Overview of ETHER Project – ETHER MANO

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www.ether-project.eu

Outline

1. ETHER Overview & Vision
2. Key enabling technologies
3. Target Use cases
4. ETHER MANO Architecture
5. Geolocalization and Mobility Management
6. Conclusions

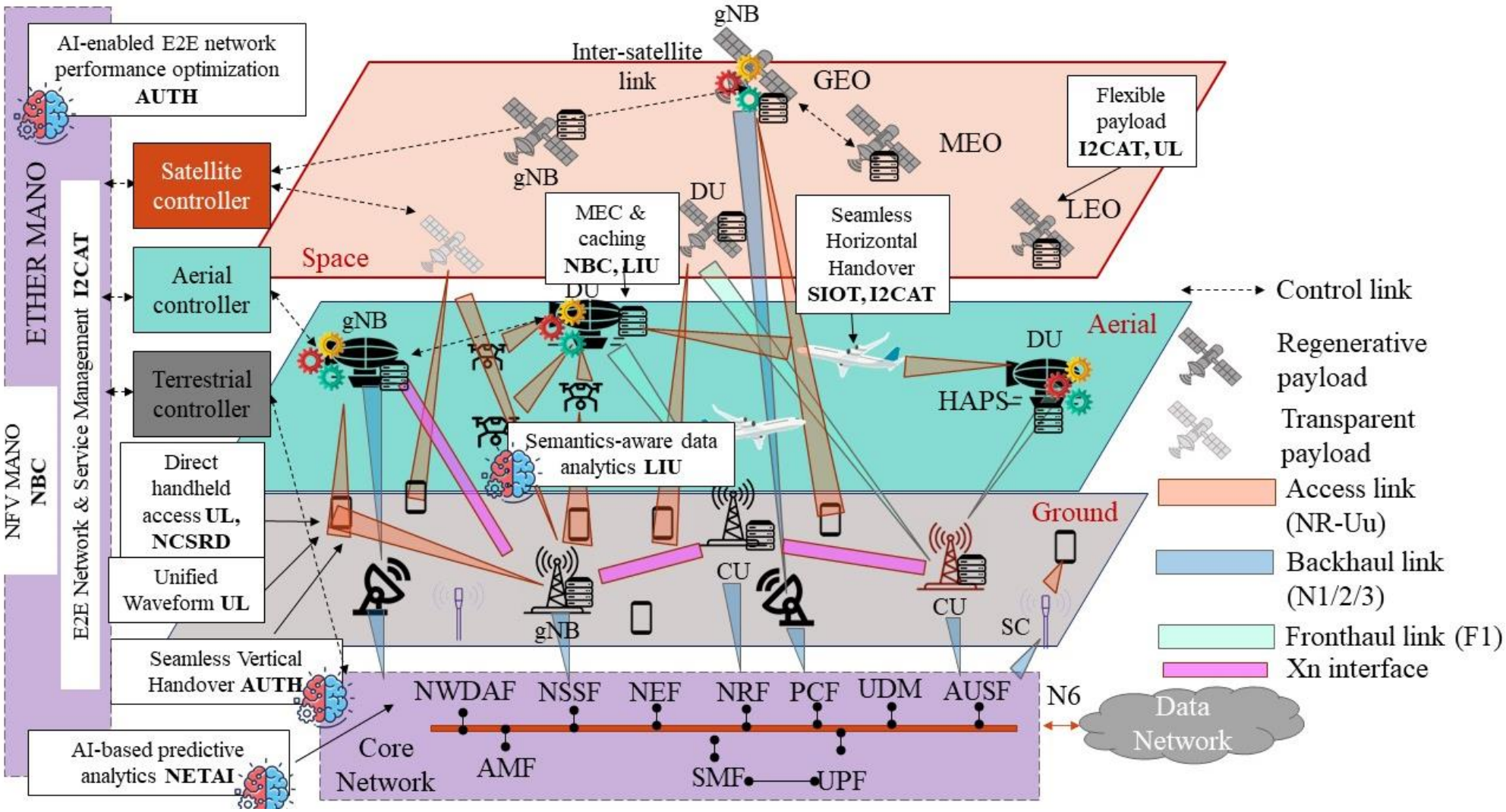
ETHER Overview

- **Project Name:** ETHER – sElf-evolving terrestrial/non-Terrestrial Hybrid nEtwoRks
- **Project website:** ether-project.eu
- **Stream:** SNS-2022-STREAM-B-01-03: Communication Infrastructure Technologies and Devices
- **Goal:** ETHER is going to provide a framework for the terrestrial/non-terrestrial network ecosystem that involves an efficient and zero-touch resource management, provides solution for key radio access network (RAN) challenges, and identifies the business opportunities for potential stakeholders
- **8** industry (**5 SMEs**) and **5** academic partners

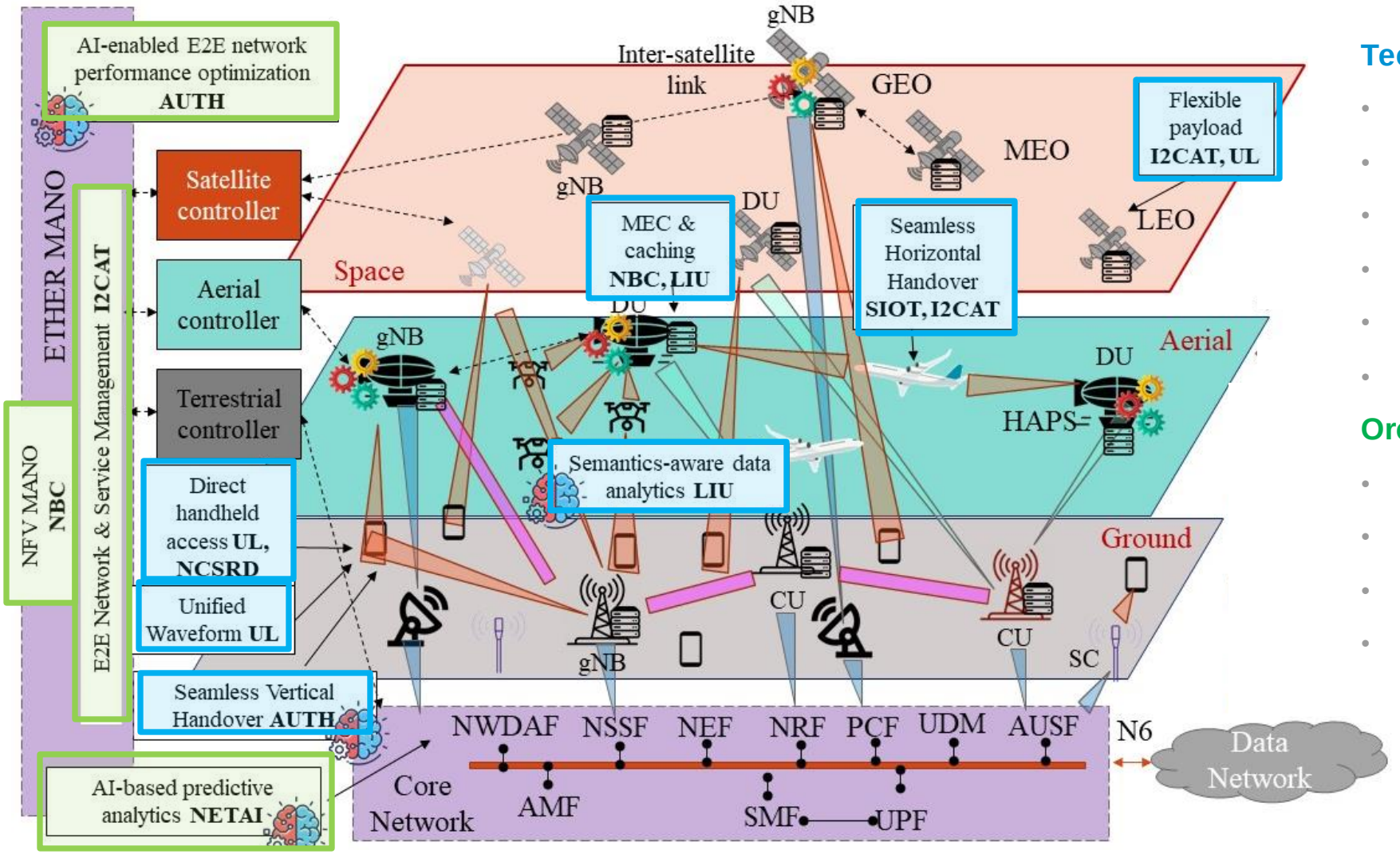
Number	Role	Short name	Legal name	Country
1	COO	uni.lu	UNIVERSITE DU LUXEMBOURG	LU
2	BEN	AUTH	ARISTOTELIO PANEPISTIMIO THESSALONIKIS	EL
3	BEN	CA	COLLINS AEROSPACE IRELAND, LIMITED	IE
4	BEN	AVA	AVANTI HYLAS 2 CYPRUS LIMITED	CY
5	BEN	SIOT	SATELIO IOT SERVICES, SL	ES
6	BEN	Ubiwhere	UBIWHERE LDA	PT
7	BEN	I2CAT	FUNDACIO PRIVADA I2CAT, INTERNET I INNOVACIO DIGITAL A CATALUNYA	ES
8	BEN	NBC	NEARBY COMPUTING SL	ES
9	BEN	NCSR "D"	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	EL
10	BEN	LIU	LINKOPINGS UNIVERSITET	SE
11	BEN	OPL	ORANGE POLSKA SPOLKA AKCYJNA	PL
12	AP	MARTEL GMBH	MARTEL GMBH	CH
13	AP	Net AI	NET AI TECH LTD	UK

- **Complete chain** to realize the ETHER vision:
  - **Provision of technological solutions:** UL, AUTH, CA, I2CAT, NBC, NCSR “D”, LIU
  - **Mobile Network Operator**: OPL
  - **Satellite Network Operators**: AVA, SIOT
  - **Integration**: UBW
  - **End user**: CA
- External advisory board consisting of the **European Space Agency** (Dr. Maria Guta) and **SES** (Dr. Joel Grotz)

ETHER Vision



Key innovations



Technological Enablers

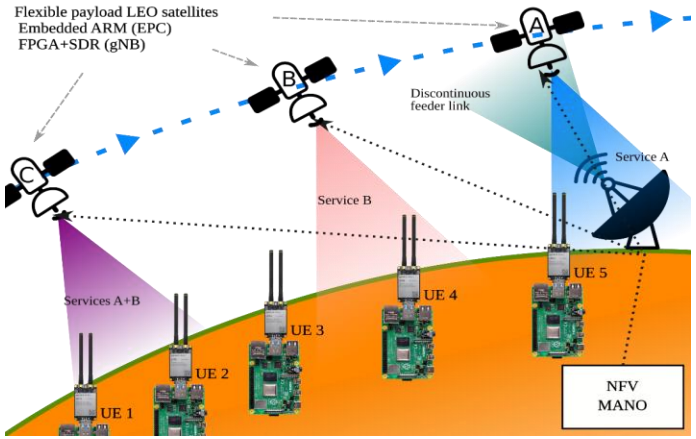
- Seamless Horizontal Handover
- Seamless Vertical Handover
- MEC & Caching
- Semantics-aware data analytics
- Direct-to-handheld access
- Unified waveform

Orchestration & Management

- TN-NTN MANO
- Network Management
- AI-based forecasting
- AI-based optimization

Target use cases

Service Provision to Delay-Tolerant IoT Applications



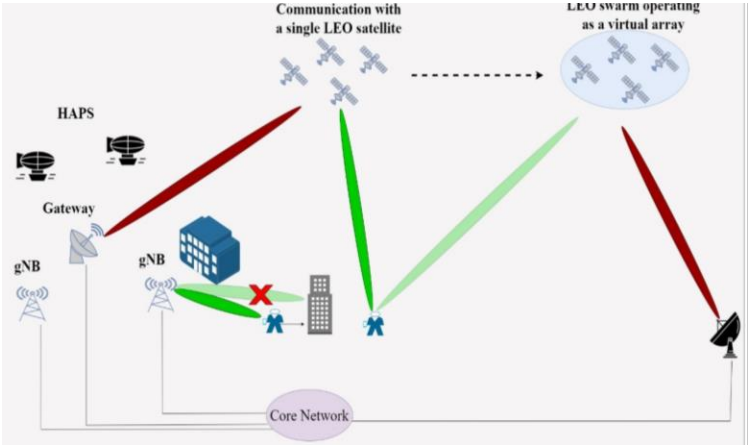
Key Innovations

- Horizontal handovers
- ETHER MANO
- Flexible payloads
- Semantics-aware information

KPIs

- 100% **coverage**
- > 75 % higher **energy efficiency**

Broadband Direct Handheld Device Access at the Ka Band



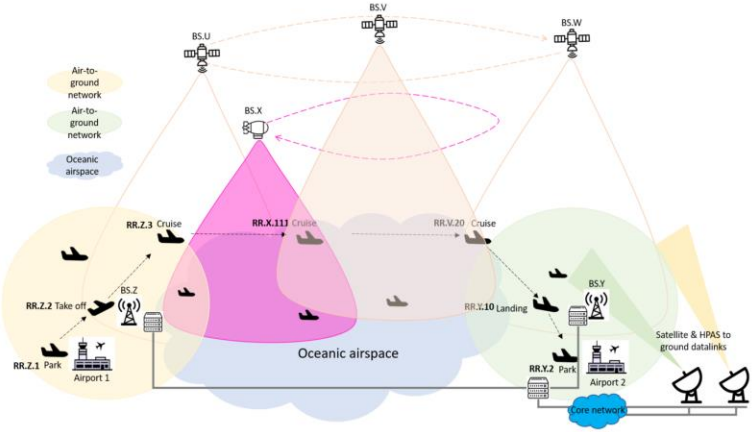
Key Innovations

- Distributed beamforming from LEO-satellite swarms
- Vertical handovers across RATs
- Unified waveform design
- Terminal antenna design

KPIs

- 100% **coverage**
- > 70% more **energy efficiency**

Air-Space Safety Critical Operations



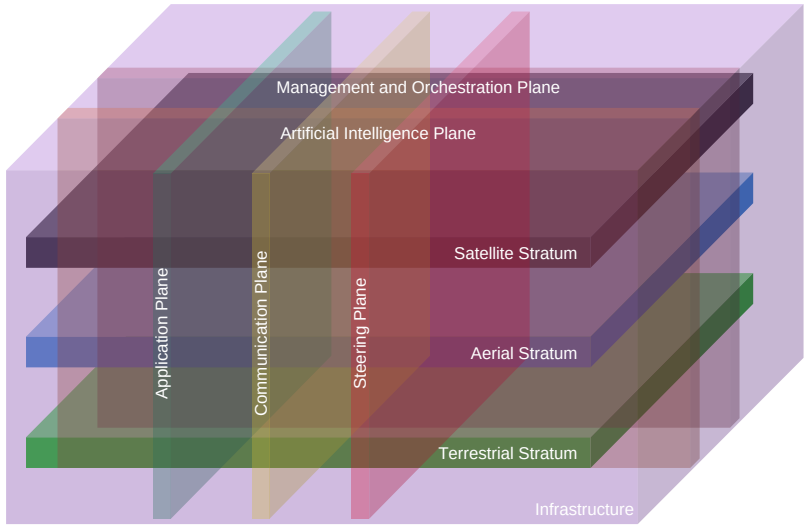
Key Innovations

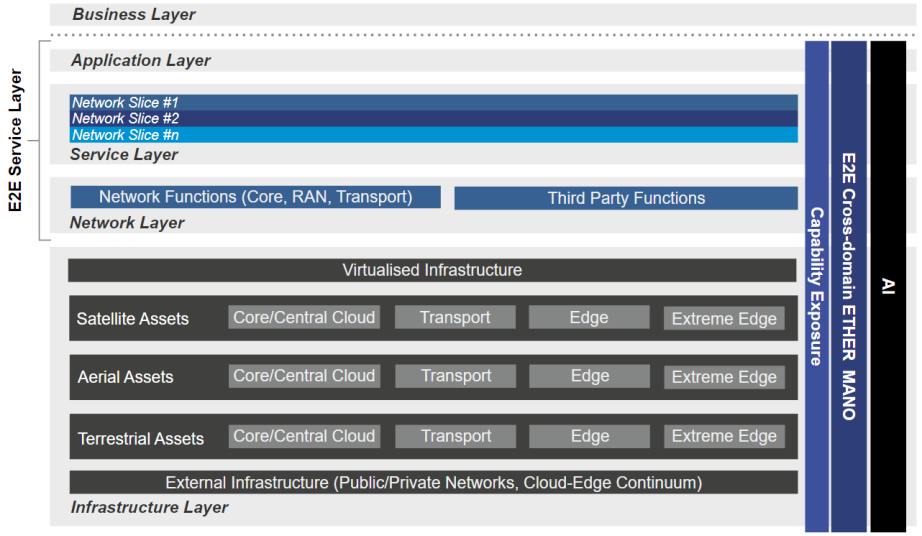
- Vertical handovers across RATs
- ETHER orchestrator
- Unified waveform design
- AI-based predictive analytics
- E2E network performance optimization algorithms

KPIs

- 100% **coverage**
- Performance **integrity** 10^{-4} to 10^{-6}
- > 80% more **energy efficiency**

Overall ETHER architecture and architecture layers





- **Shared infrastructure** - physical and virtual infrastructure resources
- **Terrestrial, aerial, and satellite strata** – through which softwarised Application, Communication, and Steering Planes are laid out
- **Application and Communication Planes** – serving the user directly
- **Steering Plane** – seamless operation of former using control mechanisms.
- **Management and Orchestration Plane** – management of the ETHER system and orchestration of resources and other planes
- **AI Plane** – support for MANO regarding automation and autonomy, service exposure to applications, communication, and steering mechanisms

Cooperation ensured by resources (especially transport ones) and mechanisms of interconnection and mediation.

- ***Infrastructure Layer*** – TN & NTN assets (Core/Central Cloud, Transport, Edge, Extreme Edge infrastructure), External Infrastructure, Virtualised Infrastructure → NFVI + non-virtualised resources
- ***Network Layer*** – NFs (e.g., 3GPP CN, RAN, transport) and third-party functions
- ***Service Layer*** – Network Slice Instances (NSIs) composed of NFs residing in the Network Layer, slice management and exposure mechanisms
- ***Application Layer*** – applications using functionalities offered by NSs
- ***Business Layer*** – business actors: Mobile Network Operators (MNOs), verticals, etc.→ out of WP2 scope (WP6)

The layers coordinated on multiple levels by the **E2E cross-domain ETHER MANO supported by AI** (internal or AIaaS)

ETHER MANO Architecture

(1) Global Level

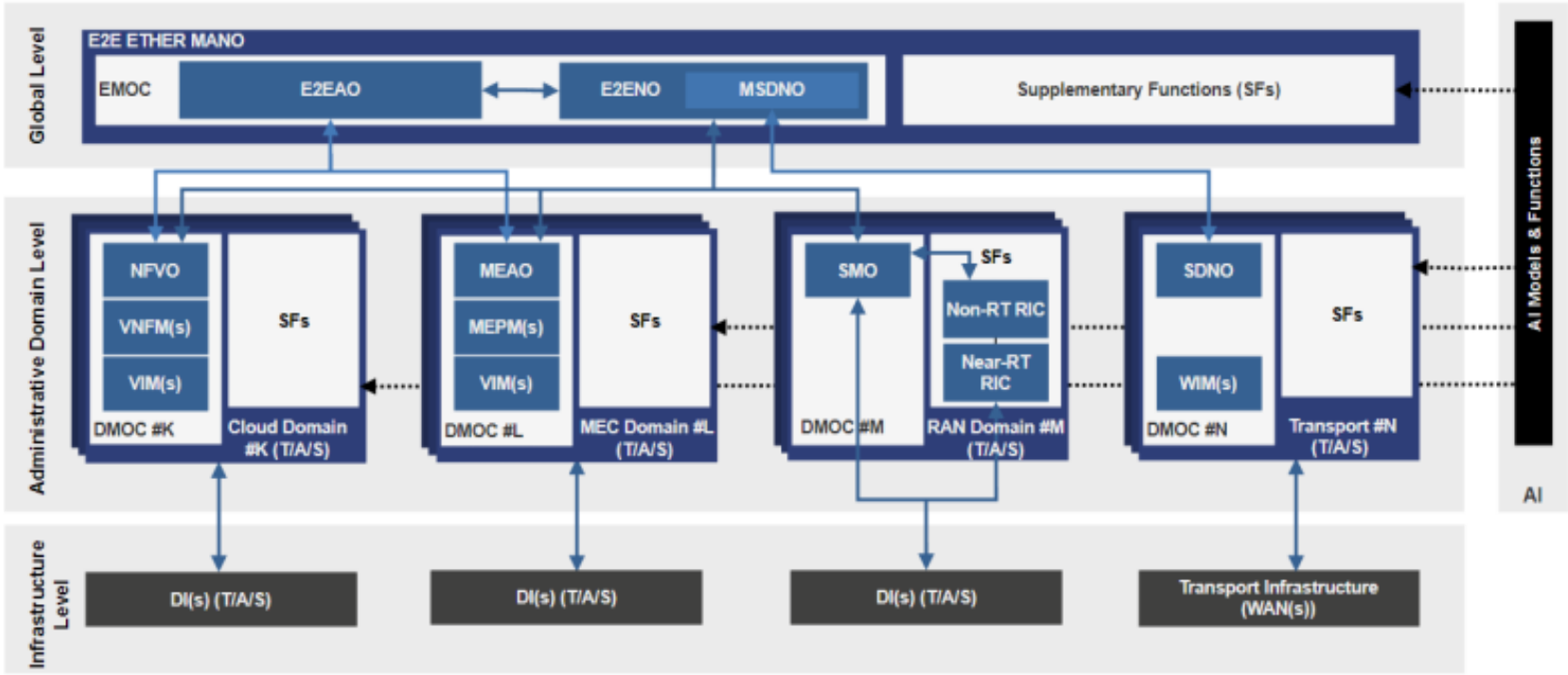
- E2E components
- E2E Application Orchestrator
- E2E Network Orchestrator

(2) Administrative Domain Level

- Multiples domains integrated
- Domain per layer (e.g., aerial)
- Domain per scope (e.g., RAN)

(3) Infrastructure and AI layers

- Presented in other sections



Domain-specific per scope

- Specific orchestrator per domain
- Connection between orchestrators
- Dedicated infrastructure

Supplementary functions

- Complement orchestration (e.g., AI modules)

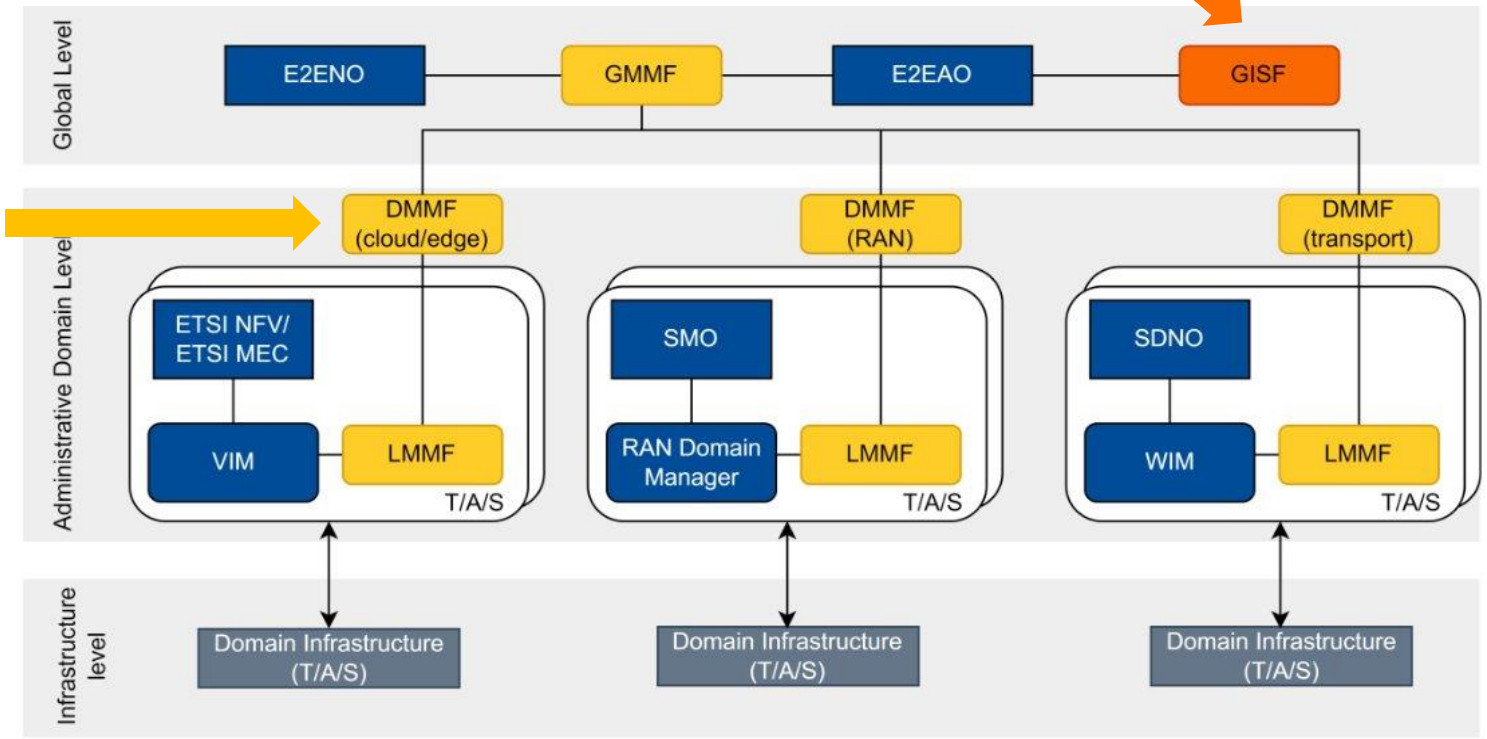
ETHER MANO - Challenges

Challenge #1: Execution on geographical location

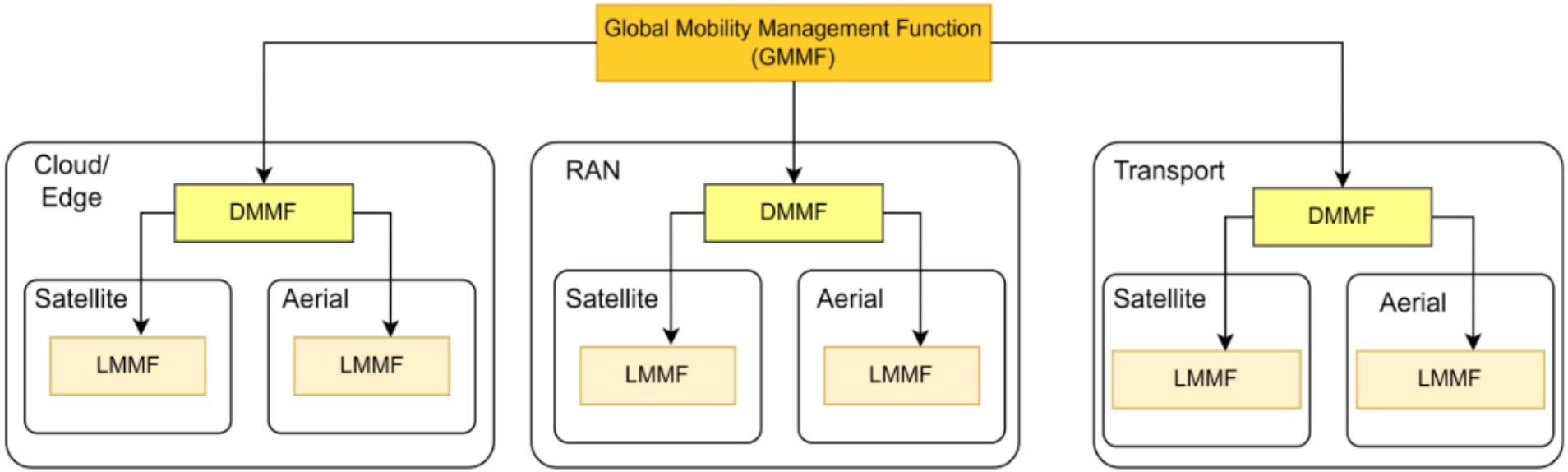
- Current technologies do not differentiate between countries
- Multiple implications (e.g., legal aspects, etc.)
- Deployments done by different clouds domains

Challenge #2: Seamless management of node mobility

- Current technologies do not integrate mobile infrastructure
- Predictive mechanisms may help to anticipate changes
- Seamless integration with current architectures



ETHER MANO – Mobility Management



Global Mobility Management Function (GMMF)
- Primary point of contact the mobility management framework
- Registering and discovering available domains

Domain MMF (DMMF)
- Identifying the domains that the physical infrastructure traverses within the target area
- Managing LMMFs

Local MMF (LMMF)
- Managing the mobility of physical infrastructure
- Discovery of the location of physical infrastructure
- Maintenance and update of node location

3GPP management plane stack interconnected hierarchically with the ETHER xMMF stack

Implementation of the MANO Architecture

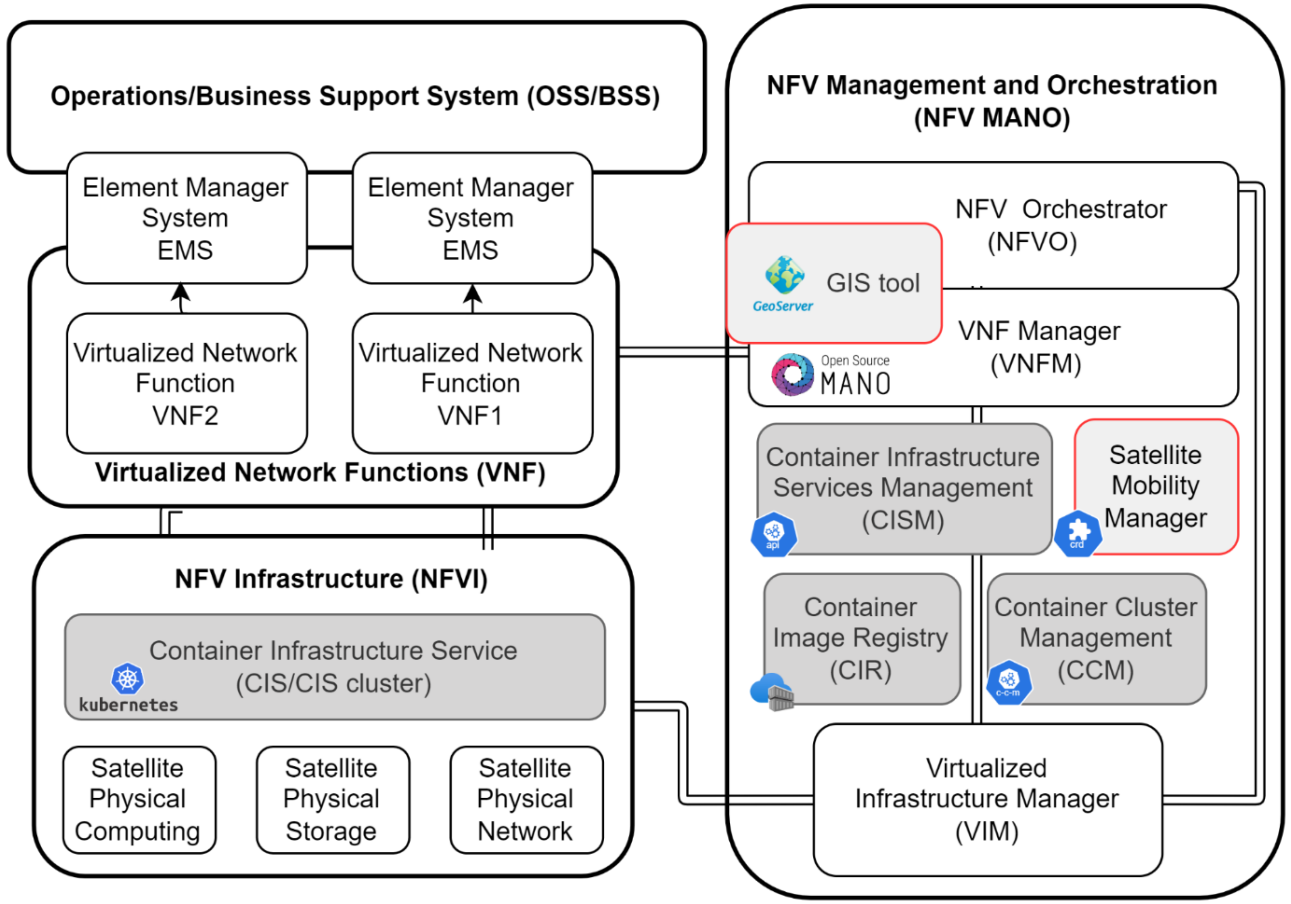
Extended ETSI MANO framework (*)

GIS Function

- Storage and query of spatial information
- Management of target areas, and visualization of satellite infrastructure
- Integration with external GIS

Satellite Mobility Manager (SMM)

- Estimate contact windows
- Schedule deployments

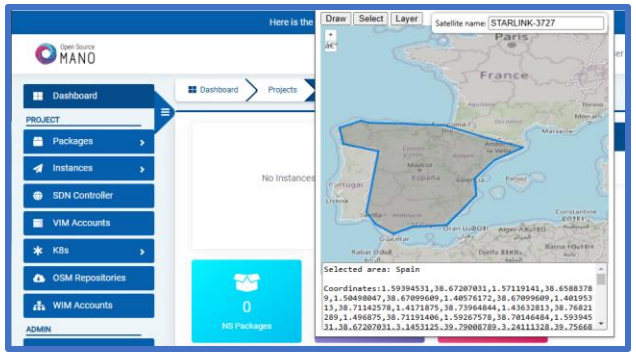


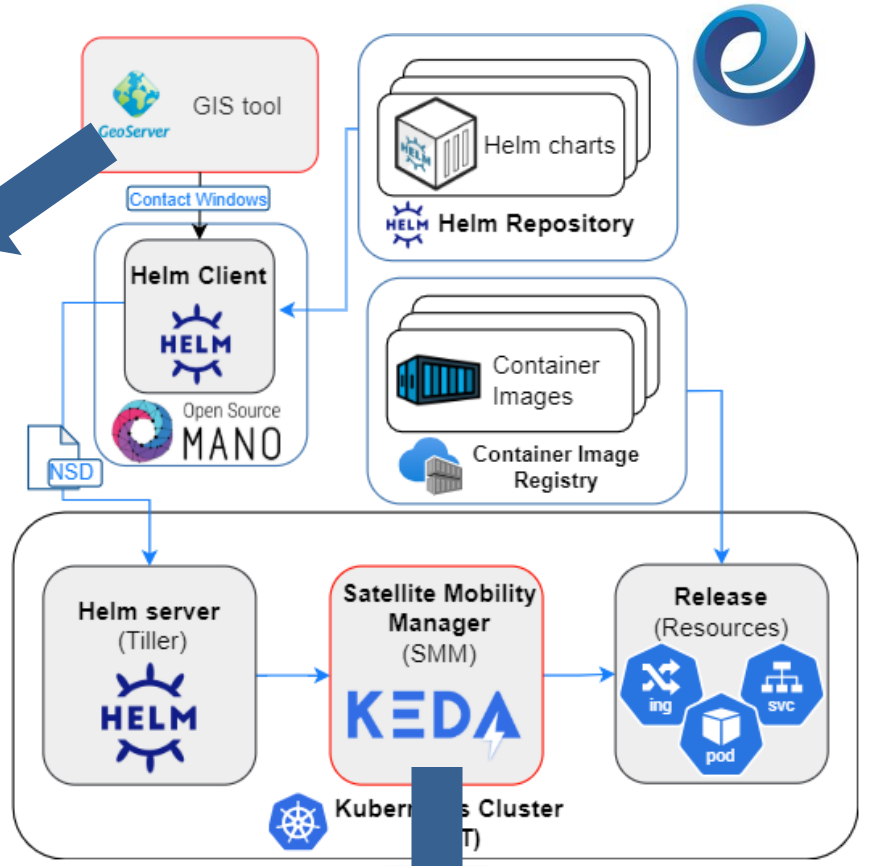
*(*) J. Avila, J.A. Ruiz-de-Azua, and A. Calveras, "*Integrating geographical information systems in management and orchestration of satellites constellation to achieve a spatial-aware 6G Non-Terrestrial Networks*", in International Astronautical Congress (IAC), 2024*

Implementation of the SMM

SMM Module

- Integrated in Kubernetes
- Deployed in satellite
- Dynamic VNF Scaling
- Scheduled Scaling factor





$S(t)$: Scaling factor at time t

$T_{\text{start}}, T_{\text{end}}$: Satellite contact window boundaries

R: Desired replica count during active window

$$S(t) = \begin{cases} R, & \text{if } t \in [T_{\text{start}}, T_{\text{end}}] \\ 0, & \text{otherwise} \end{cases}$$

Orbit Propagator

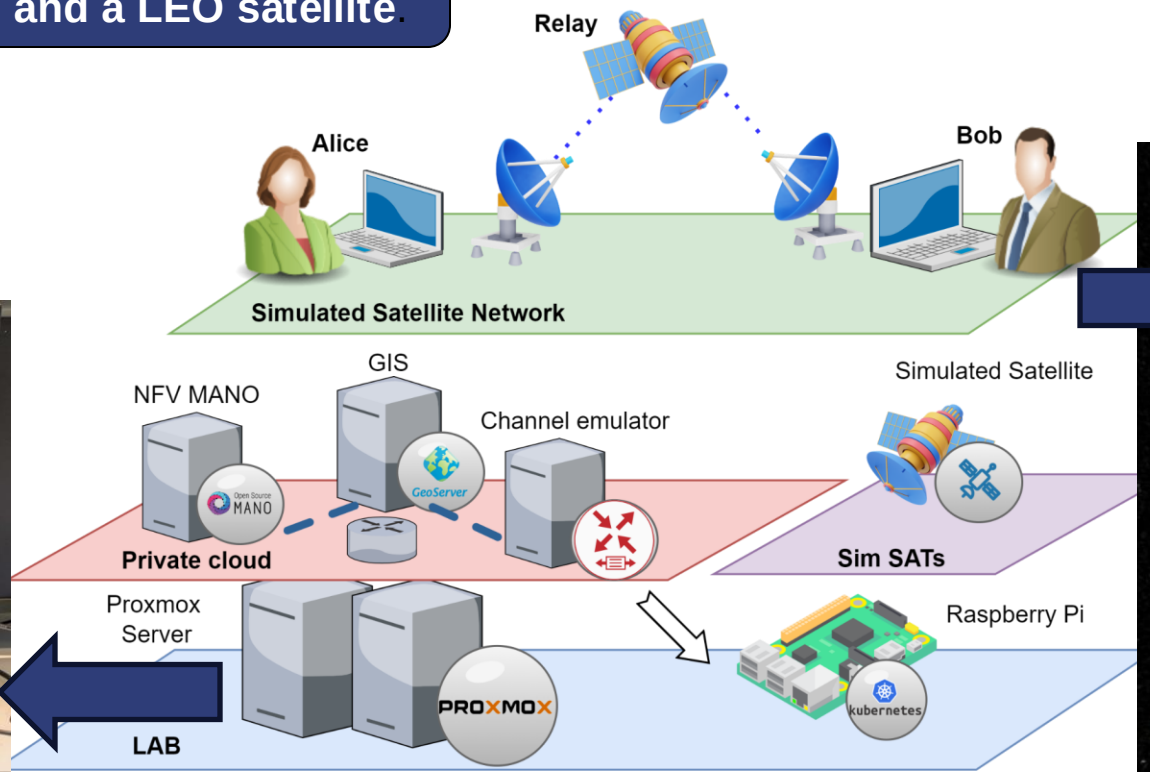
ConfigMap

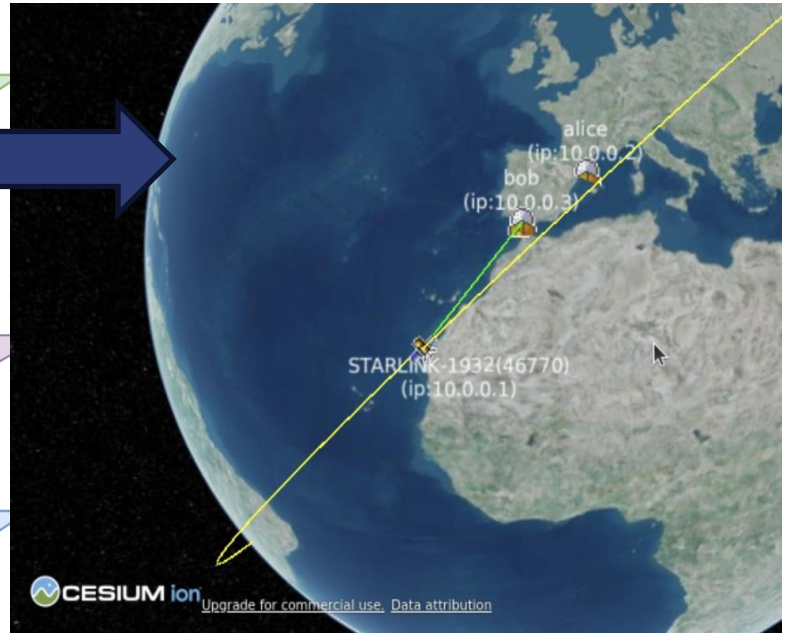
KEDA Scaled Object

SMM

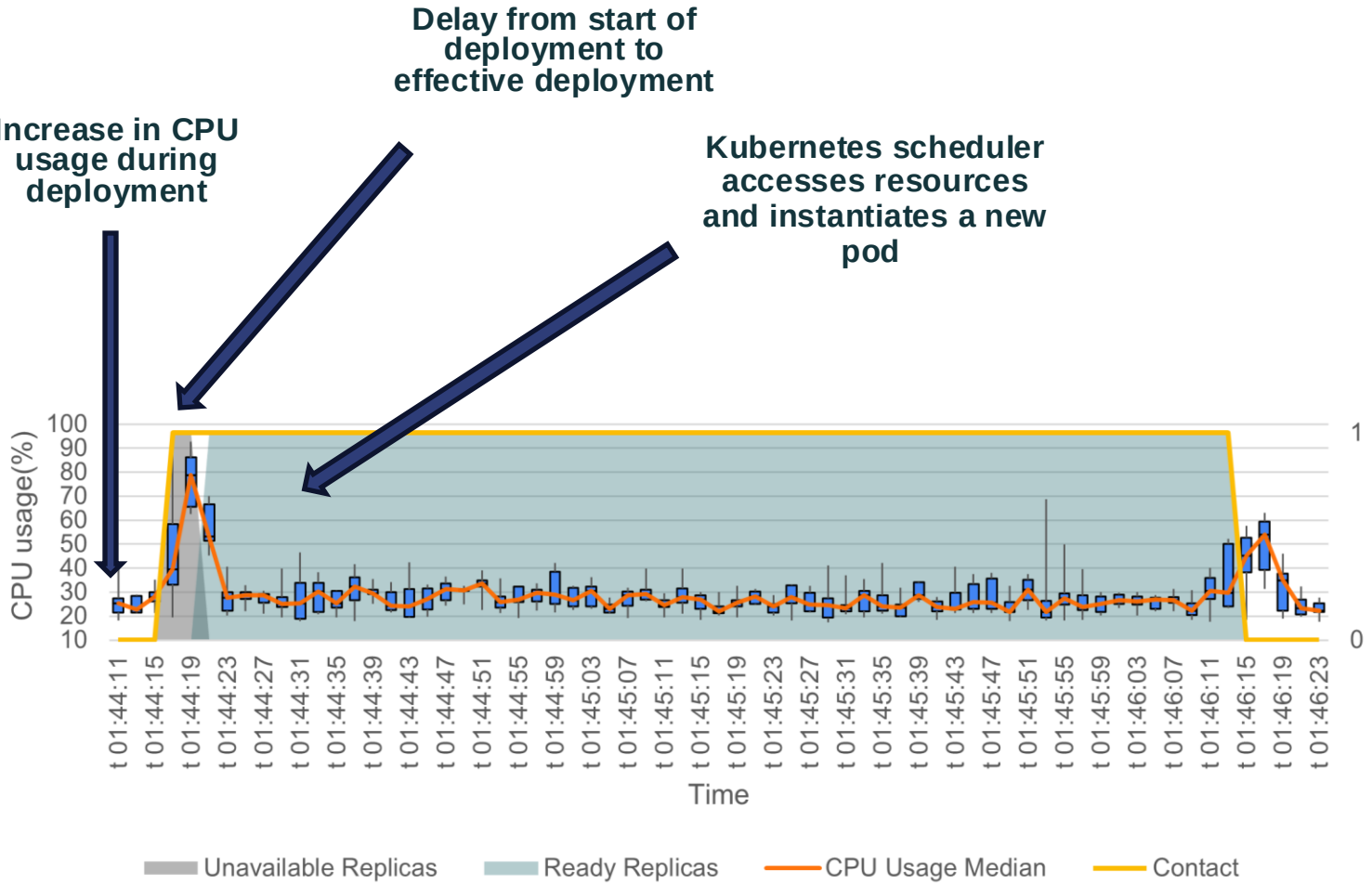
Test Environment setup

The testbed simulates two users (Alice and Bob) in the coverage area, and a LEO satellite.





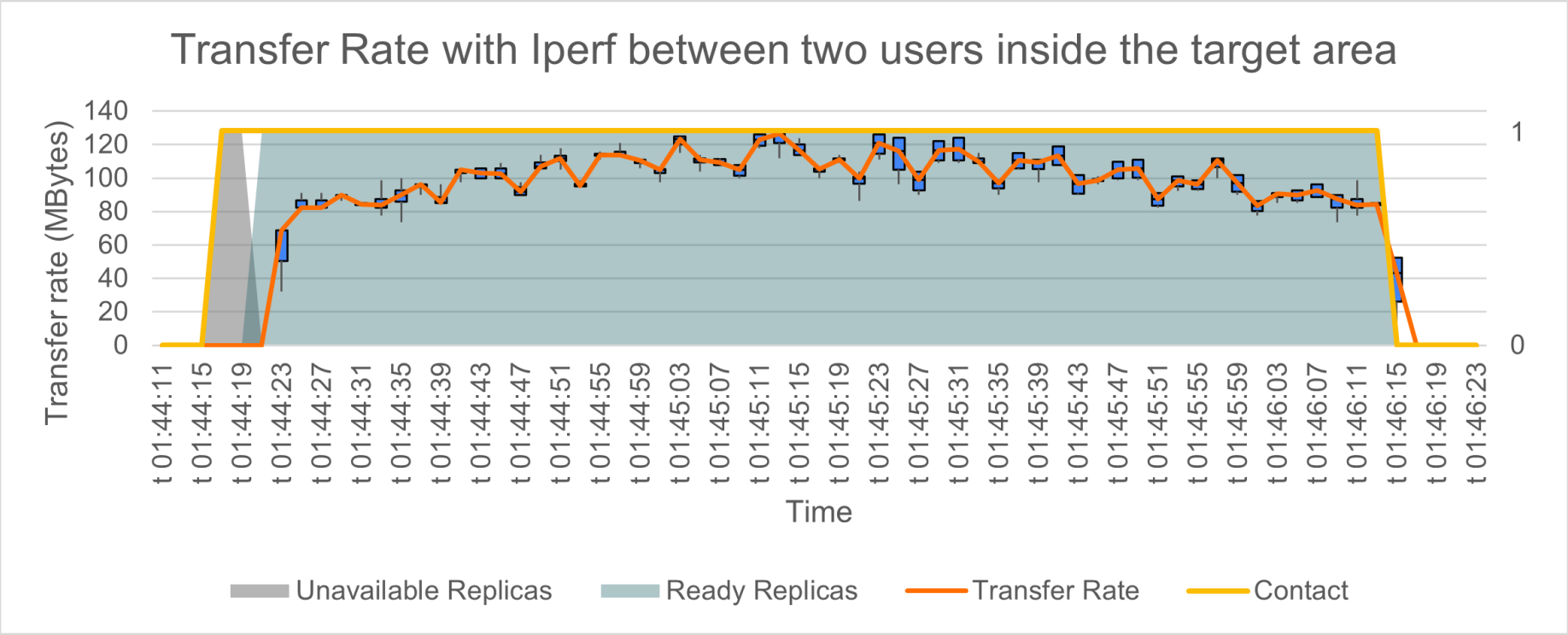
Results – Impact of initialization



- From OSM GIS plugin we selected the target area.
- The channel emulator propagates the orbit
- Custom scalers activate the service
- Relay service enables connection

sdsds

Results – Impact of the initialization time



IPERF transfer rate during contact

- We can appreciate the variation, is consequent with the orbital movement of the satellite.
- There is a delay between the contact of the satellite and the effective deliver of the service due to k3s scheduling.
- The service is offered only when the satellite is inside the target area, releasing resources of the satellite when those are not needed

Results - Deployment anticipation

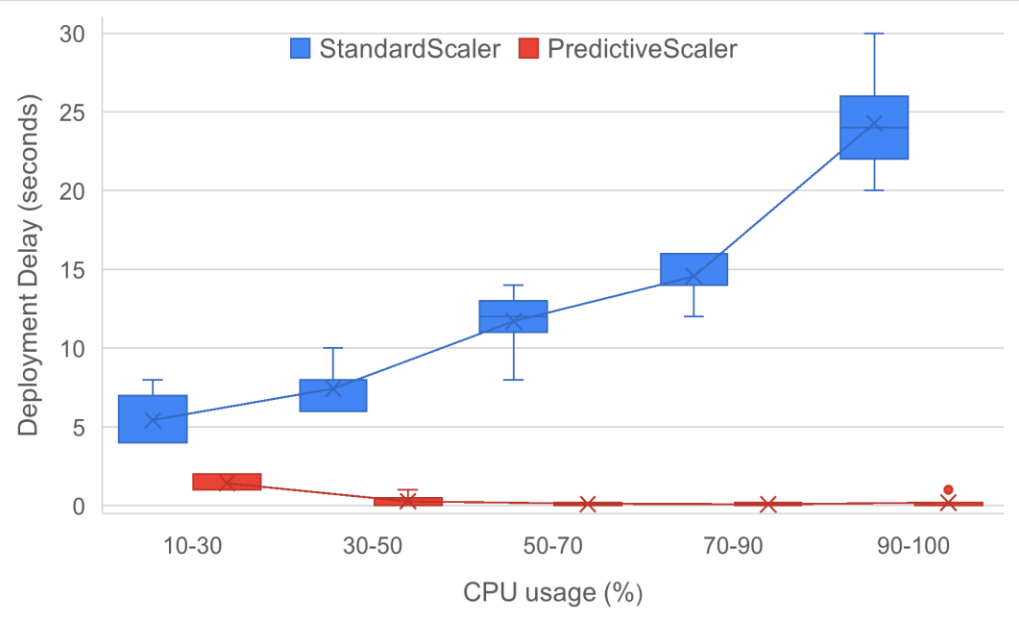
- Deployment impacted by CPU consumption
- Anticipate the deployment
- Extension of the Scaling factor
- Improvement of service availability

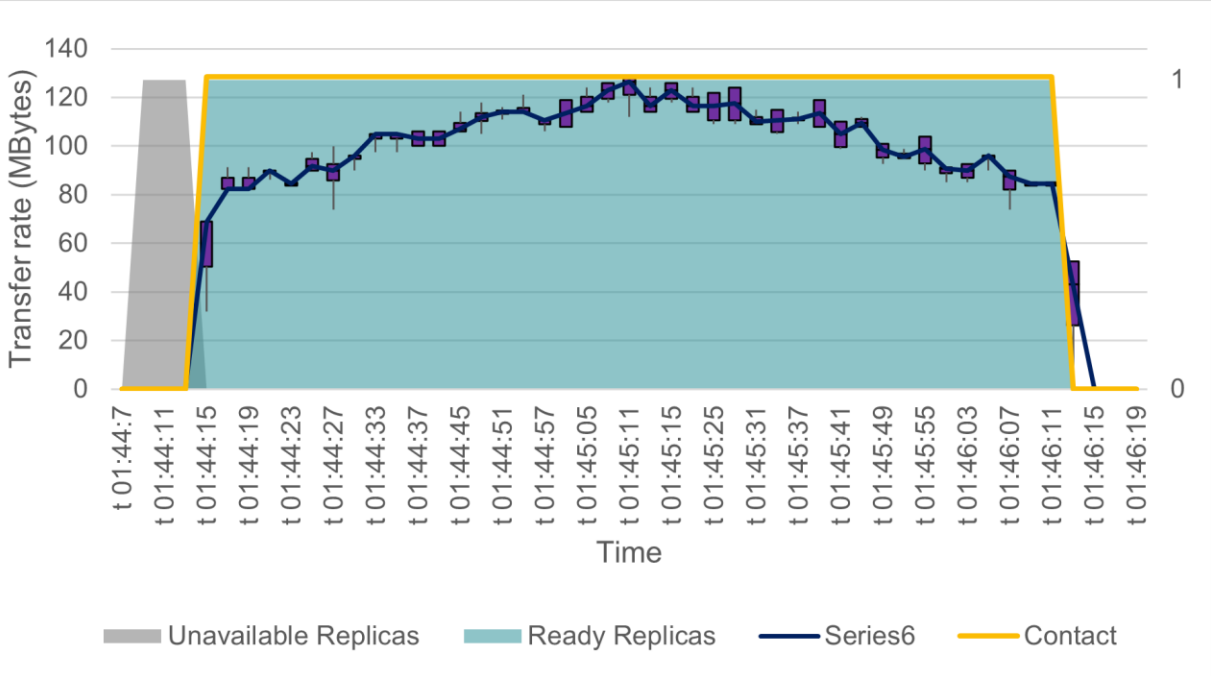
Extended factor

$$S'(t) = \begin{cases} R, & \text{if } t \in [T_{\text{deploy}}, T_{\text{end}}] \\ 0, & \text{otherwise} \end{cases}$$

$$T_{\text{deploy}} = T_{\text{start}} - D_{total}$$

$$D_{\text{total}} = D_{\text{base}} + k \cdot \left(\frac{CPU_{\text{load}}}{100} \right)^2$$





Conclusions

- ETHER project and Vision
- Key enabling technologies at different layers addressed
- Enabling three use cases
- Conceived a new ETHER MANO architecture
- Presented specific development in ETHER MANO --> Geolocalization and Mobility Management
  - Implementation using terrestrial technologies --> No direct modification
  - Extension with dedicated pods or plugins
  - Results demonstrate the feasibility of using these technologies --> no required adhoc satellite developments
  - Single-Master satellite scenario
- Future Work
  - Single-Master satellite presents certain limitations (*)
  - Integrate multiple satellites, which present additional challenges
    - Connectivity
    - VNF migration
    - Satellite selection

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Thanks

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