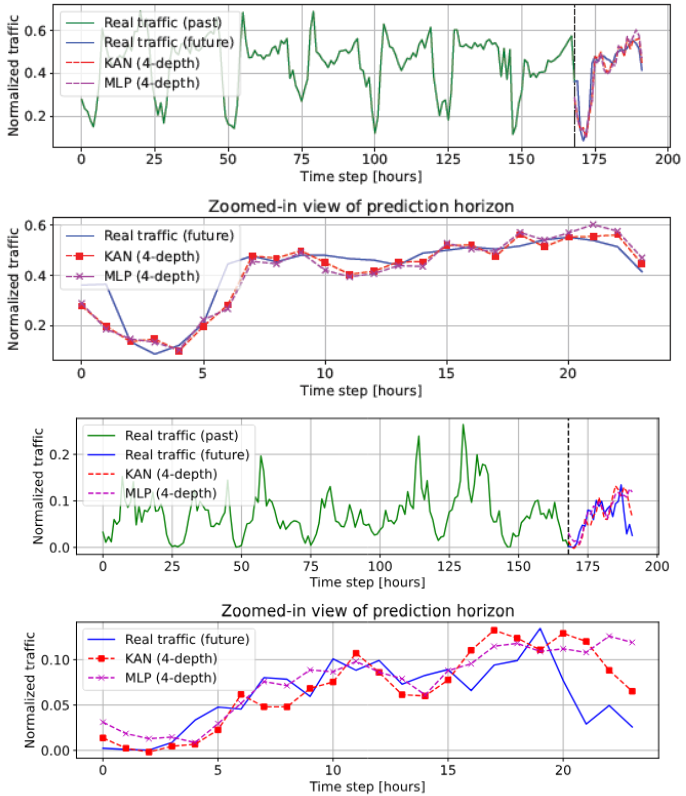
- **TRAFFIC OFFLOADING**
  - **RAN consumes most of the energy** of the cellular network
  - Traffic load in some regions (e.g. rural areas, technopoles) is usually low at nights.
  - **NTN nodes could be used to offload TN traffic during nighttime**.
  - **TN cells or carriers could switched off** in low traffic periods.
  - Complementary scenario (traffic offload at peak hours) is a use case of 3GPP for NTN.

Traffic forecasting and data-driven BW allocation

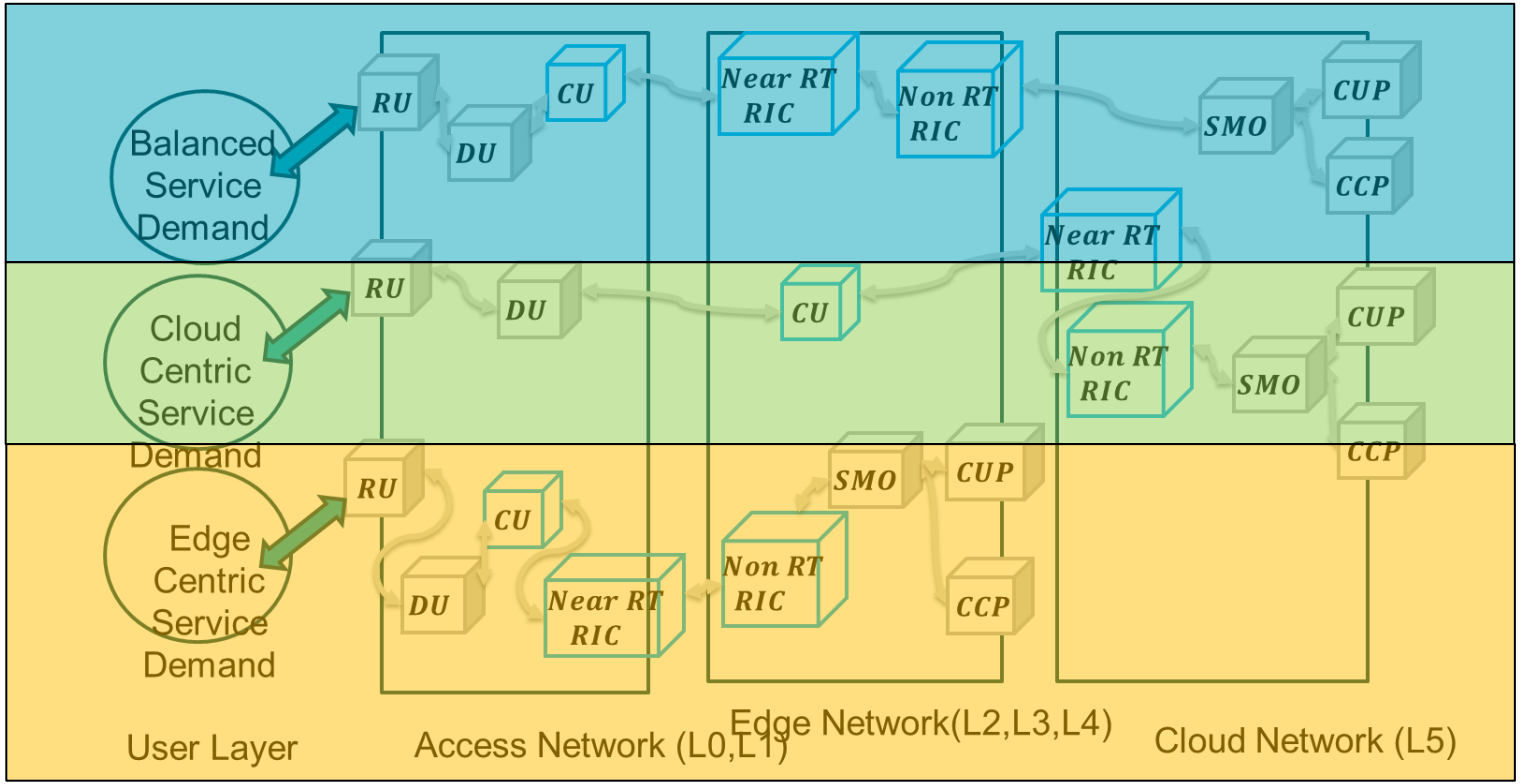
- **Evaluation in real-world HSP traffic dataset**
- Measure forecast capabilities of **Kolmogorov-Arnold Networks (KANs)**
- **KANs can achieve higher or comparable forecasting accuracy with simpler and potentially faster models.**

Table 2: Results summary

Model	MSE ($\times 10^{-3}$)	RMSE ($\times 10^{-2}$)	MAE ($\times 10^{-2}$)	MAPE	Parameters
MLP (3-depth)	6.34	7.96	5.41	0.64	238k
MLP (4-depth)	6.12	7.82	5.55	1.05	329k
KAN (3-depth)	5.99	7.73	5.51	0.62	**93k**
KAN (4-depth)	**5.08**	**7.12**	**5.06**	**0.52**	109k

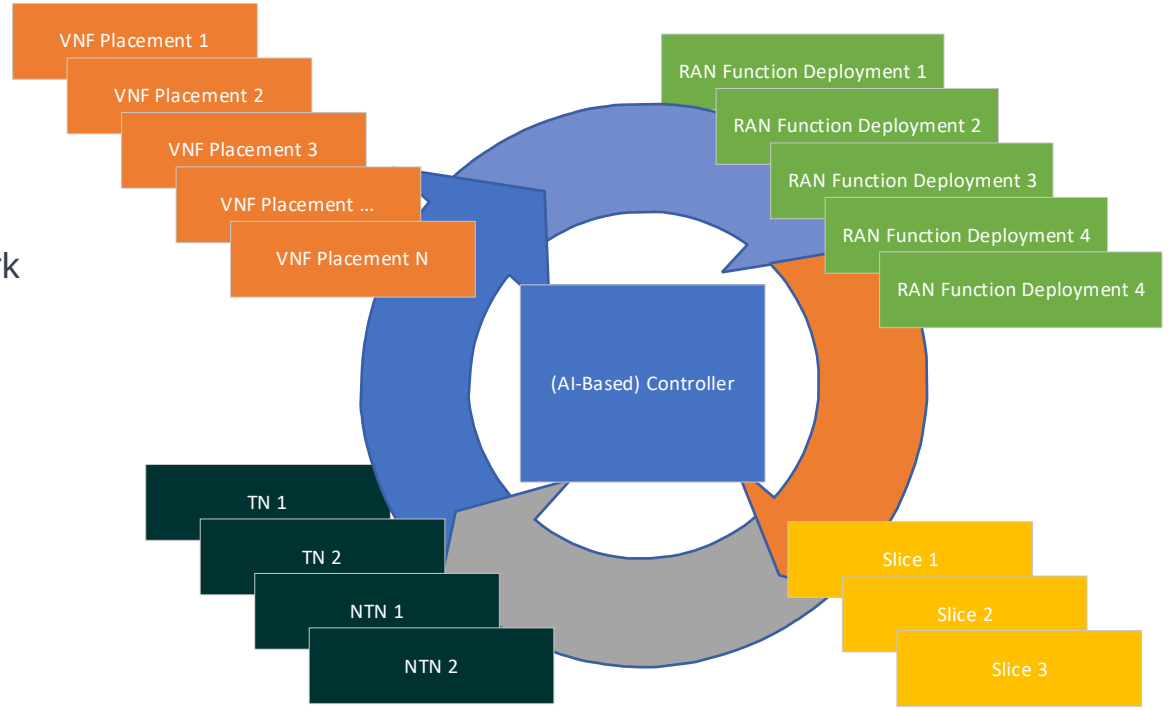


Multi-Service Deployment



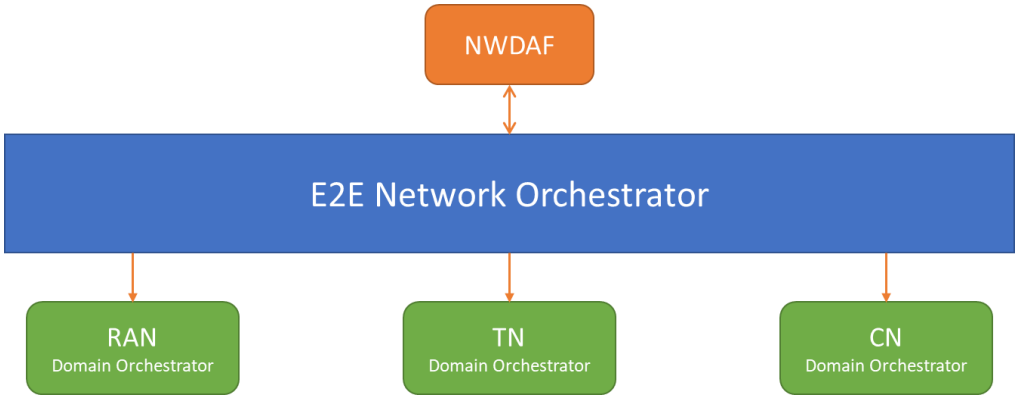
Network Controller Actions

- 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



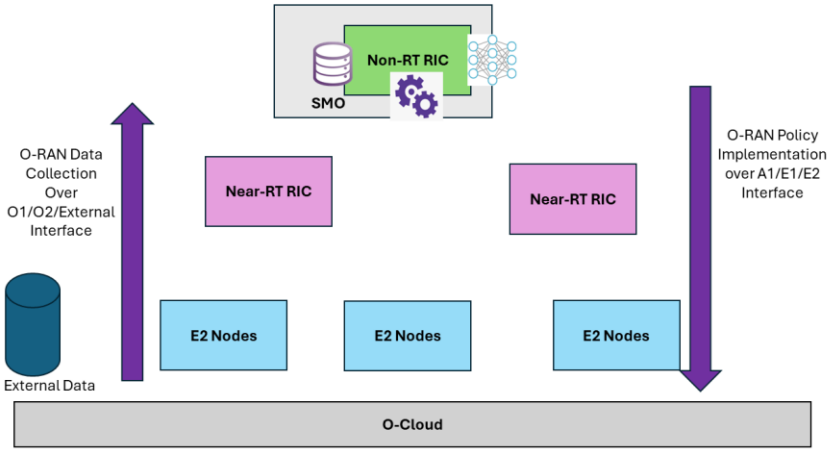
AI-driven Network Slicing

- The role of AI in E2E Network slicing
  - Core Network
  - RAN
- E2E Network Orchestrator controls the Orchestrator at each domain
- The placement of Domain Orchestrators.

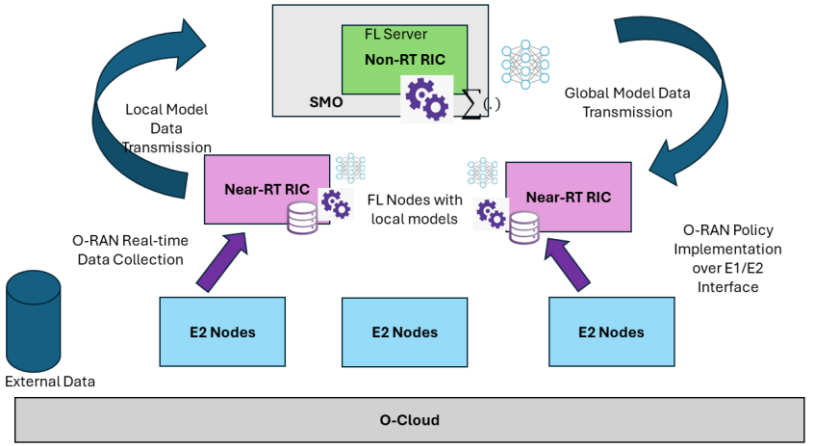


Centralised vs. Distributed AI

O-RAN Centralized AI Solution



O-RAN distributed AI (FL) solution



Conclusions

- Automatisation of network operation is a formidable challenge for 6G ecosystem:
  - Network heterogeneity
  - Different operational model imply different optimisation problem
  - AI-driven optimisation at system level is a compelling necessity
- 5G-STARDUST proved the added value offered by data-driven strategies for:
  - Resource allocation
  - Multi-link connectivity
  - Network orchestration and slicing
- Future work
  - System-wide optimisation framework (beyond 5G-STARDUST)

5G stardust

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Website
5g-stardust.eu

Email
info@5g-stardust.eu

Twitter
@5G_Stardust

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6G SNS

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