5GMED Architecture for Advanced Automotive and Railway Communication Services in Cross-Border Scenarios

Jad Nasreddine, Estela Carmona-Cejudo, Ricard Vilalta, Raúl Parada, Philippe Veyssiere, Angelos Antonopoulos, José López Luque, Judit Bastida, Raül González, George N. Triantafyllou, Nuria Trujillo Quijada, Jorge García Hospital, Julian Garbiso, and **Francisco Vazquez-Gallego**

This work was supported by the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 951947 (5GMED), by the grant ONOFRE-3 PID2020-112675RB-C43 funded by MCIN/AEI/10.13039/501100011033, and by the regional FEDER FEMIoT P1(IU16-011655) project.

IEEE Future Networks World Forum, 12-14 October 2022, Montreal, Canada

Index

- 5GMED Project Overview
- Use Cases
- Challenges
- Cross-Border 5G Network Architecture
- Conclusions

5GMED Project Overview

- Innovation action funded by the Horizon 2020 research and innovation program of the European Commission

- **Main goal**: evaluate the capabilities of 5G technologies (3GPP Rel.16) to meet the requirements of advanced CAM and FRMCS use cases in cross-border scenarios

- Deploy two 5G Stand-Alone (SA) networks along 65 km of the Mediterranean cross-border corridor between Figueres (Spain) and Perpignan (France)
  - E-15 highway
  - High-speed rail track including a railway cross-border tunnel

- Conduct large-scale trials in the cross-border corridor to collect measurements of service KPIs and network metrics for performance evaluation

Use Cases (1/2)

- UC1: Remote driving
  - Teleoperation of autonomous vehicle that finds complex traffic situation (accident, weather conditions, etc.)
  - Transmission of video images, sensors data and commands → requires sufficient quality and ultra low latency (guarantee and predict QoS)

- UC2: Road Infrastructure Digitalization
  - Intelligent traffic management to ensure safe and efficient mobility in mixed traffic scenarios with legacy vehicles and connected vehicles
  - Cooperative sensing to detect hazards and abnormal traffic situations
  - TMC generates and disseminates traffic recommendations → requires low latency

Use Cases (2/2)

- UC3: Future Railway Mobile Communications
  - FRMCS performance and business services (non-critical)
    - Monitor sensors on-board the train
    - Detect obstacles on rail tracks
    - Detect risk situations of passengers on-board
    - Provide high-performance wireless connectivity to passengers
  - Requires low latency and very high data rates

- UC4: Follow-Me Infotainment
  - Distribution of high-quality media content to passengers
  - Virtual Network Functions of media services deployed on edge nodes, achieving very low latency and high data rates

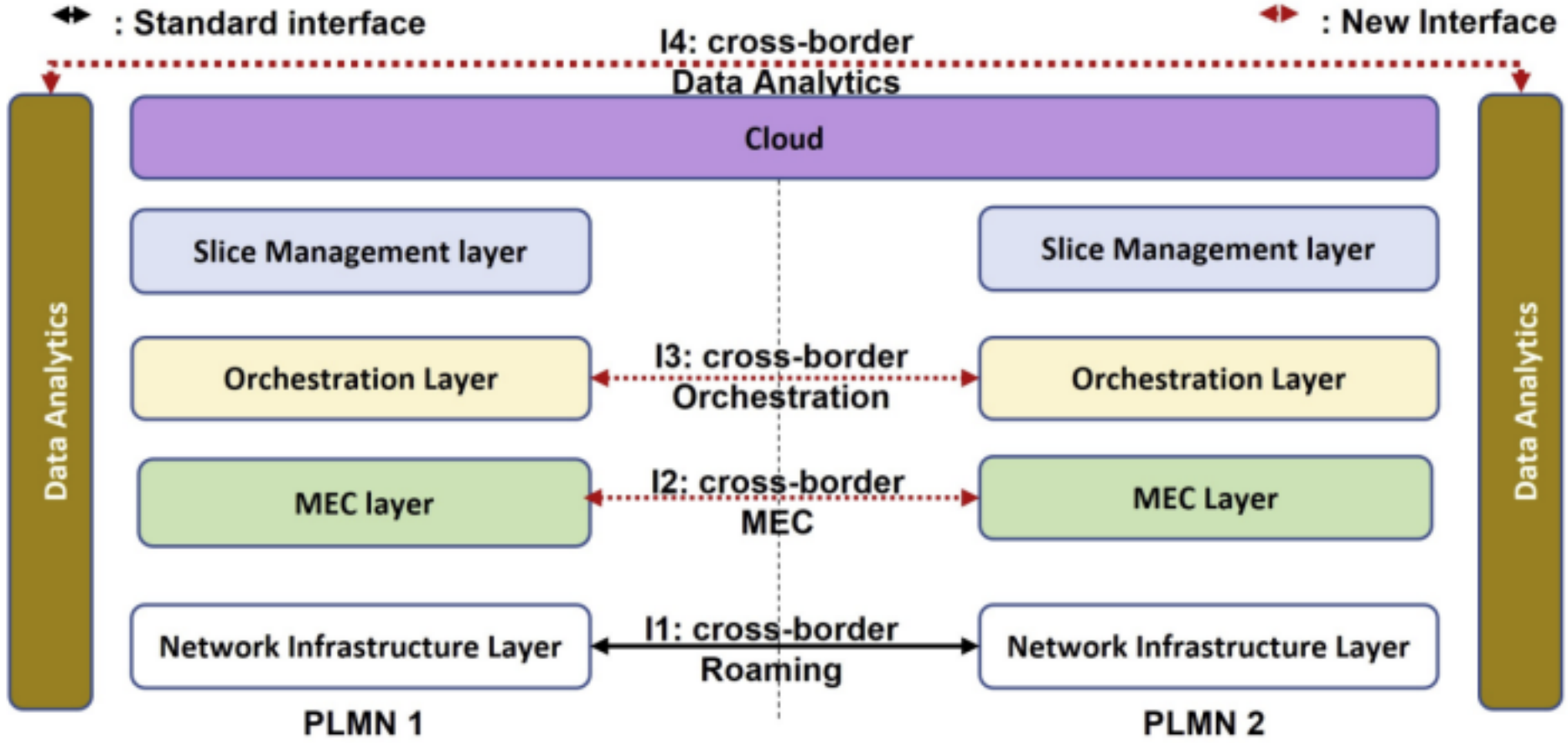
Challenges (1/2)

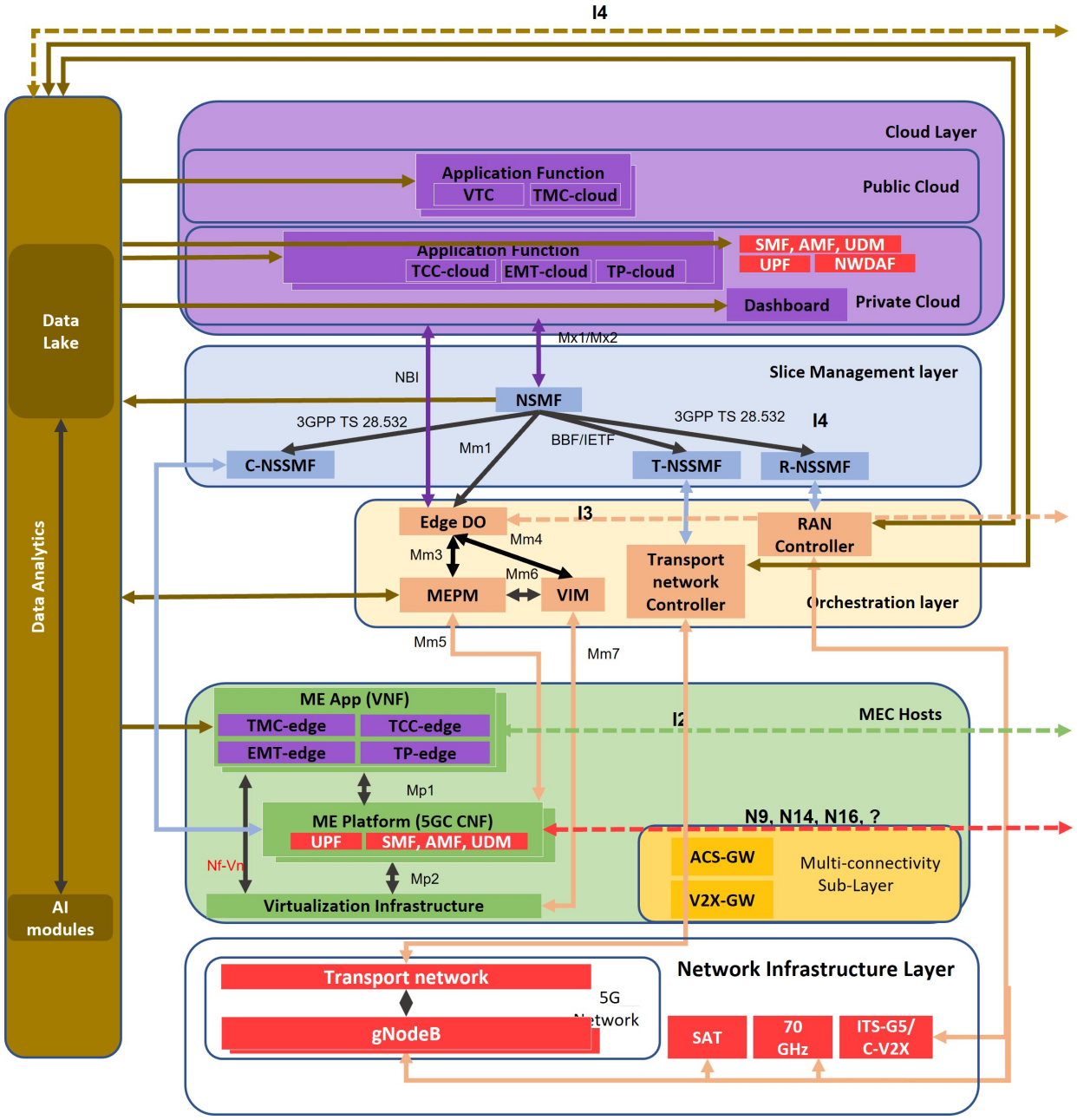
- Strict performance requirements of CAM and FRMCS use cases: end-to-end latency, data rate, reliability, service interruption time
- Challenging environment, irregular orography and dense vegetation → diverse radio technologies: 5G NR, C-V2X, 70 GHz & satellite in remote/isolated areas
- Heterogeneous radio access technologies (handover) → multi-connectivity gateways to move between different RAT with minimum delay
- Current Home Routed Roaming introduces long service interruption times (unfeasible for CAM & FRMCS) → solutions needed at 5G Core and RAN

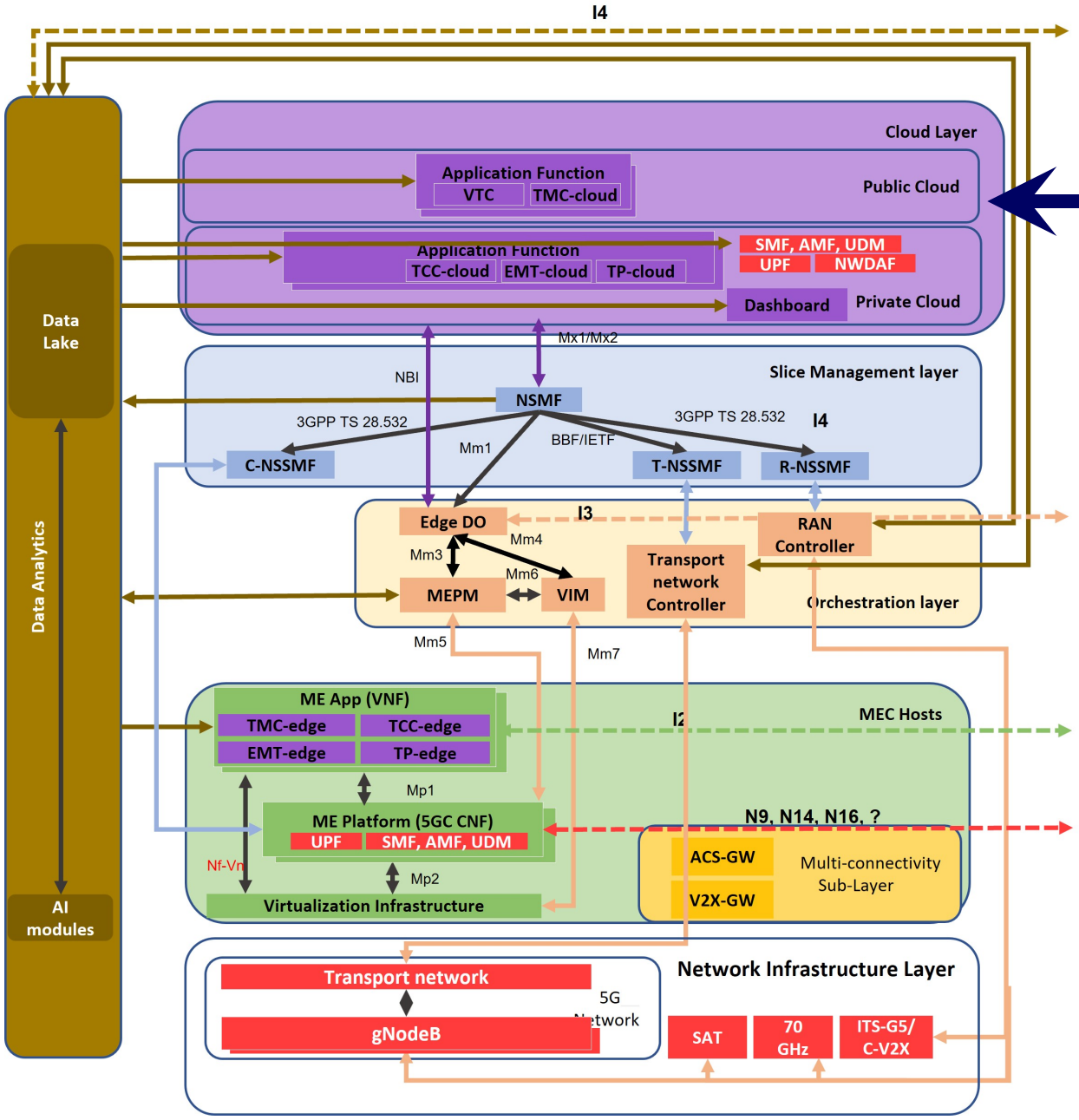
Challenges (2/2)

- HRR induces high latency because user data are routed to the home UPF even if the UE is in a visited PLMN → Local Break-Out (LBO) roaming
- To reduce latency, migrate services between MEC nodes to follow the UE's movements → deploy instances of the User Plane Function (UPF) in MEC nodes
- Virtualization of services and network functions in 2 different networks → to provide service continuity, we need cross-MNO interface between orchestrators
- AI in 5G to optimize network configuration → for service continuity of AI

Cross-Border Network Architecture

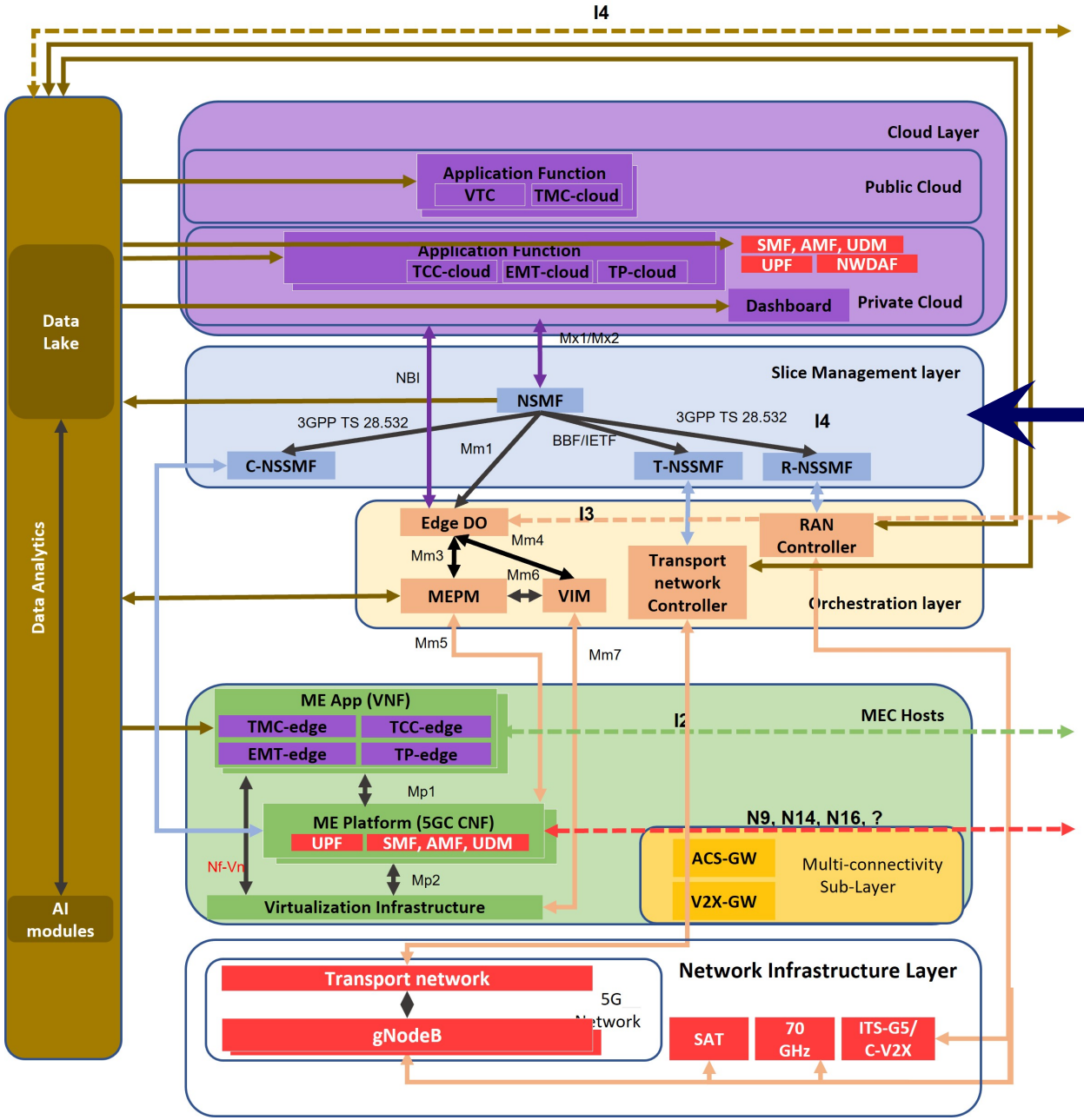



I4
Data Lake
Cloud Layer
Application Function
VTC
TMC-cloud
Public Cloud
Application Function
TCC-cloud
EMT-cloud
TP-cloud
SMF, AMF, UDM
UPF
NWDAF
Dashboard
Private Cloud
Mx1/Mx2
NBI
Slice Management layer
NSMF
3GPP TS 28.532
3GPP TS 28.532
I4
Mm1
BBF/IETF
C-NSSMF
T-NSSMF
R-NSSMF
I3
Edge DO
Mm4
Mm3
Mm6
MEPM
VIM
Transport network Controller
RAN Controller
Orchestration layer
Mm5
Mm7
Data Analytics
ME App (VNF)
TMC-edge
TCC-edge
EMT-edge
TP-edge
I2
MEC Hosts
Mp1
ME Platform (5GC CNF)
UPF
SMF, AMF, UDM
N9, N14, N16, ?
Nf-Vn
Mp2
Virtualization Infrastructure
ACS-GW
V2X-GW
Multi-connectivity Sub-Layer
AI modules
Transport network
5G
gNodeB
Network Infrastructure Layer
SAT
70 GHz
ITS-G5/ C-V2X



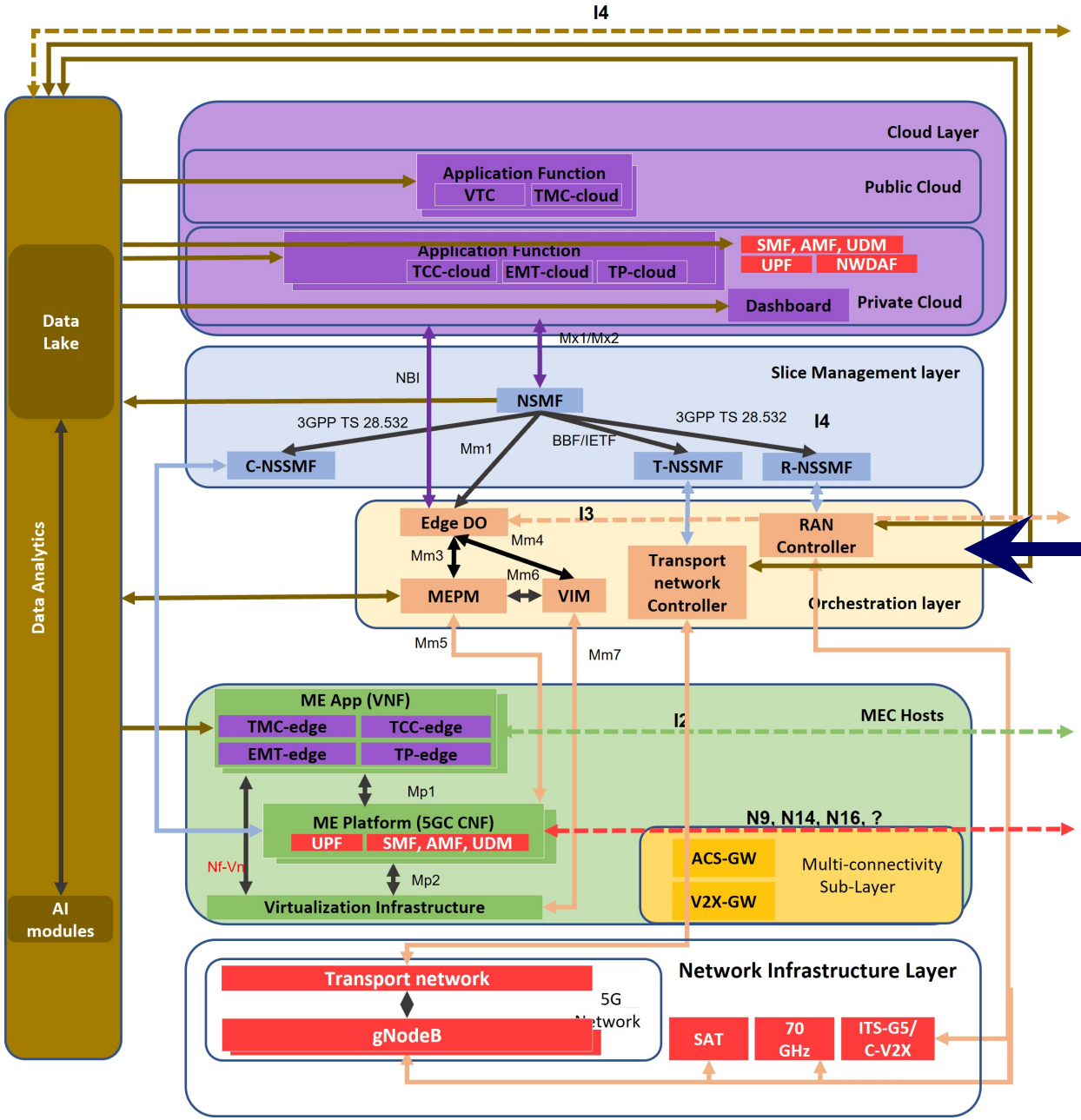
Cloud layer

- Backend applications hosted by public and private Clouds
- All control plane core elements and a centralized UPF
- Dashboard to:
  - Create and configure network slices
  - Monitor network metrics and service KPIs



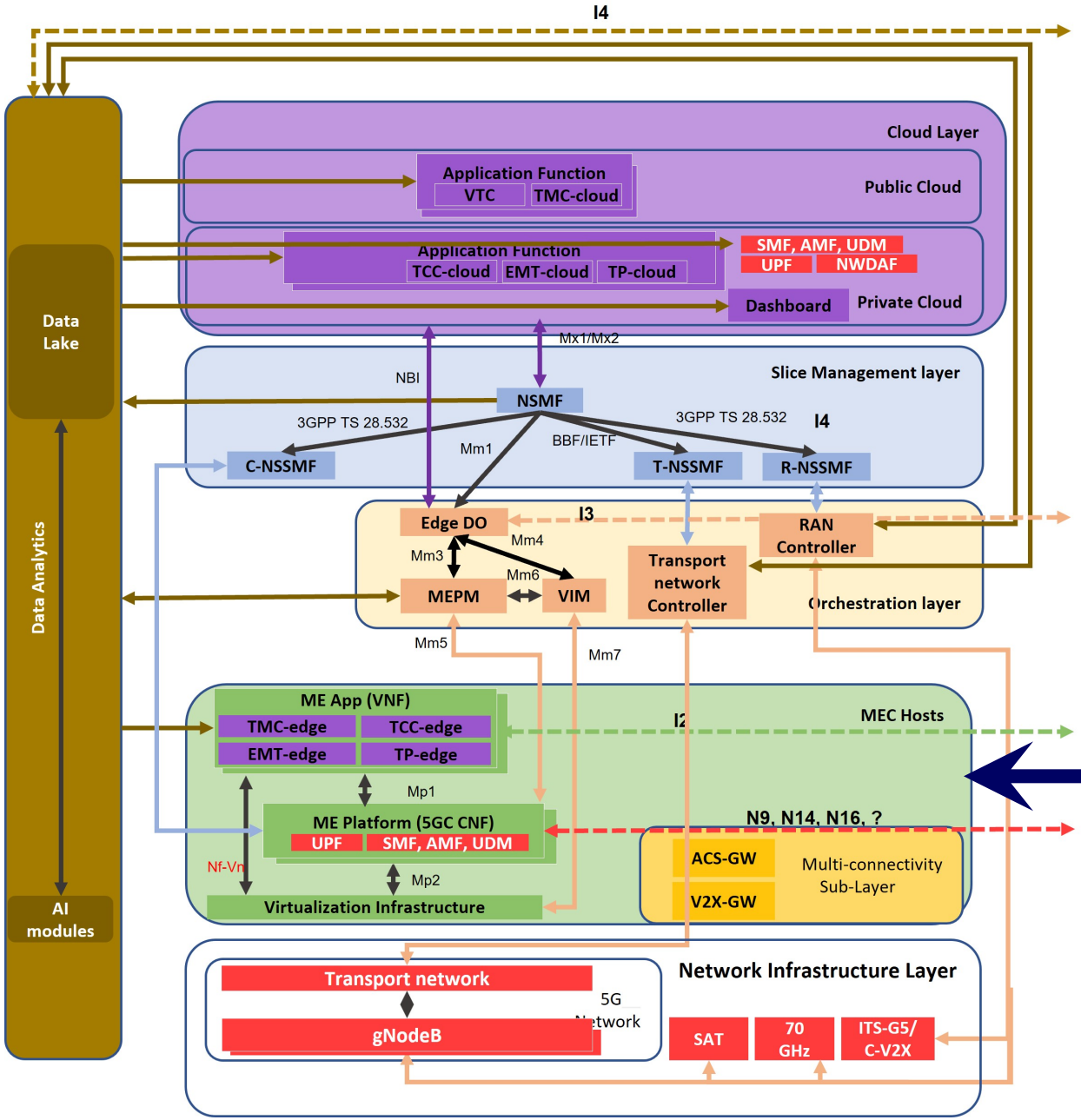
Slice Management layer

- To manage end-to-end network slice instances
- Network slices are statically deployed at both sides of the border
- Slicing is provided in transport network, 5G Core, and RAN



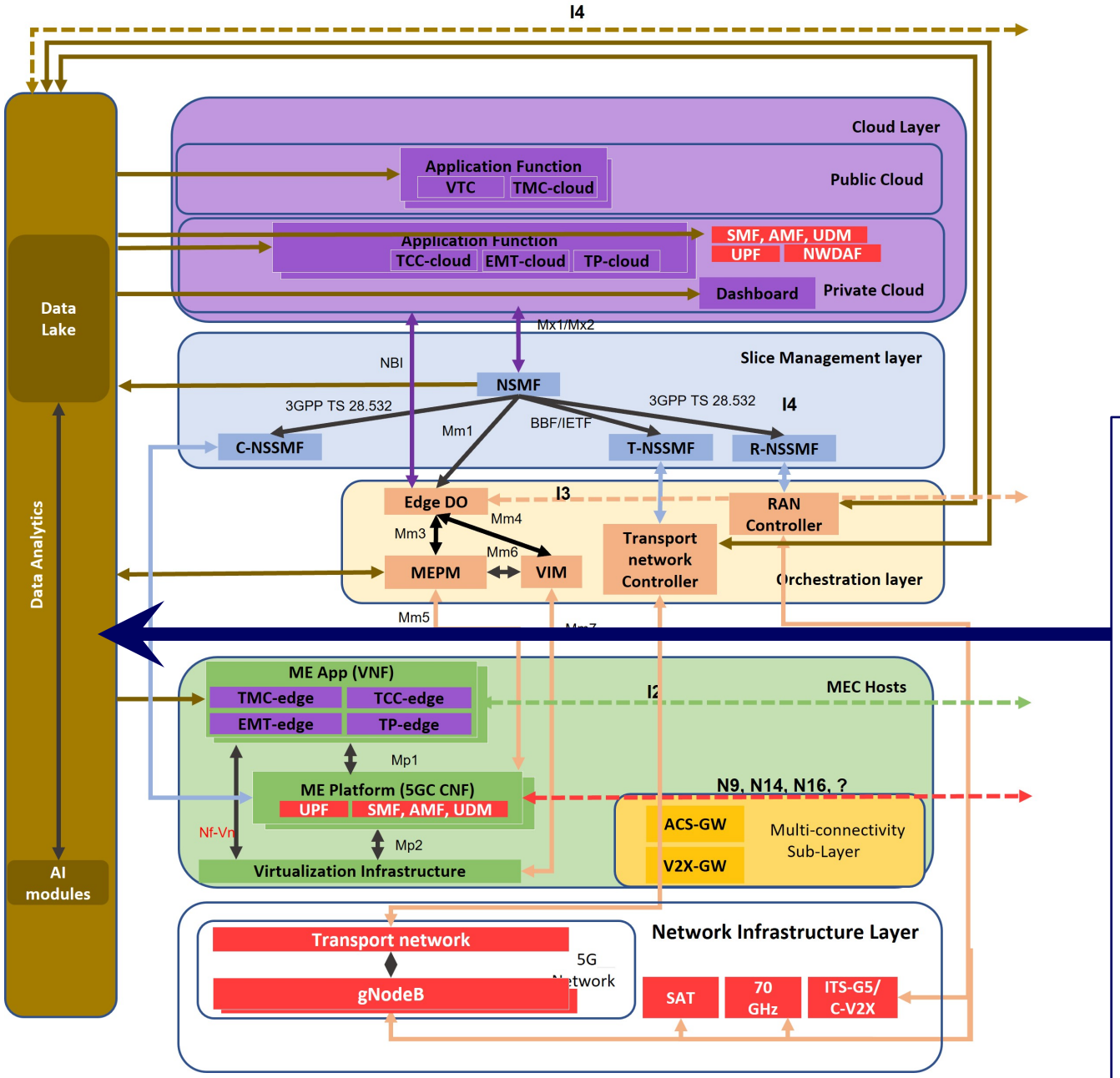
Orchestration layer

- Facilitates network & service orchestration of different administrative domains
- Facilitates the migration of services between Edge nodes
- It federates two different instances of the Domain Orchestrators (one in each country)



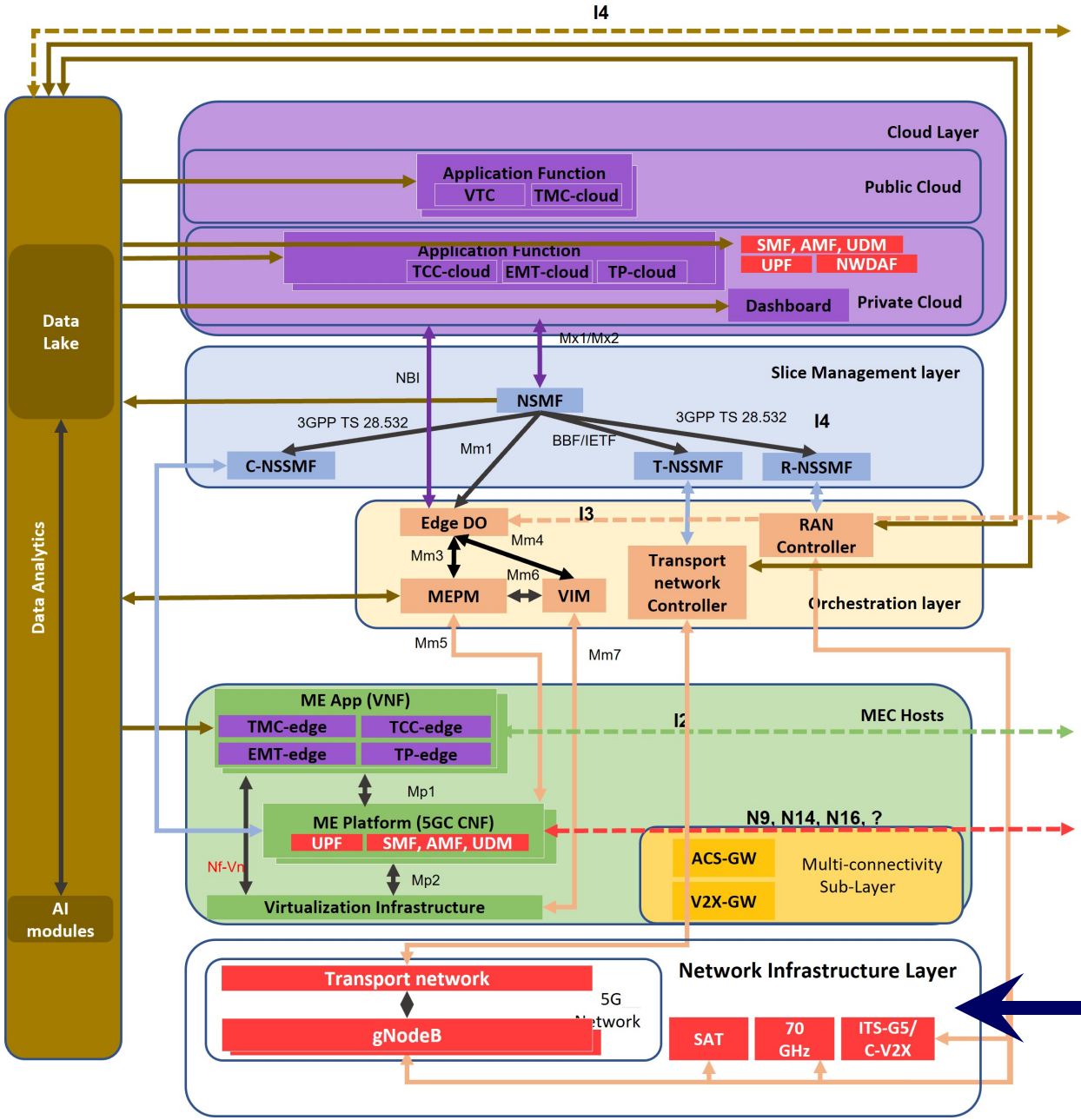
MEC layer

- Distributed edge computing platform to host services that require
  - Low latency
  - AI functions (video analytics, obstacle detection…)
- Multi-connectivity gateways
- Cross-MNO inter-MEC interface to facilitate
  - Transfer of service's state and data between countries with low latency



Data Analytics layer

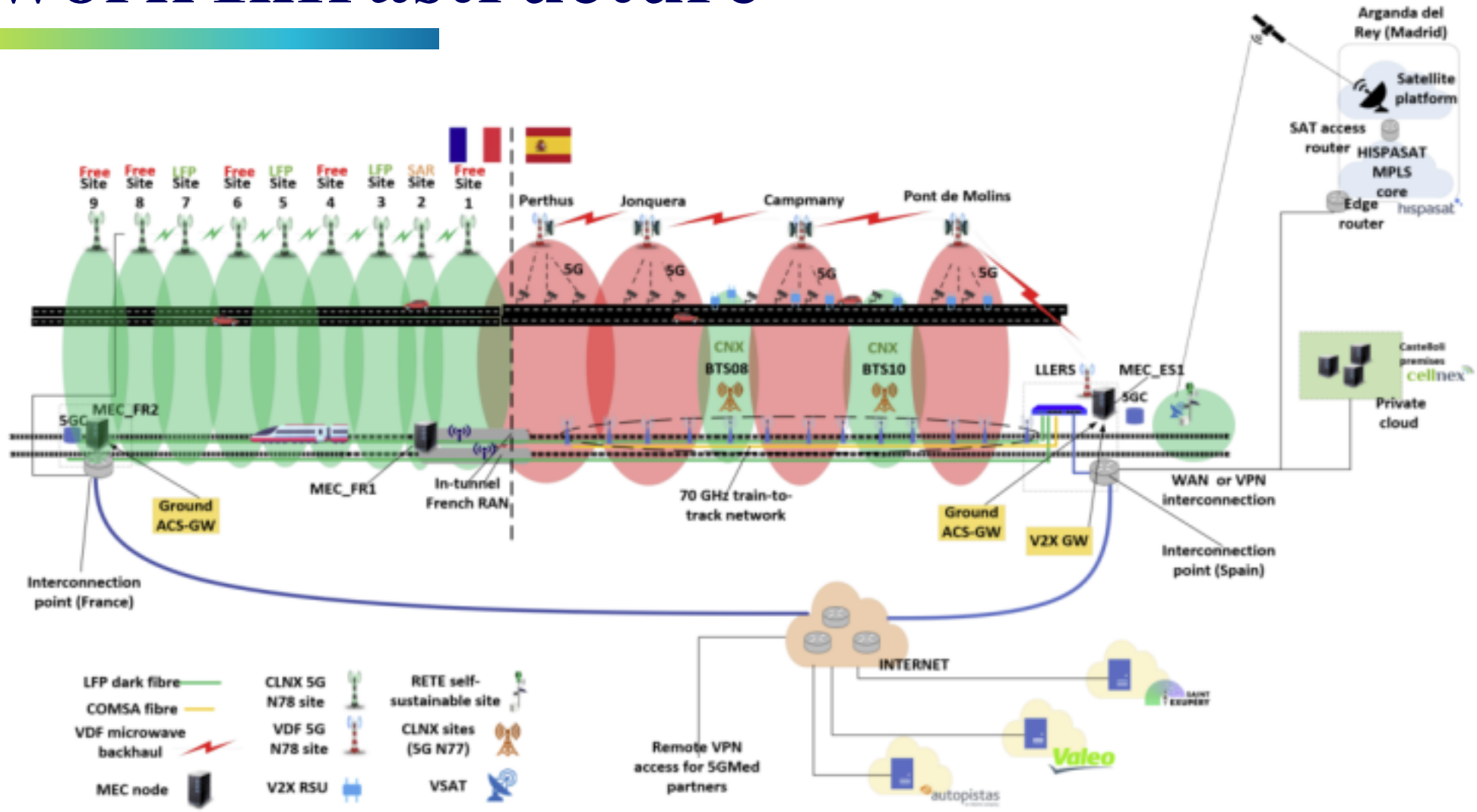
- Collects network metrics and service KPI measurements from other layers
- Contains AI modules managed by the network operator
- Generic AI modules that can be used by applications that subscribe to them
- Cross-border interface between Data Analytics layers of different MNOs



Network Infrastructure layer:

- Radio access network
  - 5G NR gNodeBs
  - 70 GHz IEEE 802.11ad access points
  - C-V2X RSUs
  - VSAT terminals
- Transport network
  - Microwave, fiber optic, satellite backhaul
- Core network
  - 1x 5G Core in Spain, 1x 5G Core in France
  - Roaming optimization mechanisms (N14, N16)

Network Infrastructure



Conclusions

- We have presented the 5GMED's network architecture that is being deployed in the Mediterranean cross-border corridor
- It addresses the challenges imposed by cross-border scenarios in CAM and FRMCS use cases
- 5GMED architecture
  - 6 layers (network infrastructure layer, MEC layer, orchestration layer, slice management layer, cloud layer, and data analytics layer)
  - 4 interfaces for management of cross-border connectivity

- Future work: validation of use cases, and execution of small-scale and large-scale trials

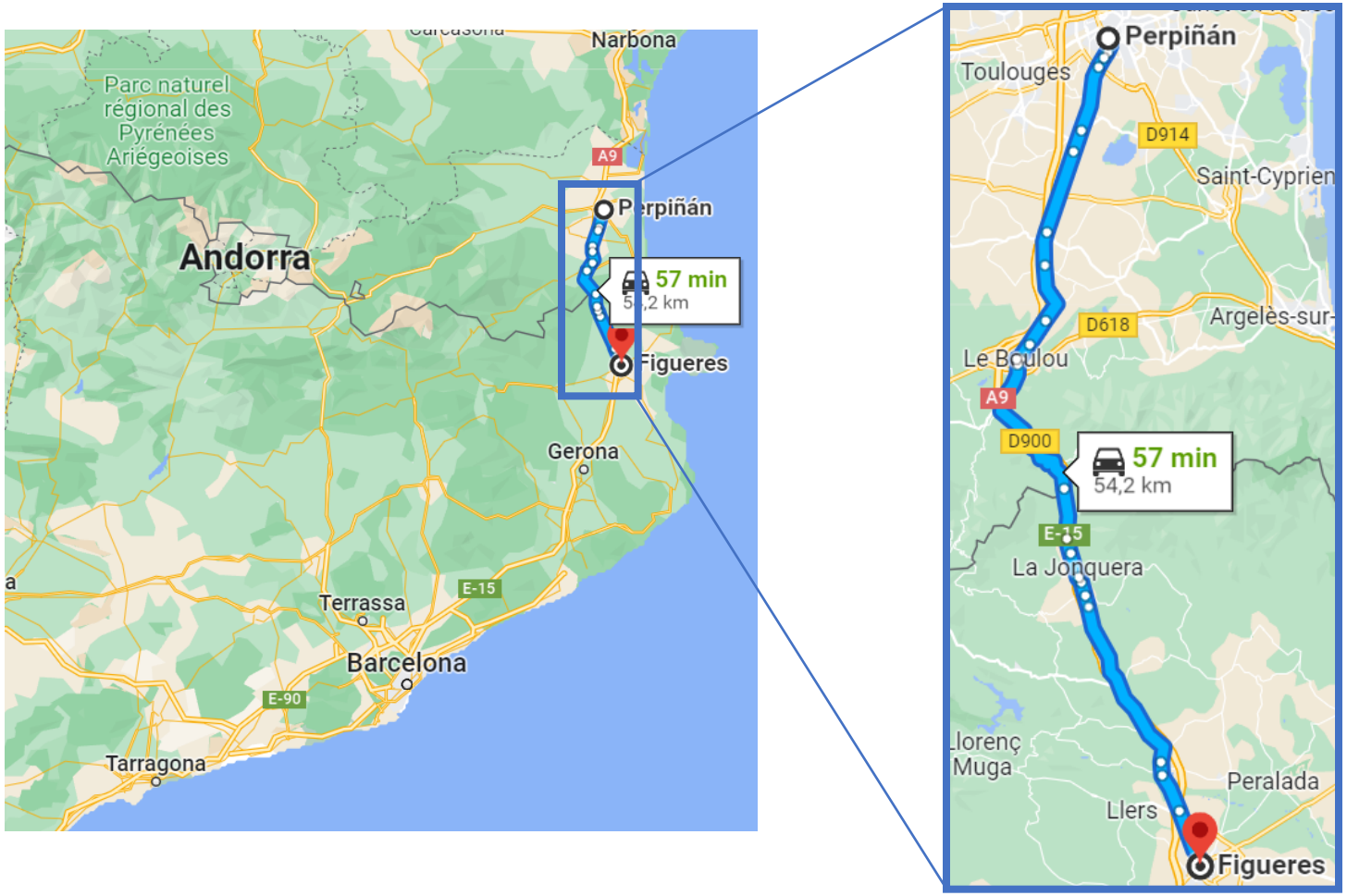
Francisco Vázquez Gallego, PhD
Technical Manager of 5GMED
Head of V2X Research Line at i2CAT Foundation
francisco.vazquez@i2cat.net

Thank you!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 951947

@5GMED_EU
5GMED
www.5gmed.eu

Mediterranean cross-border corridor



- 65 km of Mediterranean corridor between Spain and France
- Highway E-15 for CAM use cases
- High-speed rail track for FRMCS use cases
- Highway and rail track very close → shared 5G network infrastructure
- 8 km rail track inside cross-border tunnel (Le Perthus)