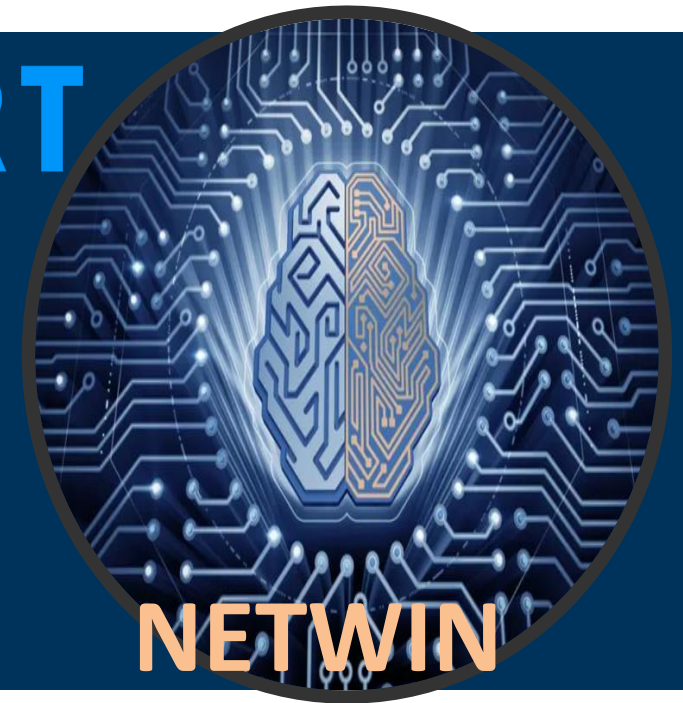


Towards an Automated and Reliable Management and Orchestration of 5G and Beyond Networks: Standardization and Considerations for Emulation/Simulation Platforms

 **RESTART**



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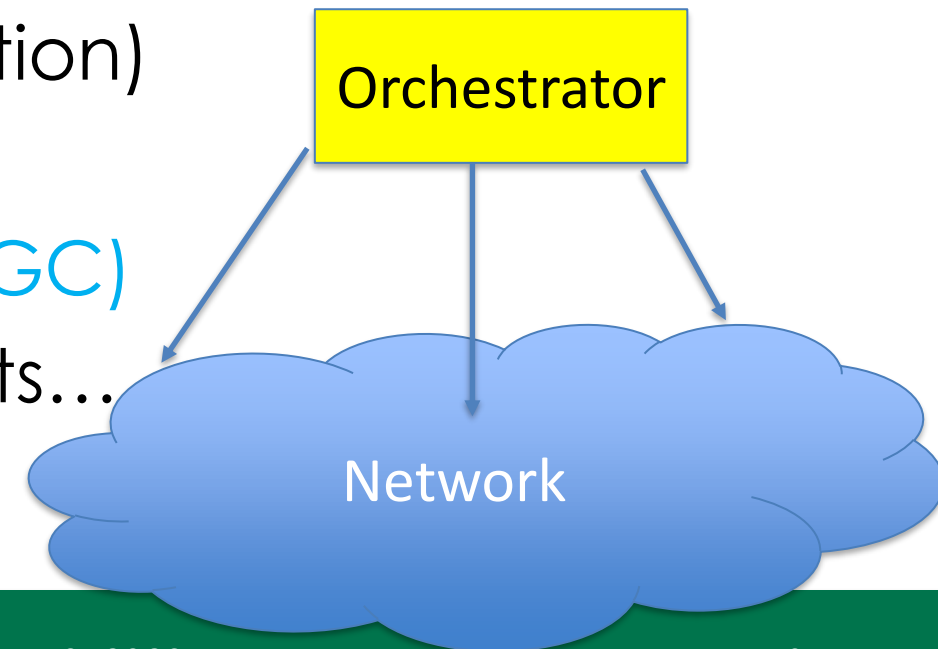
msettembre@fub.it

Fondazione Ugo Bordonì

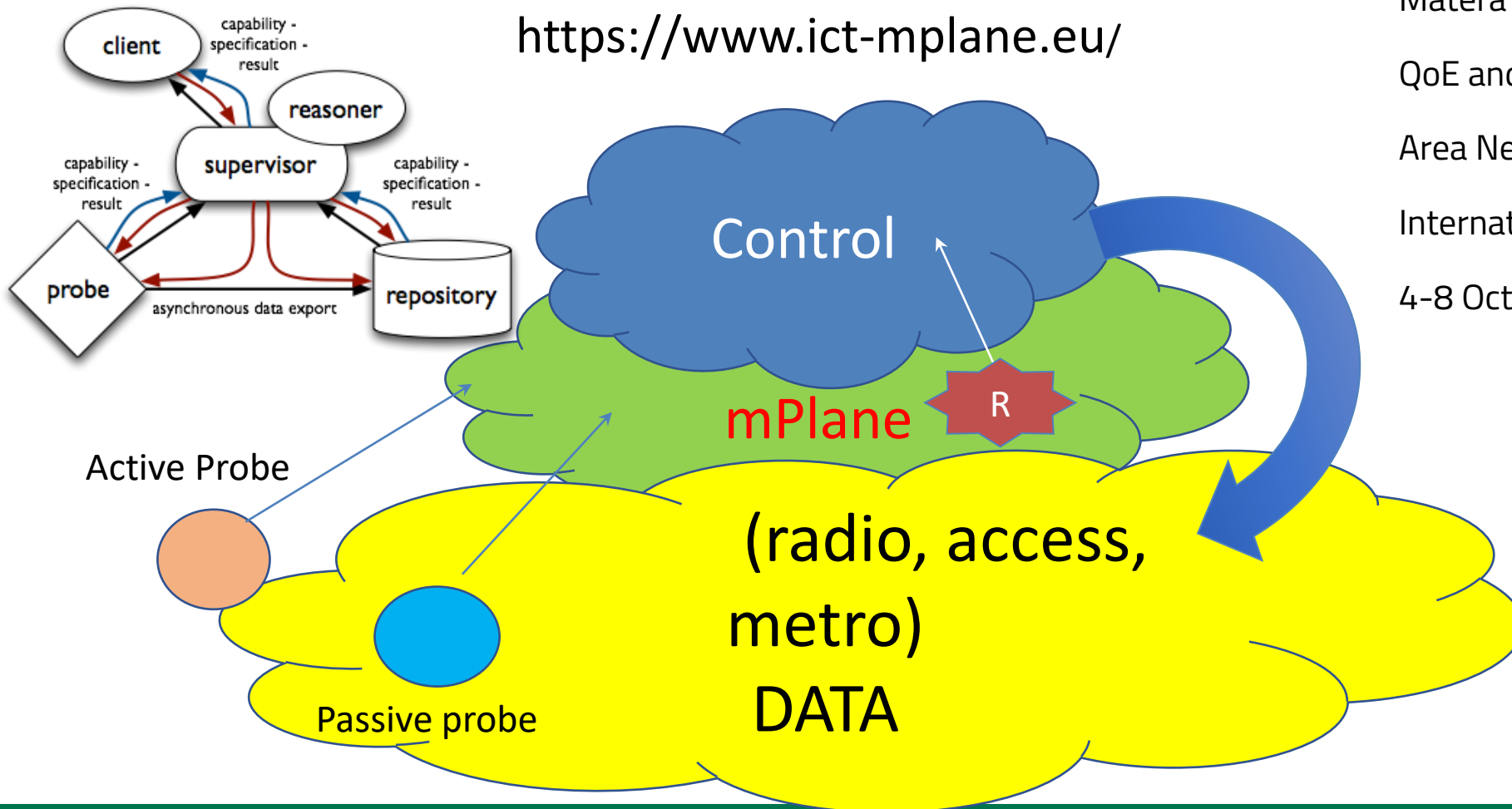
- Reset Workshop ISSRE 2023 Florence October 9, 2023

- Introduction:
 - need of automatic and dynamic management (SDN)
- 5G environment
- AI in Network architecture
- Main current standard
- Networks more and more complex: towards 6G and T-NT
- How simulate/emulate
 - Some platforms
- Conclusions

- Around 2010: design of automatic management in core network (Software Defined Networks, SDN)
 - Orchestration
 - OPENFLOW (N. McKeown, T. Anderson, H. Balakrishnan, G. Parulkar, L. Peterson, J. Rexford, S. Shenker, and J. Turner, “Openflow: Enabling innovation in campus networks,” SIGCOMM CCR, vol. 38, no. 2, pp. 69–74, 2008)
- Virtualization (Network Function Virtualization)
- 5G (core+radio access)
 - 3GPP defines SDN/NFV architecture (5GC)
- Networks spread including novel segments...
 - IoT, Non Terrestrial (NT),.....



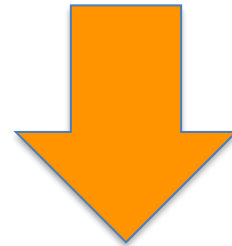
<https://www.ict-mplane.eu/>



Matera F., Tego E. "Machine Learning for QoE and QoS Control of Slices in a Wide Area Network Test Bed" 113th AEIT International Annual Conference (AEIT), 4-8 October 2021

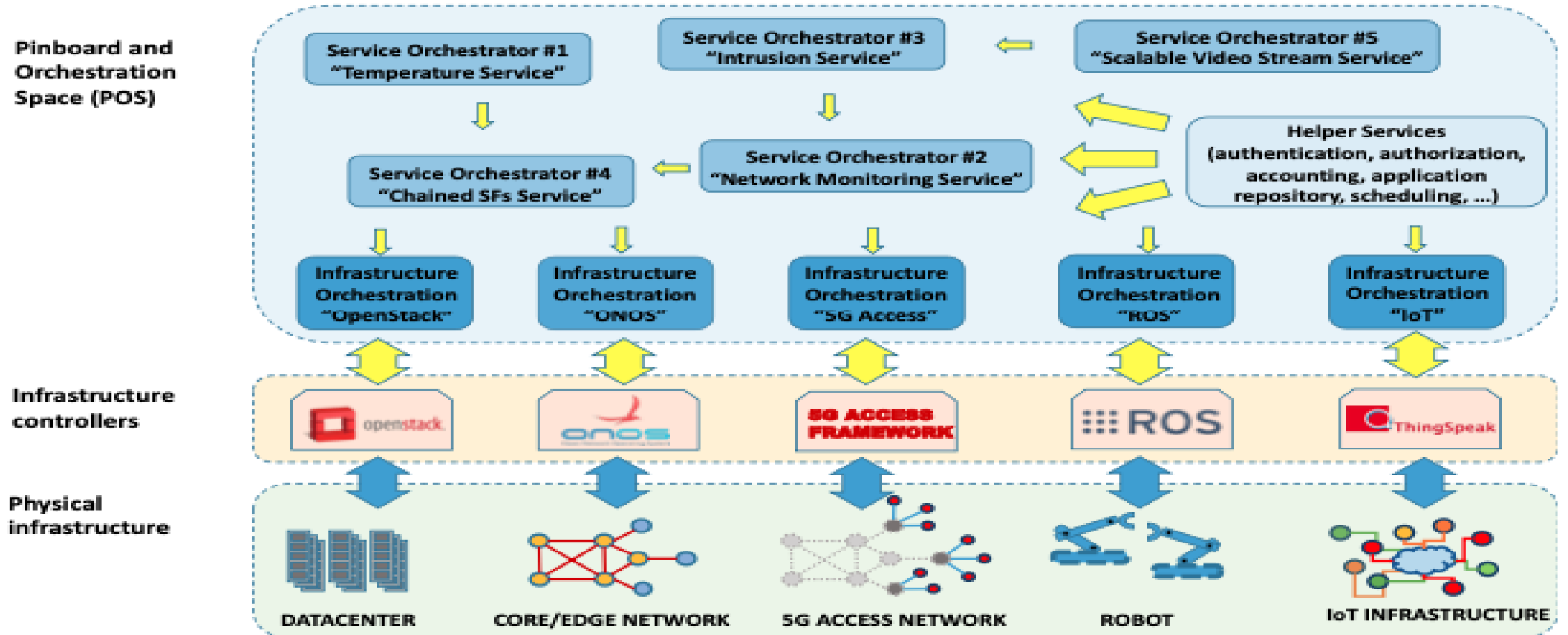
5G and beyond ecosystem complexity

- Integration of multiple and different types of technologies, supporting different services and verticals
- Increasing number of sub-systems with high dynamics and variability
- Full programmability
- Many deployments and configuration options
- Many configuration options
- Many stakeholders
- New threat landscape

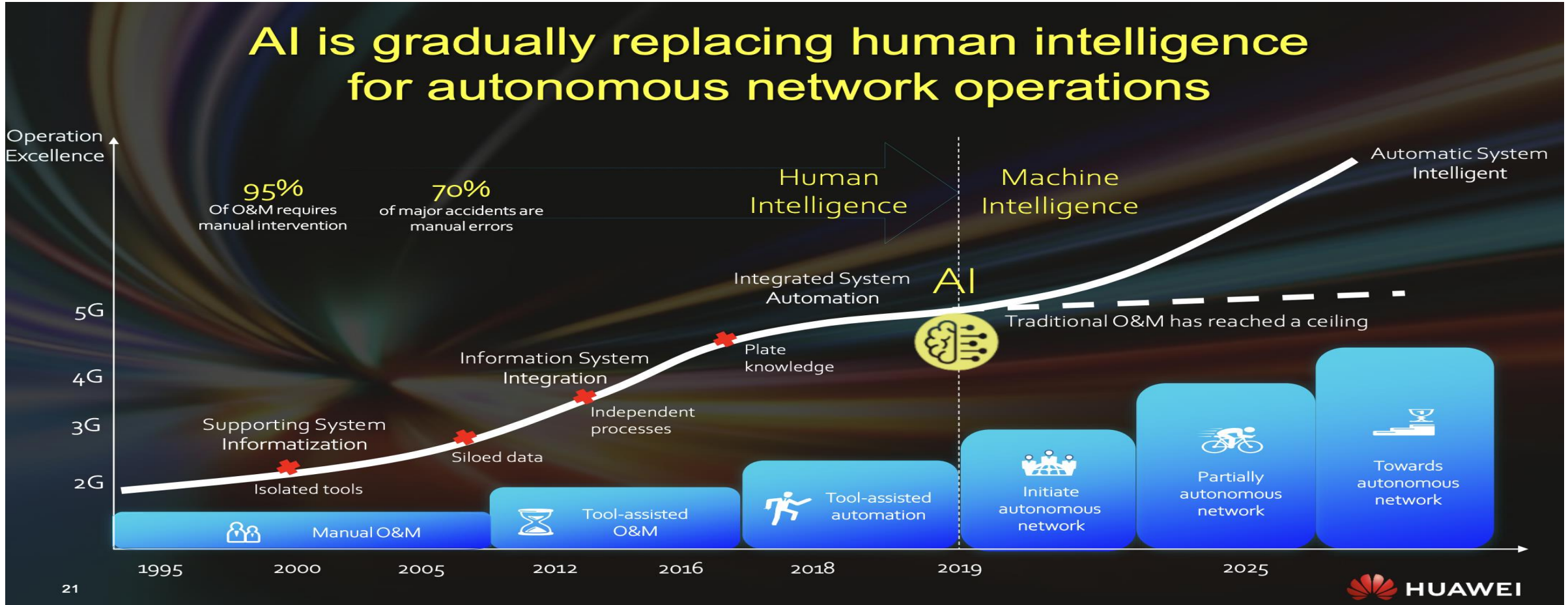


Traditional approach of static, fixed, and human-managed physical networks is evolving towards automatic, efficient dynamic, **reliable** management and orchestration

How many orchestrations?



Source: A unifying orchestration operating platform for 5G, Manzalini et al International Conference on Green, Pervasive, and Cloud Computing (GPC 2017) [10.1007/978-3-319-57186-7_20]



Source: <http://wilab.cnit.it/wp-content/uploads/2021/01/Soldani.pdf>

What does the orchestrator need?



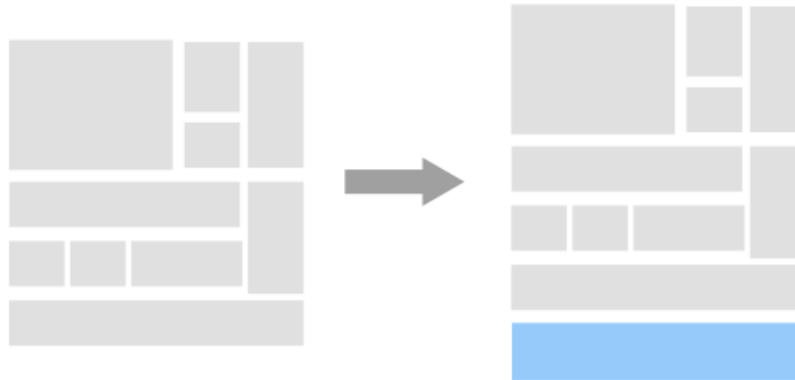
**AI is a key enabler for network automation
solutions: implementation approaches**

How to embed AI for automation in Networks?

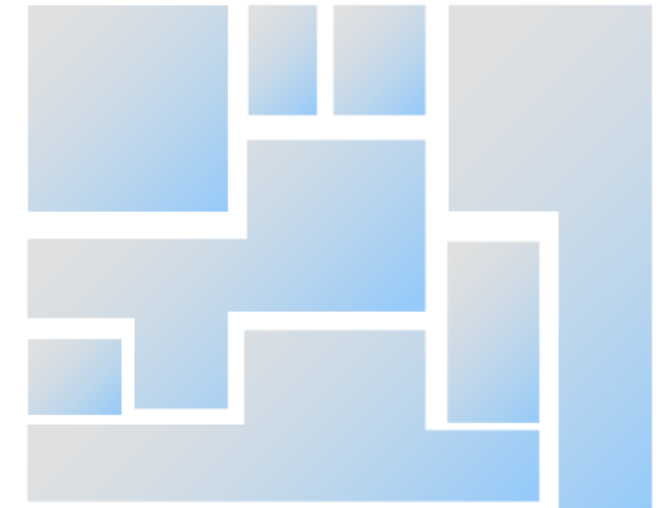
Replacing an existing component with an AI-based component



Adding a new AI-based component



Adding AI-based control to legacy component(s)



AI-native is where all components potentially use AI in and among each other

Source: Ericsson White Paper *Defining AI native...* (February 2023)

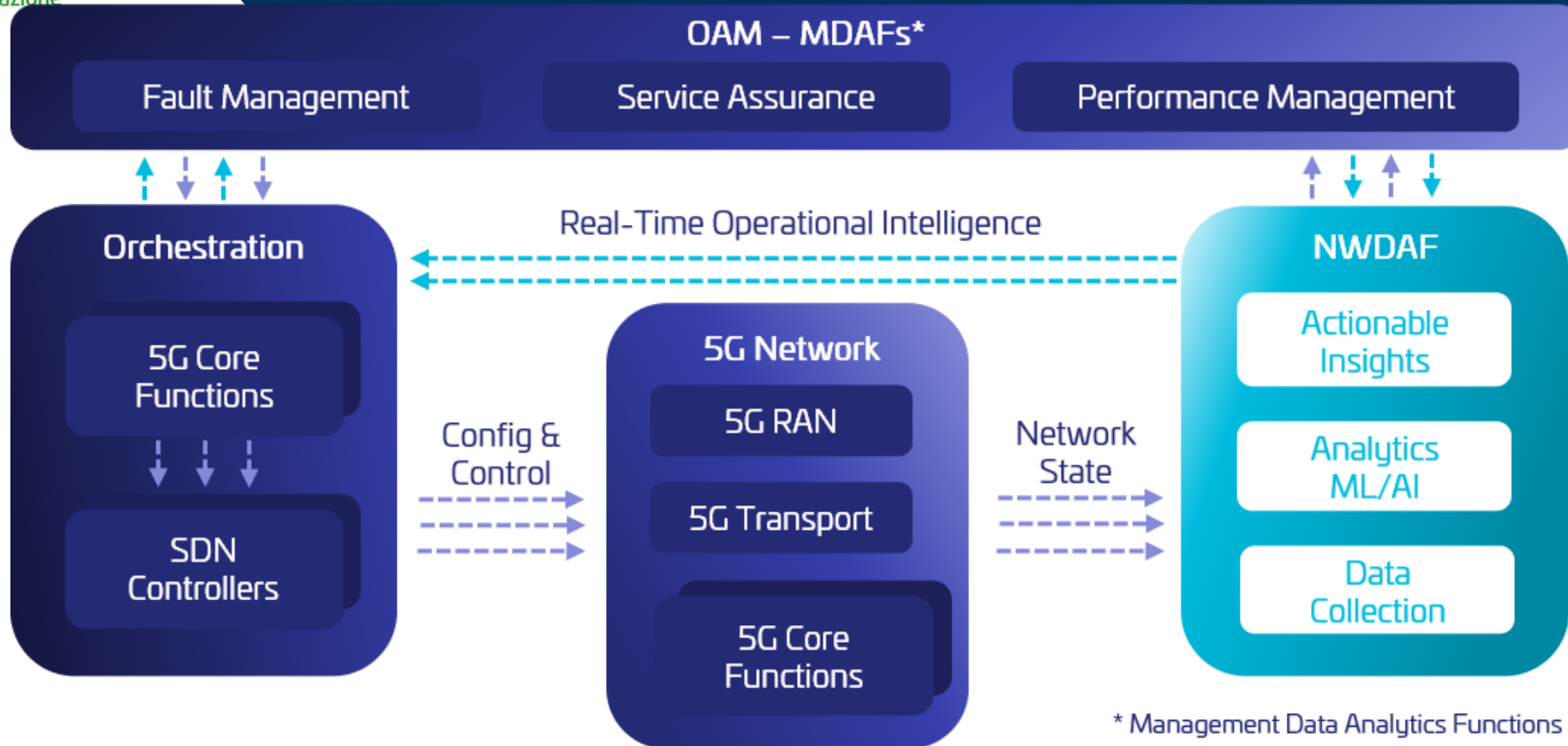
- Traditional static monolithic RAN network -> ORAN
- Traditional Core network -> Service Based Architecture (SBA)
- Intelligent elements (NWDAF, MDAF, RIC..)

**A reengineering
of the network architecture is in progress
to bring intelligence and automation**

- While open source and standardization are enablers for increased AI adoption, the scenario related to early phase of industrial specifications is very fragmented

- 2017: 3GPP SA2 defined the AI network function **NWDAF (Network Data Analytic Function)**. (Currently, the Chinese and American operators are conducting the function test of NWDAF for commercial use in 5G SA)
- 2017: ETSI EXPERENTIAL Networked intelligence (**ETSI ENI**) aiming at improving the operator experience, using closed-loop AI mechanisms based on context-aware, metadata-driven policies. ETSI has now completed Release 2 of its Experiential Networked Intelligence (ENI) specifications with the ETSI GS ENI 005 system architecture.
- 2017: ETSI founded Zero Touch Network and Service Management (**ETSI ZTM**) for a full end to end automation of network and service management
- 2018: O-RAN Union has formulated **RIC (AI-enabled RAN intelligent controller)** and interfaced with **Management & Orchestration (MANO)** function of core network.
- 2018: 3GPP Radio Access Network Working Group 3 (RAN3) started researching the data acquisition mechanism on wireless side and **RAN DAF** (RAN Data analytic function) has been introduced
- 2018: 3GPP SA5 began the research on AI and defined a new management plane function: **MDAF (Management Data Analytic Function)**
- **2020**: 3GPP SA5 started the research topic about network automation classification

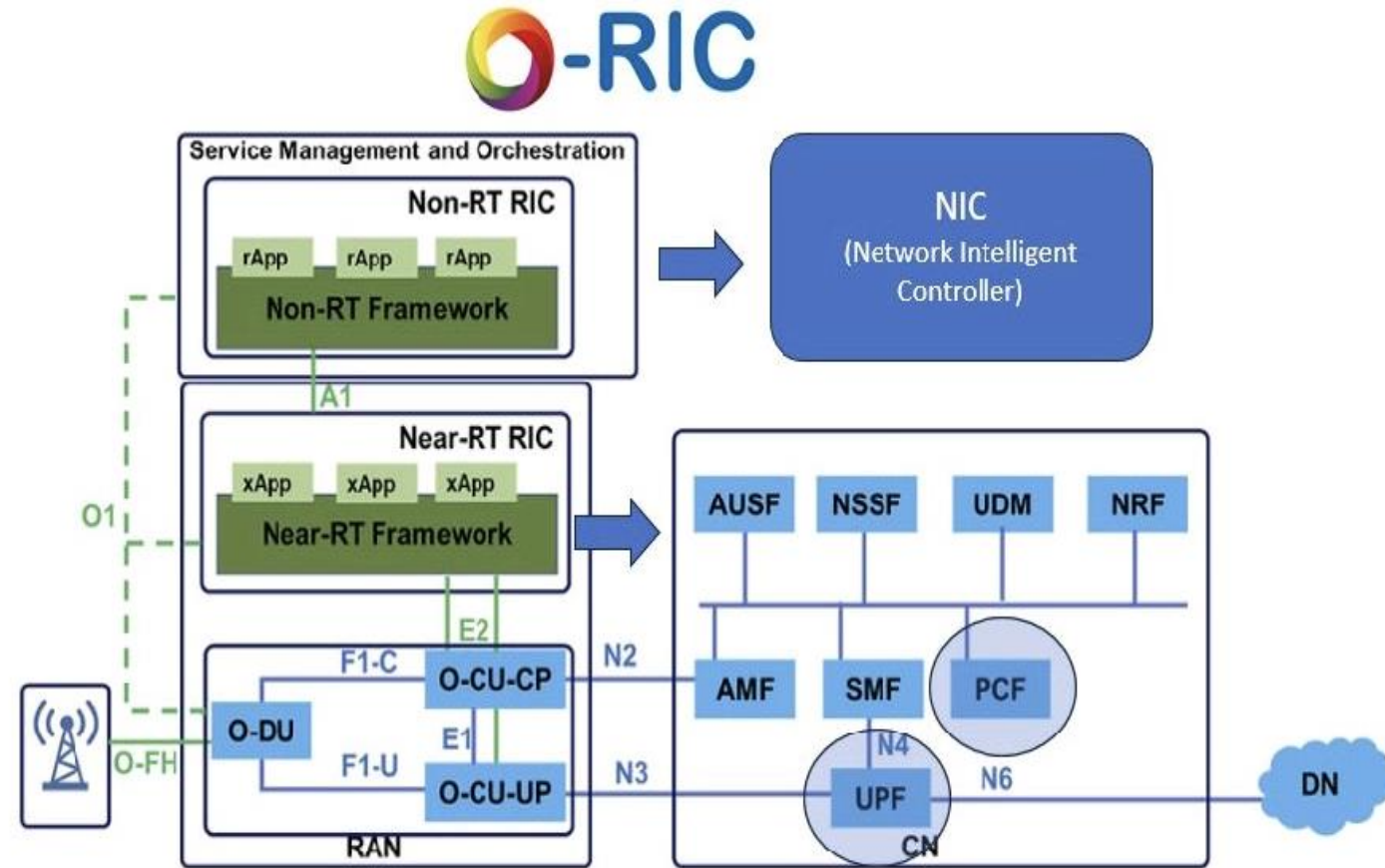
NWDAF as for Monitoring plane



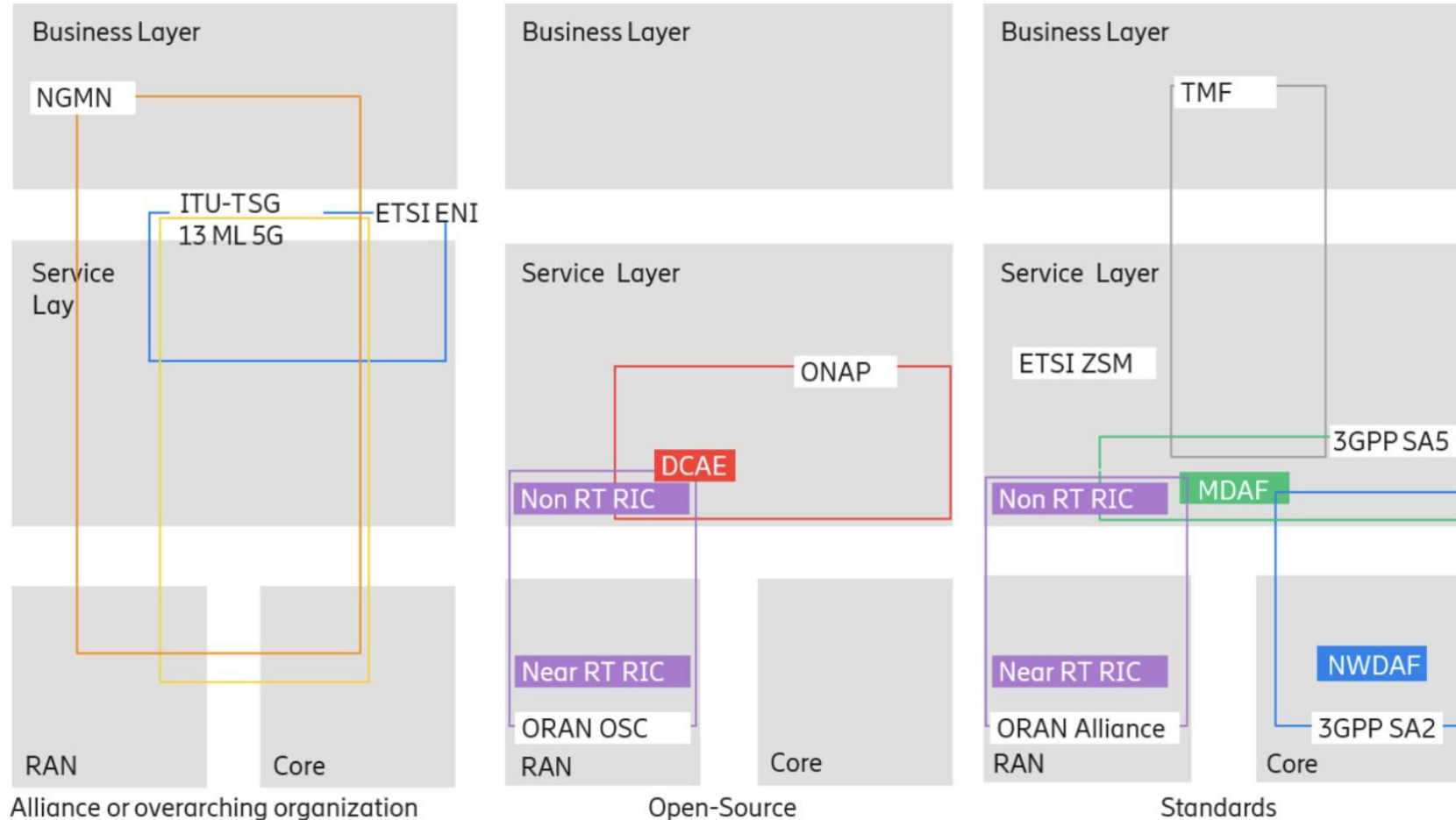
source : <http://www.guavus.com/will-5g-complexity-overwhelm-mnos/>

The evolution of O-RAN RIC

- Evolution of O-Ran RIC towards Core network
- **Network Intelligent Controller (NIC)** represents the next step after O-RAN RIC, supported by NWDAF and PCF
- O-RAN RIC can use OpenAPI to communicate with UPF, PCF over SBA architecture based https/jsonprotocols

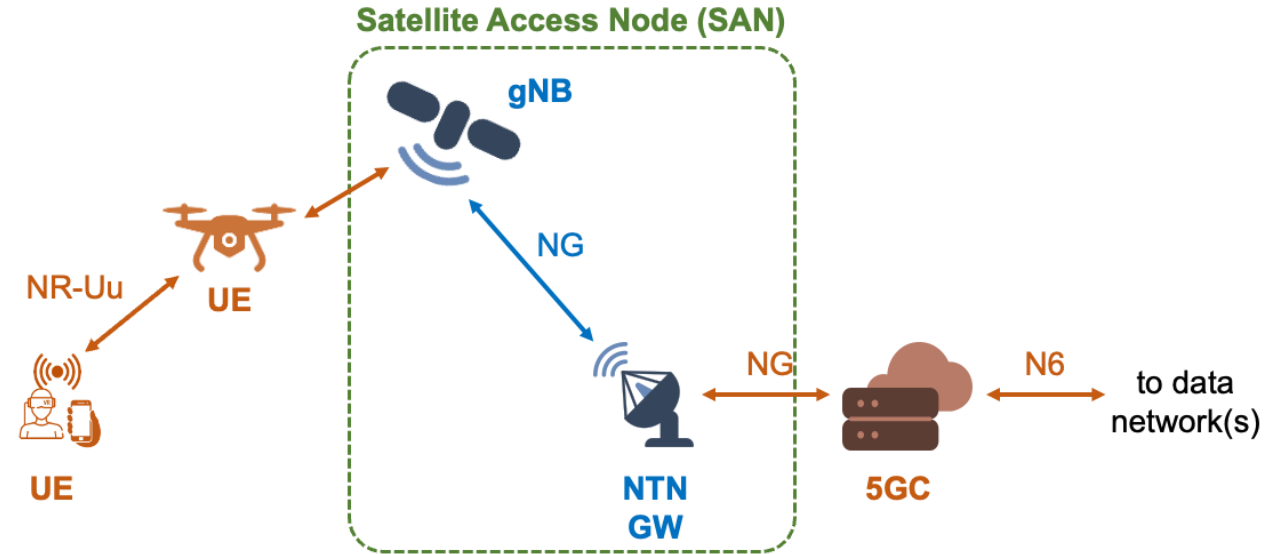
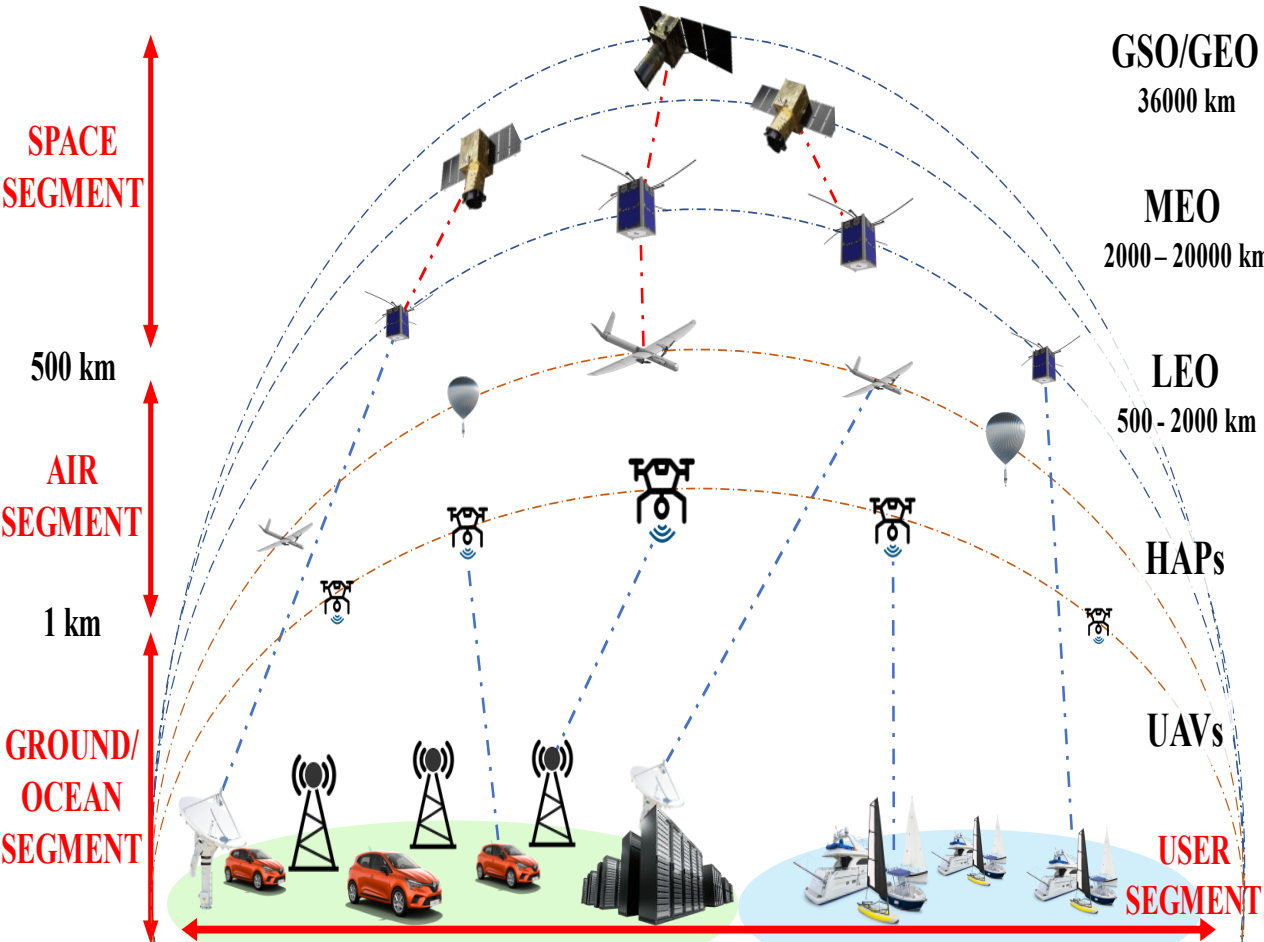


AI based architectures approaches



Source: Ericsson White Paper *Accelerating the adoption of AI...*, (August 2021)

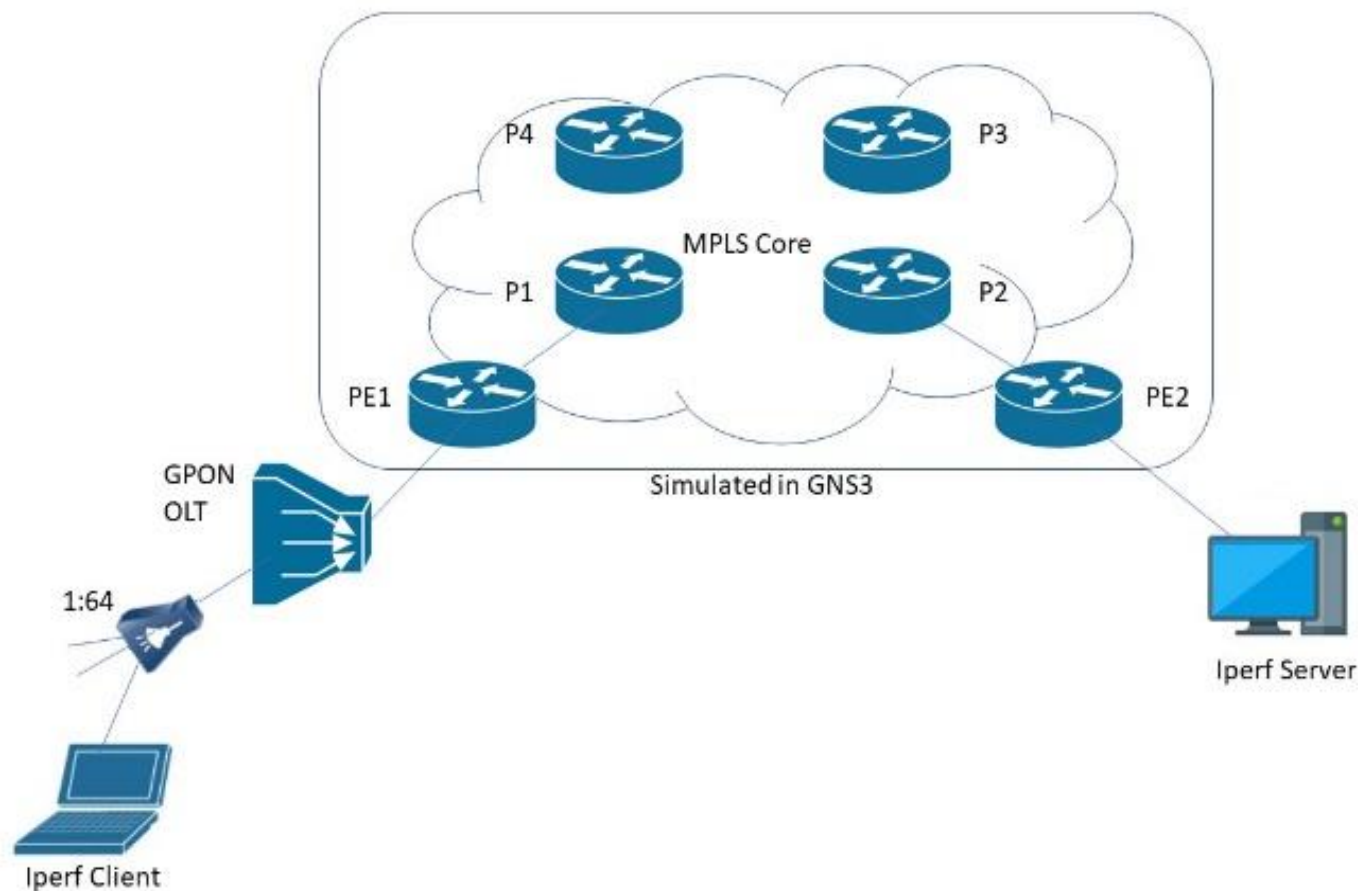
To make more difficult....Non Terrestrial!



Too complex! May I emulate/simulate any part?

- Different emulation/simulation codes
- Do they cooperate with real network segments?
- Which OSI Layers?
- Ns3 (discrete-event network simulator) simulation of L1-L4 (not physical signal behaviour), specially for RAN with 5G NR interface
 - A. Lacava, F. Cuomo et al “ns-O-RAN: Simulating O-RAN 5G Systems in ns-3”
- MININET (network emulation orchestration system running on switches, routers,...) emulation for SDN (management)
- GNS3 (network simulator that lets you run real networks), it can be linked to real networks
- Colosseum (network emulator, <https://www.northeastern.edu/colosseum/>)

Connecting GNS3 to real world



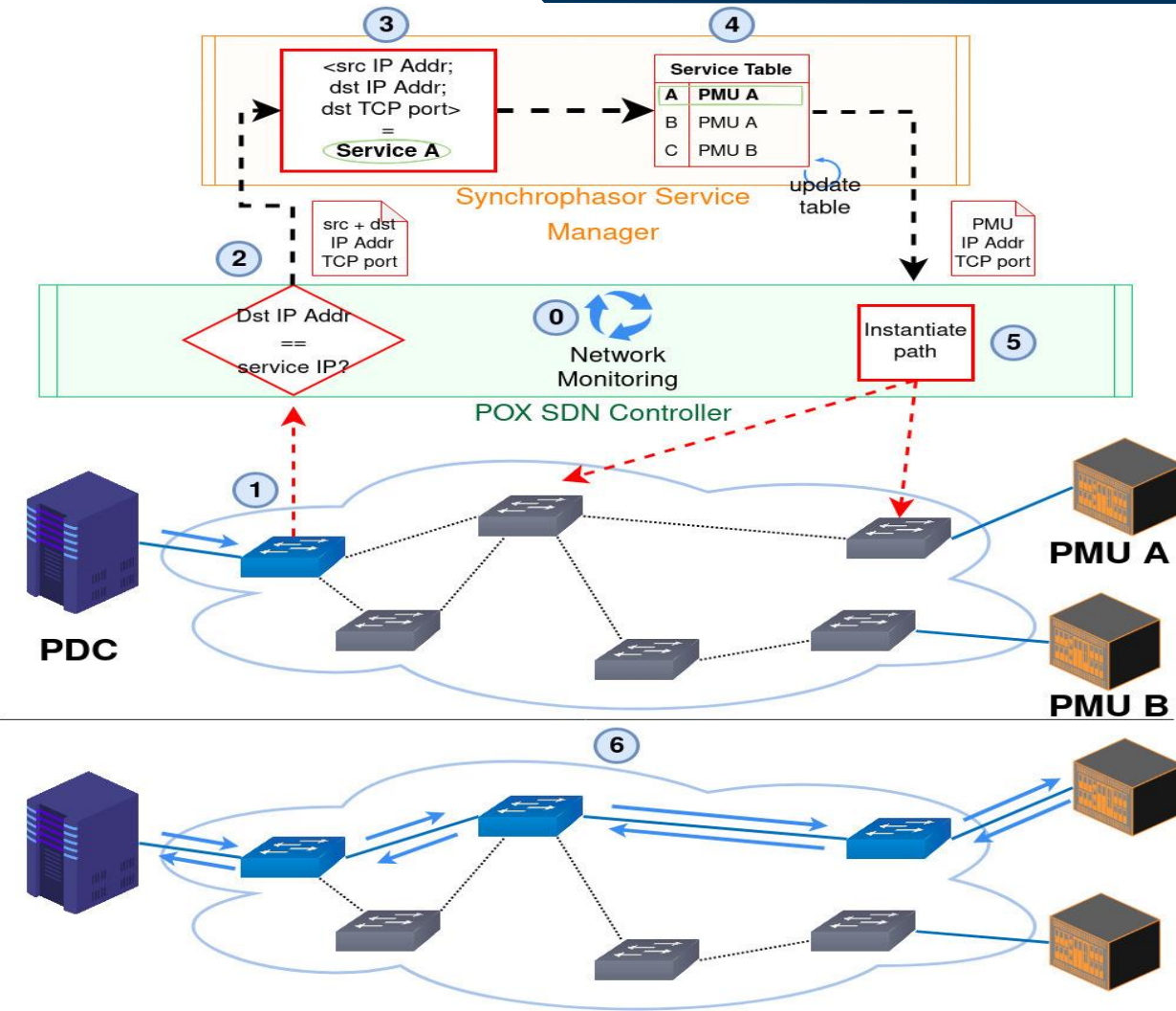
```
[ ] ~
[ ] > ping 8.8.8.8

Esecuzione di Ping 8.8.8.8 con 32 byte di dati:
Risposta da 8.8.8.8: byte=32 durata=40ms TTL=46
Risposta da 8.8.8.8: byte=32 durata=40ms TTL=46
Risposta da 8.8.8.8: byte=32 durata=41ms TTL=46
Risposta da 8.8.8.8: byte=32 durata=42ms TTL=46

Statistiche Ping per 8.8.8.8:
  Pacchetti: Trasmessi = 4, Ricevuti = 4,
  Persi = 0 (0% persi),
Tempo approssimativo percorsi andata/ritorno in millisecondi:
  Minimo = 40ms, Massimo = 42ms, Medio = 40ms
```

Matera F., Tego E., Attanasio V. "GNS-3 Emulation Platform to Study Wide Area Network Performance in Contexts Close to Reality" AEIT International Annual Conference, 03 – 05 October 2022, Rome

MININET in SDN for Smart grid environment



D'Alterio F., Cazzaniga A., Lavacca F., Garrone F., Persia S., Tornelli C."SDN implementation based on Mininet to support Synchrophasor Measurement Systems for Smart Grid Management" AEIT International Annual Conference, 03 – 05 October 2022, Rome

- Insights into different architectural options for integration of AI into the network infrastructure taking into account different standard approaches (e.g. 3GPP, O-RAN, ETSI, ITU-R)
- Insights into the following key network intelligent functions related to AI based solution for management and orchestration:
 - NWDAF (Network Data Analytics Function) introduced by 3GPP SA" group, providing machine intelligence in the 5G Core and driving close loop network automation.
 - RAN DAF (RAN Data Analytic Function) introduced by 3GPP RAN3 group
 - MDAF (Management Data Analytic Function) introduced by 3GPP SA5 group
 - RIC (AI-enabled RAN intelligent controller introduced by O-RAN interfacing with Management & Orchestration (MANO))
- Insights into functional architecture of ETSI ENI, ZTM engine for AI based orchestration
- Preliminary Insights on Intent based networking as introduced in 3GPP and ETSI ENI, ZTM

- Insights on AI/ML pipeline (also for a specific use case)
- Analysis of different AI approach (reinforcement learning, federated learning) vs AI objectives
- Insights into early phase deployments and specifications finalized to developing simulators/emulators, prototyping and testing
- Performance measurements and testing by means of simulators/emulators / prototypes
- Lab Tests

- Many network domains to be orchestrated
- RIC (ORAN), NWDAF, ETSI ZSM, MDAF, NIC appear how the best solution to bring automation and intelligence
- How cooperate these architectures and intelligent elements?
- How to include Non Terrestrial in a wide orchestration?
- Help from emulation/simulation platforms