

IEEE 5G for CAM Summit 2021

Presentation of the ES – PT Cross Border Corridor

Diana Blanco Pérez – European Project Manager at CTAG

11th May 2021



5GMOBIX



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825496

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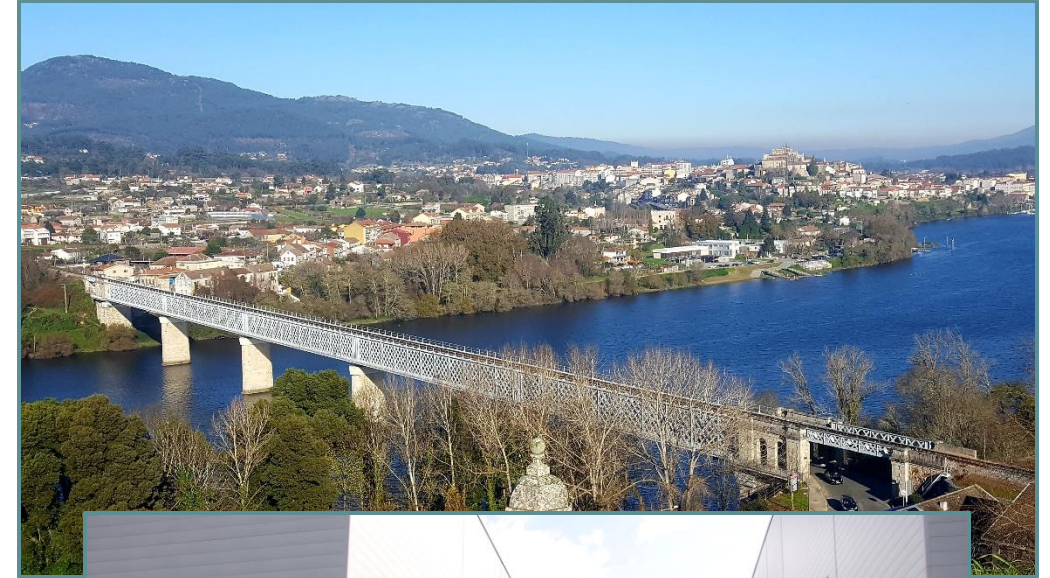
- CBC Overview
- User stories
- Trials Location
- 5G Network
- Roadside, cloud and Remote control Infrastructure
- Vehicles and OBUs
- Evaluation
- Preliminary results.
- Trial Plan
- Conclusions

CBC Overview

































ES-PT CBC Overview

- The Spanish-Portuguese corridor connects the cities of Vigo and Porto (250 Km,) and use next roads/highways:
 - **Spain:**
 - City of Vigo (4 Km).
 - A55 (10 Km).
 - AP9 (5 Km).
 - **Portugal:**
 - A3 (5 Km).
 - N13 (1km).
 - A28 (7 Km) near the Porto Airport and Boat Passenger Terminal.
 - **Cross-Border:**
 - Located in the border of the north of Portugal with Spain.
 - Established by the Minho/ Miño river, disposing of two bridges providing the road infrastructure serving trucks, cars and pedestrians.
 - International trade as well as large passenger commuting flows are of great importance and provide ideal conditions for the execution of diversified trials to showcase the advantages offered by the 5G connectivity to CCAM use cases.



ES-PT CBC Overview

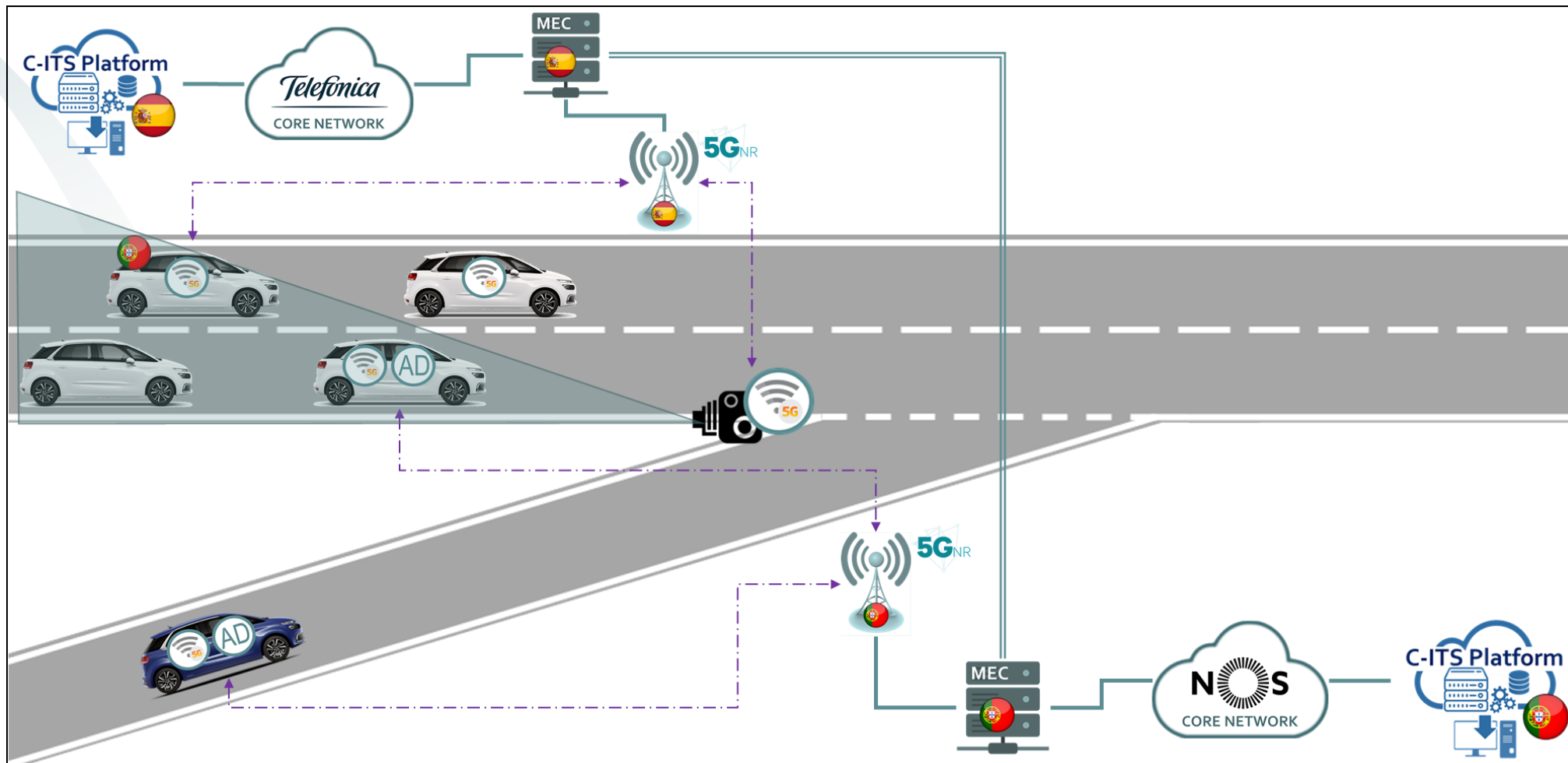
Corridor Leader		
Country Coordinator	 	 
Road Operator		 <small>INSTITUTO DA MOBILIDADE E DOS TRANSPORTES, I.P.</small>  <small>Infraestruturas de Portugal</small> 
MNO & TELECOM	  <small>Telefónica I+D</small>	 
OEM	 Associated Partner 	
City Council		
Associations, Institutes, Technology Centres and Universities	   	  <small>instituto de telecomunicações</small>  <small>INSTITUTO SUPERIOR DE ENGENHARIA DE LISBOA</small>
Testing and Homologation	 <small>On the safe side.</small>	
Technological Innovation/ Electronics		 <small>Powered by Briso</small>  <small>TRANSPORTES, INOVAÇÃO E SISTEMAS</small> 
Advisory and associated	Advisory Board  Associated Partners 	

User stories



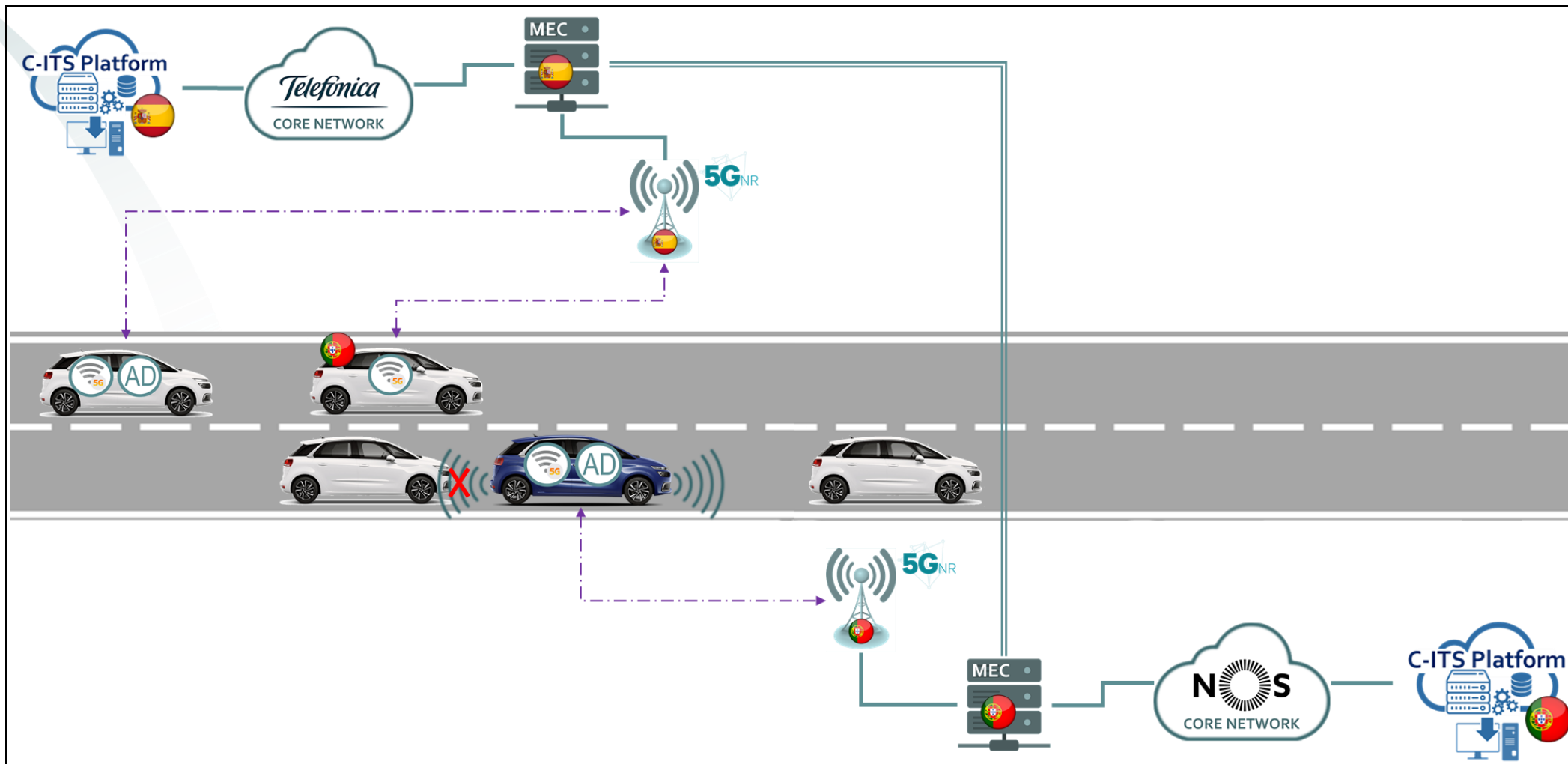
User Stories

Lane Merge



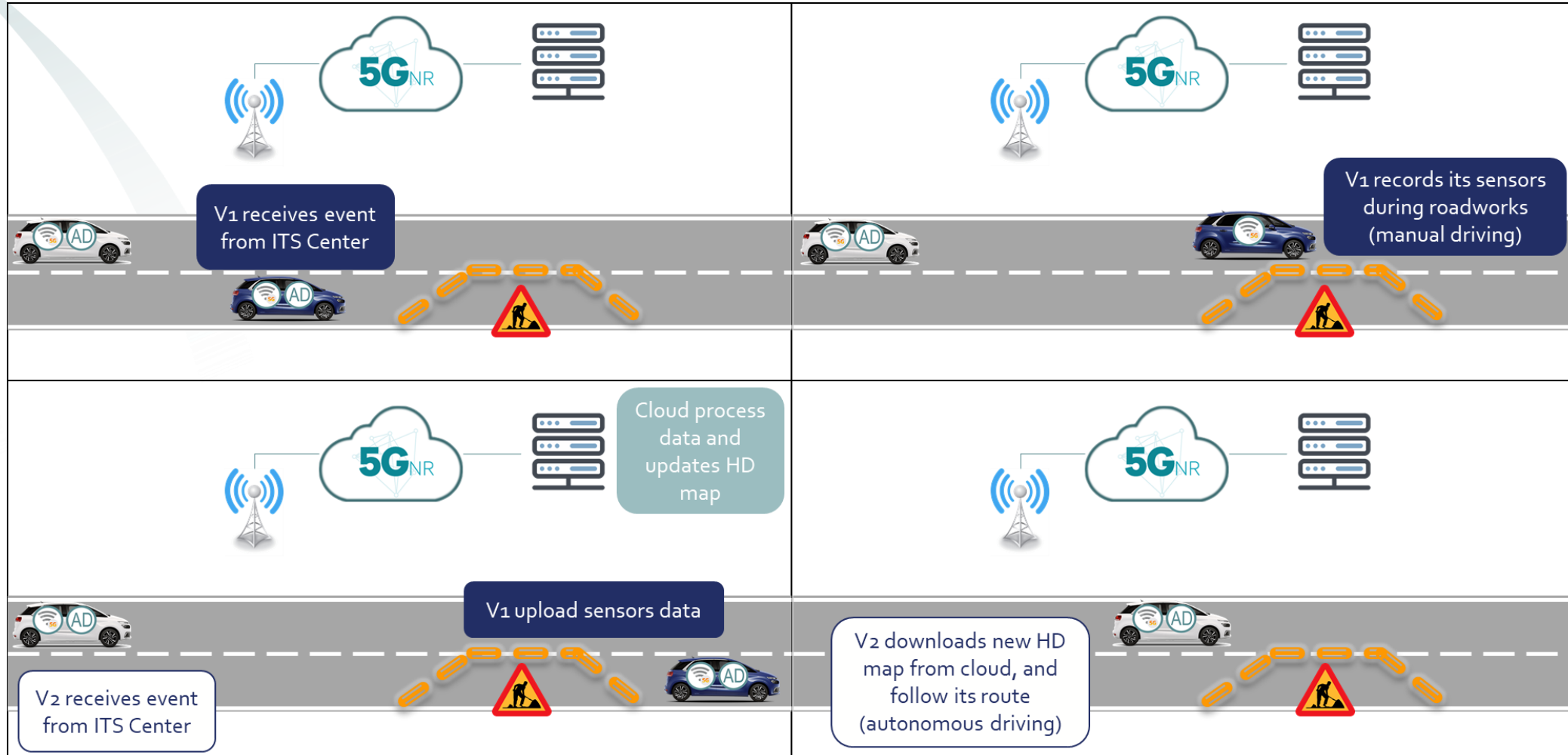
User Stories

Automated Overtaking



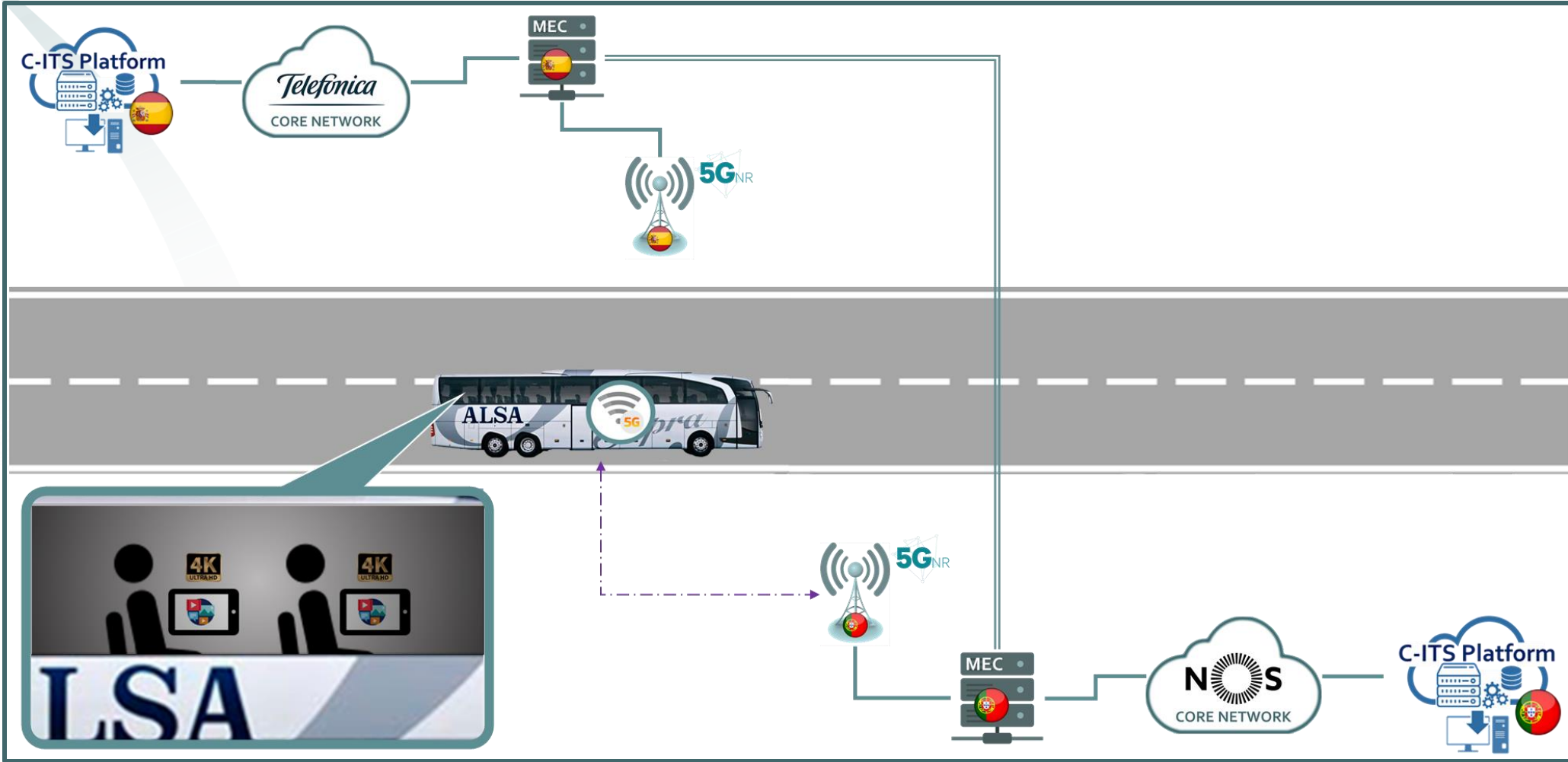
User Stories

HD Maps



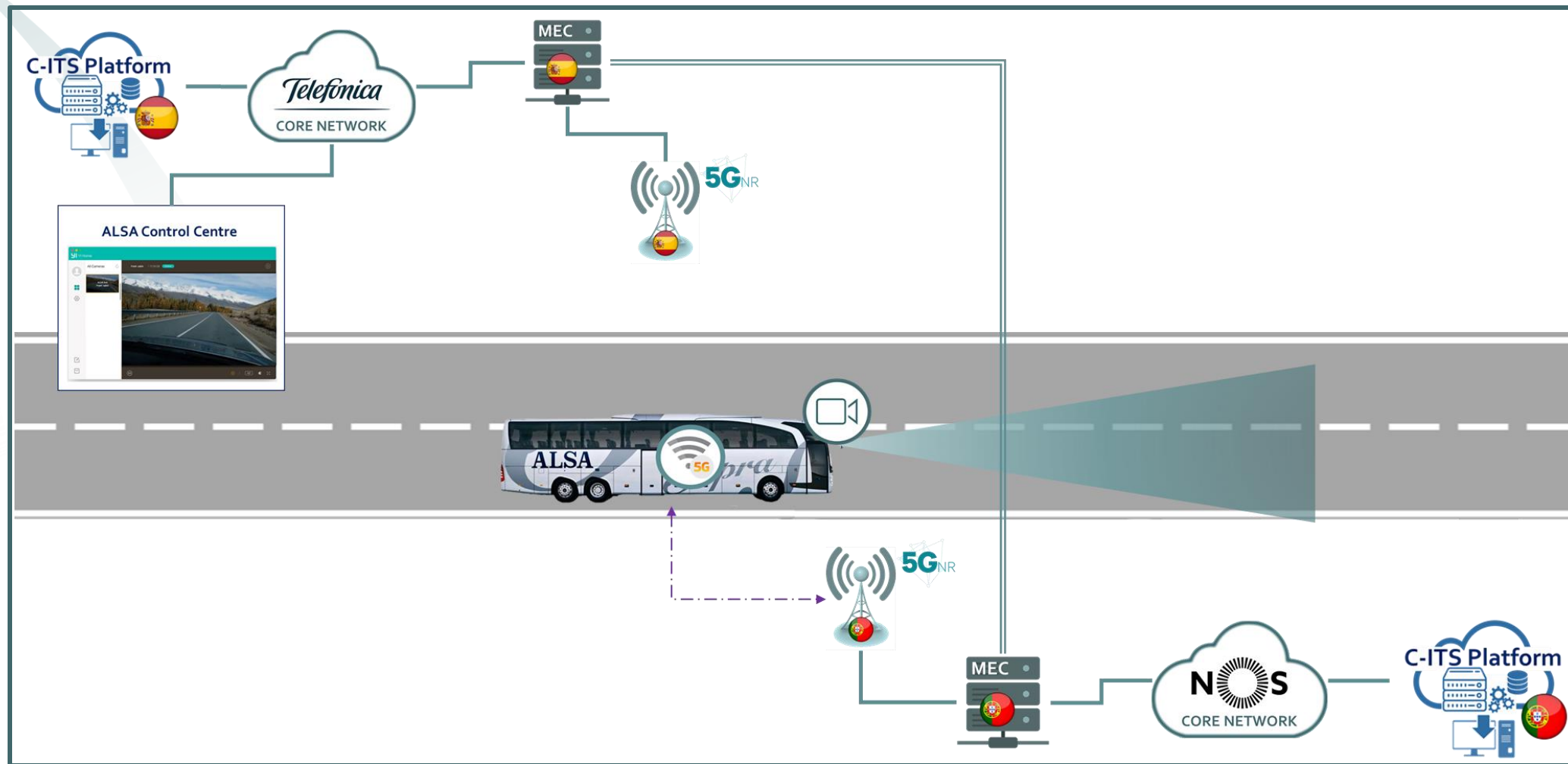
User Stories

Multimedia service for passengers



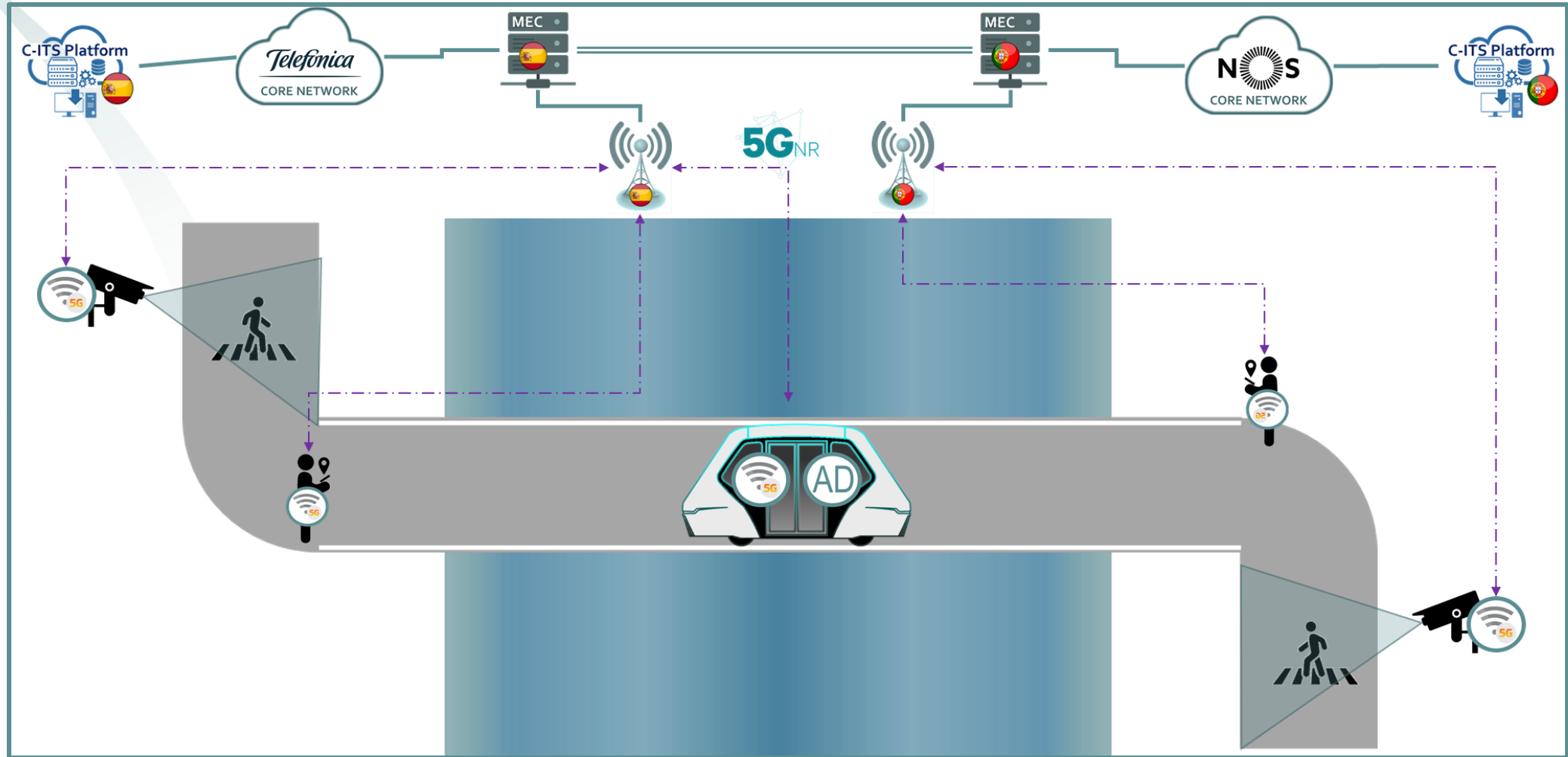
User Stories

4K Video Surveillance



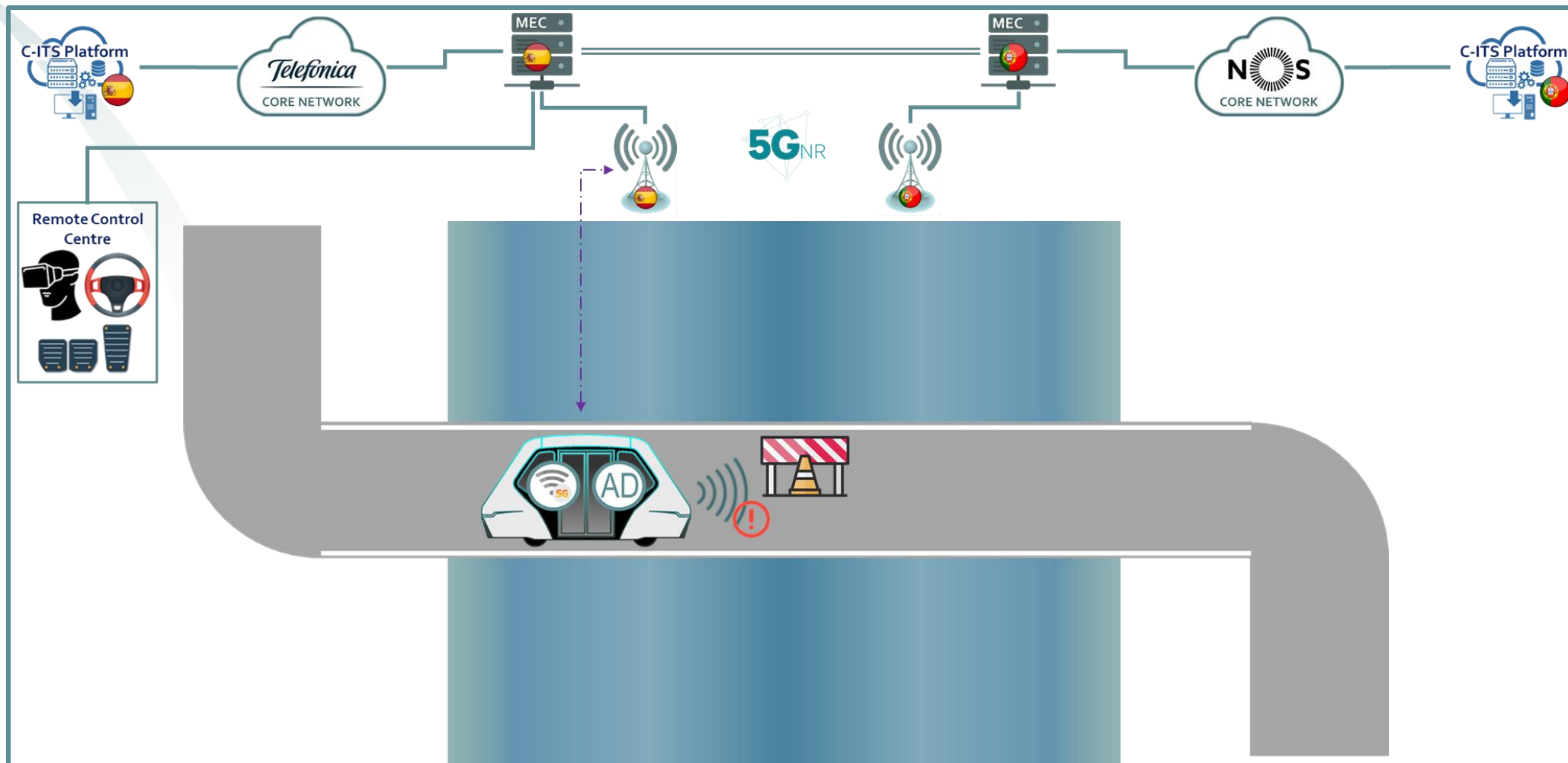
User Stories

Cooperative Automated Operation



User Stories

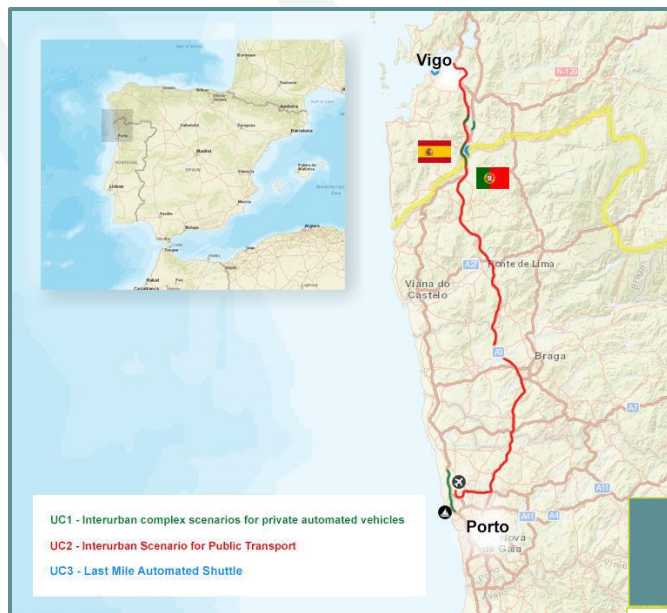
Remote Control



Trials Location

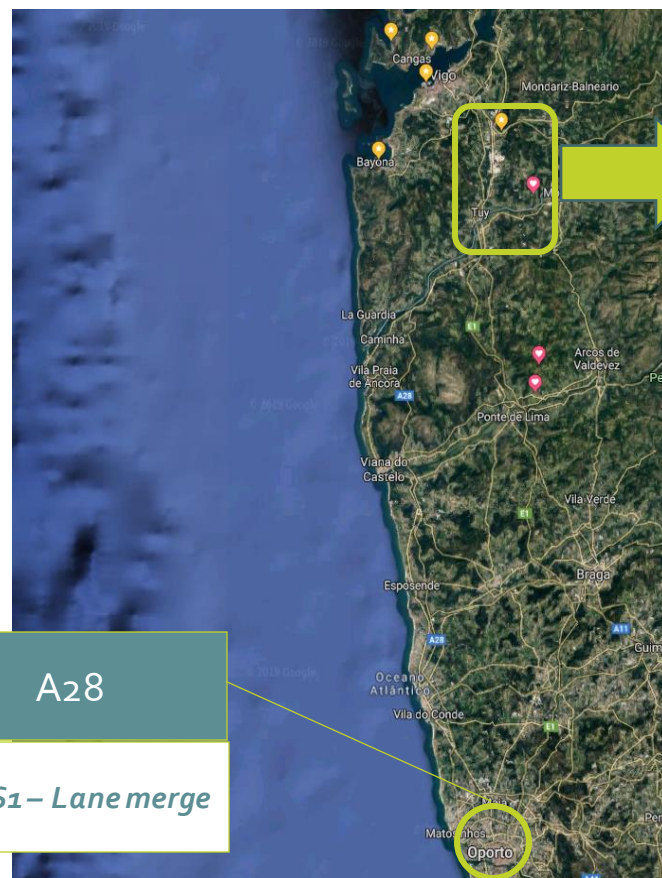


Trials Location



Whole ES-PT corridor Vigo-Porto

- US2 – 4k bus monitoring
- US2 – Multimedia service for passengers



- US1 – Lane merge



US3 – Cooperative automated operation

AP9-A55

US1 - Lane merge
 US1 - Overtaking
 US1, US2 - HD maps

Old Bridge
 ES-PT CB

US3 – Cooperative automated operation
 US3 – Remote control

New Bridge
 ES-PT CB

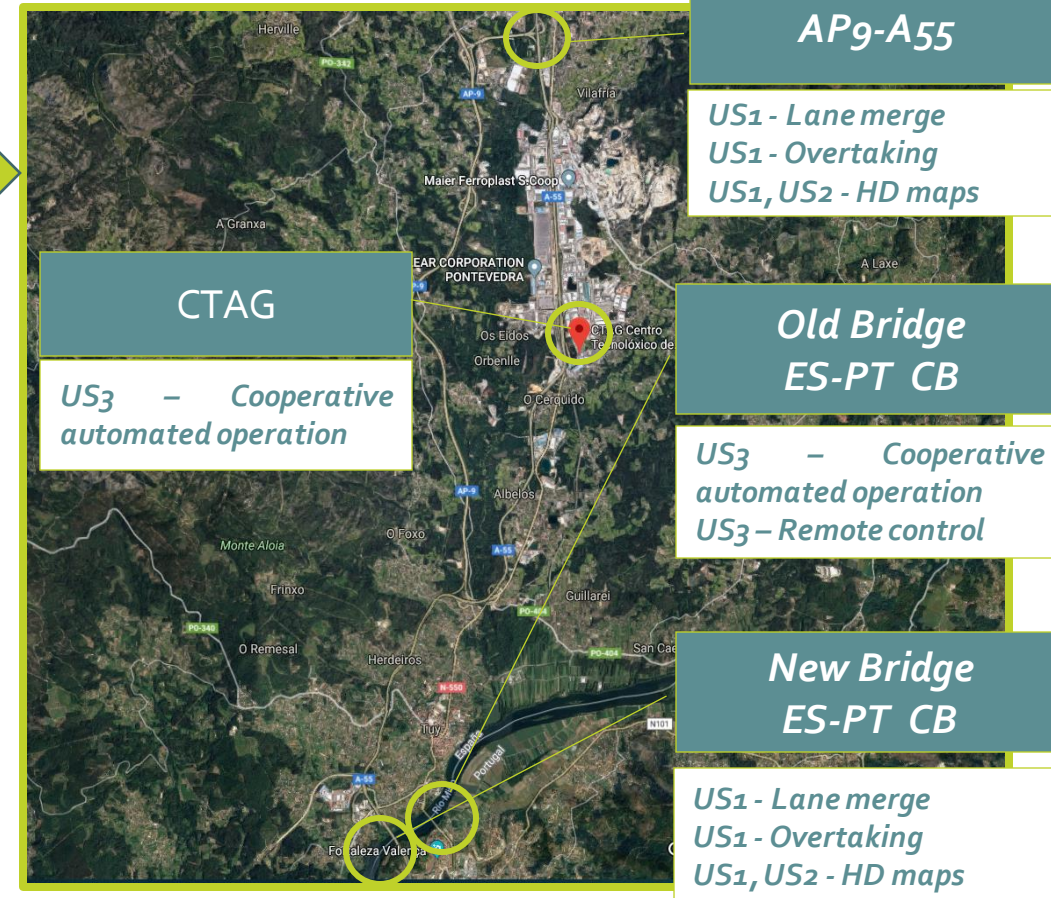
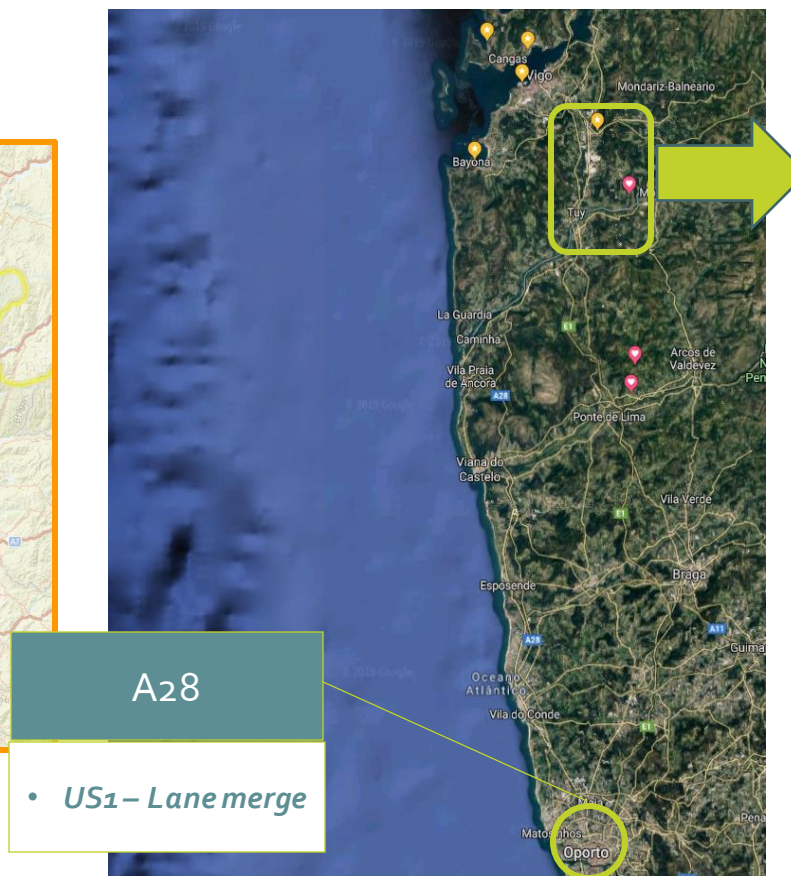
US1 - Lane merge
 US1 - Overtaking
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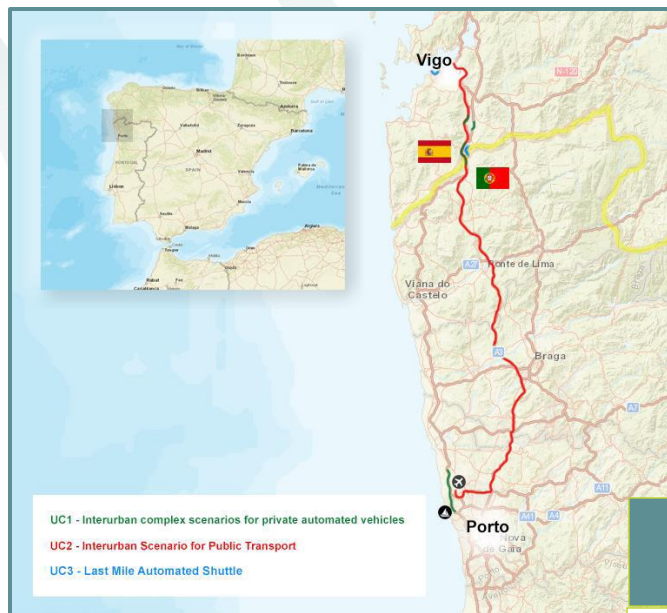


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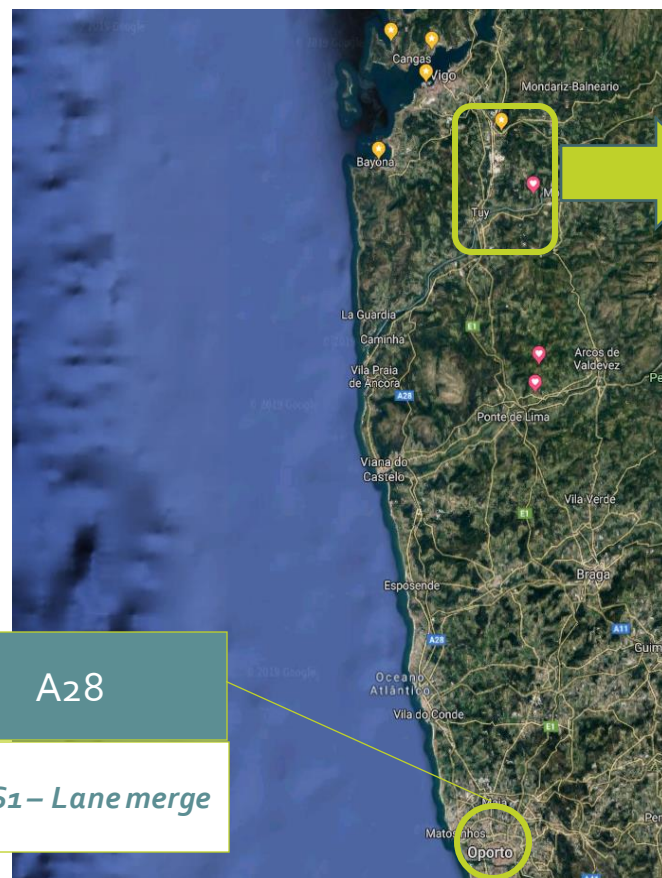


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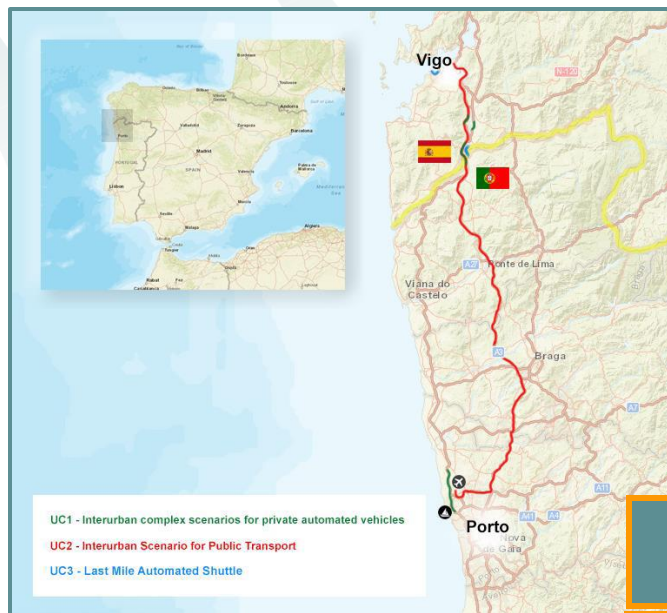
Old Bridge
 ES-PT CB

US3 – Cooperative automated operation
 US3 – Remote control

New Bridge
 ES-PT CB

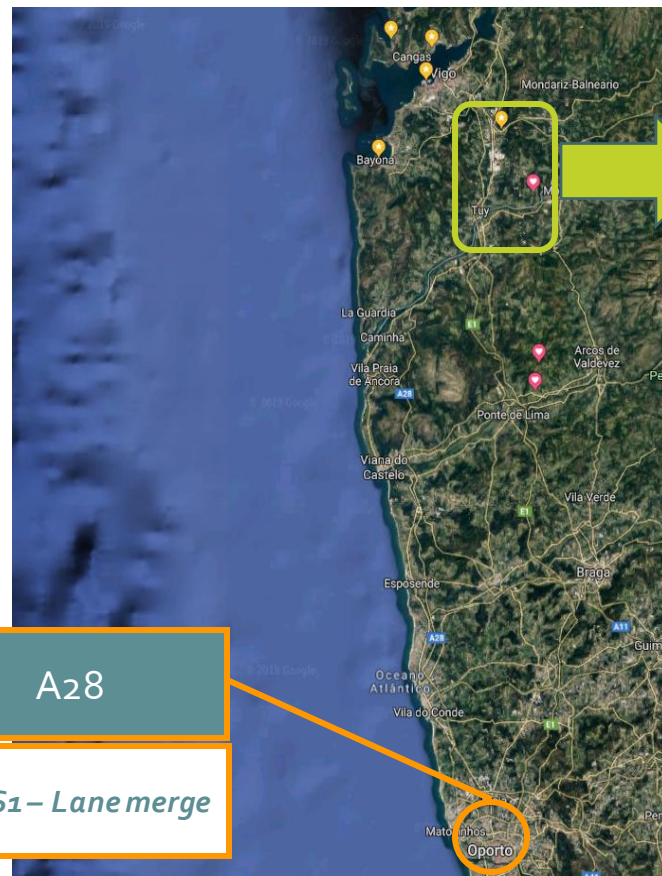
US1 - Lane merge
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 US1, US2 - HD maps

Trials Location



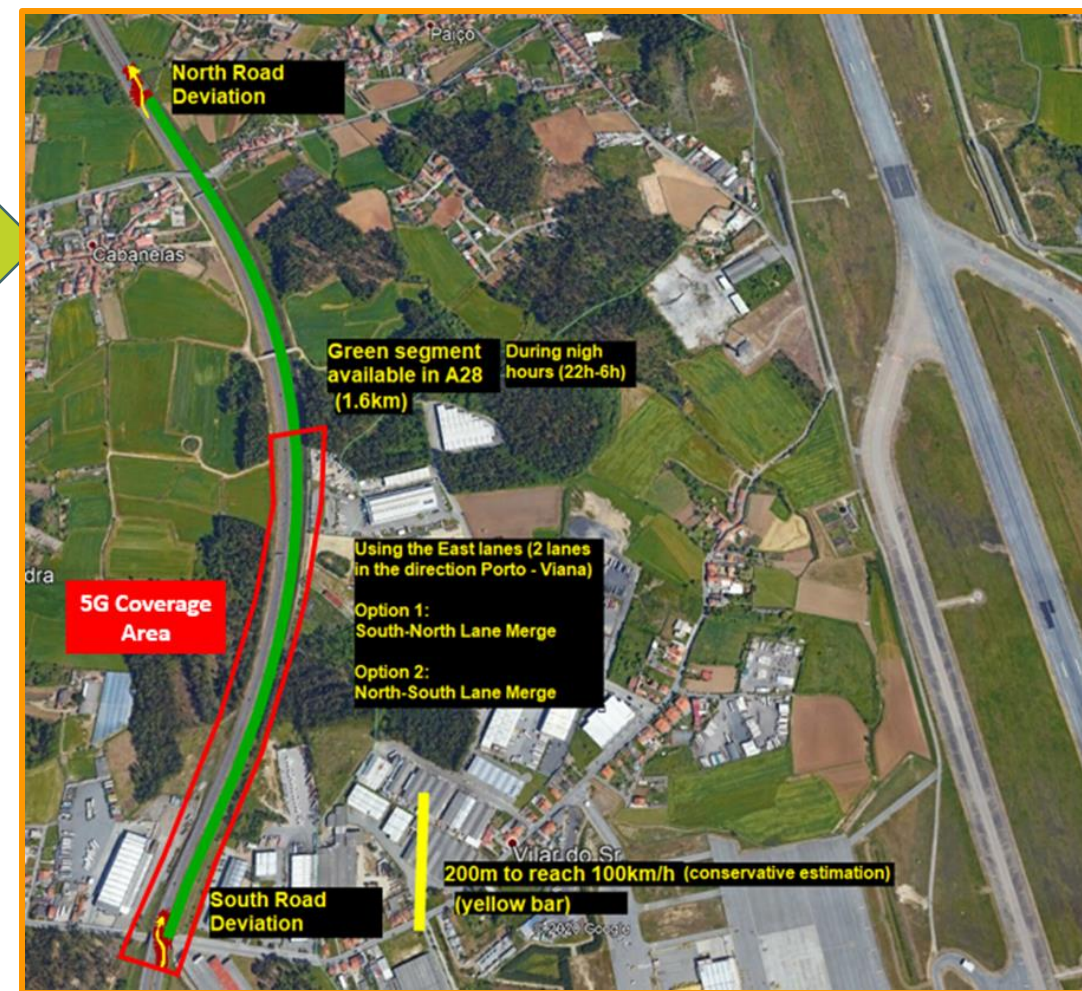
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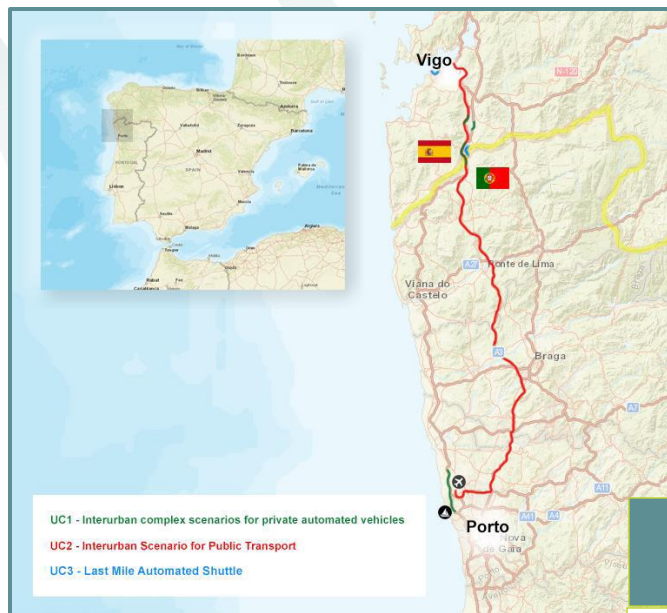


A28

- US1 – Lane merge

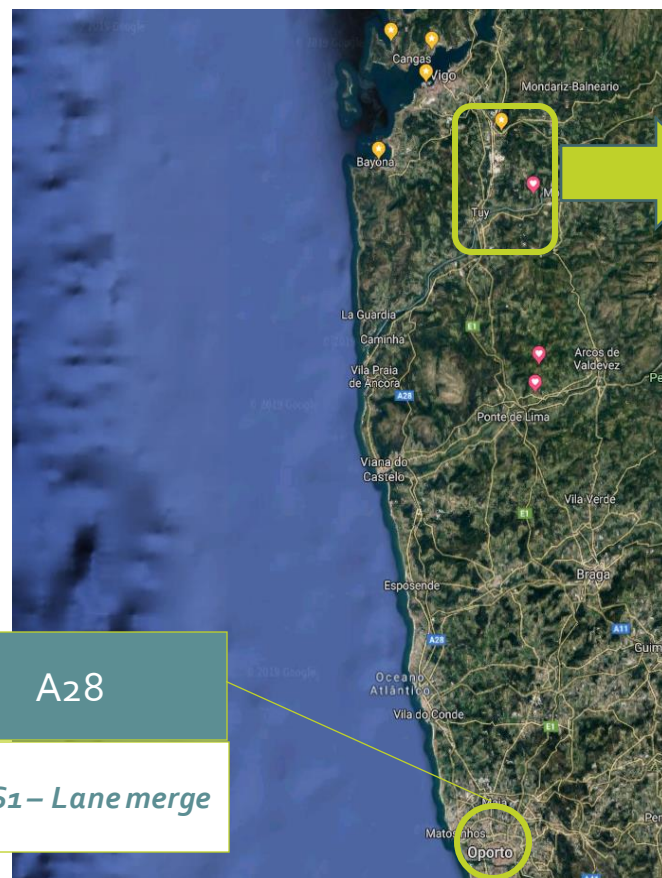


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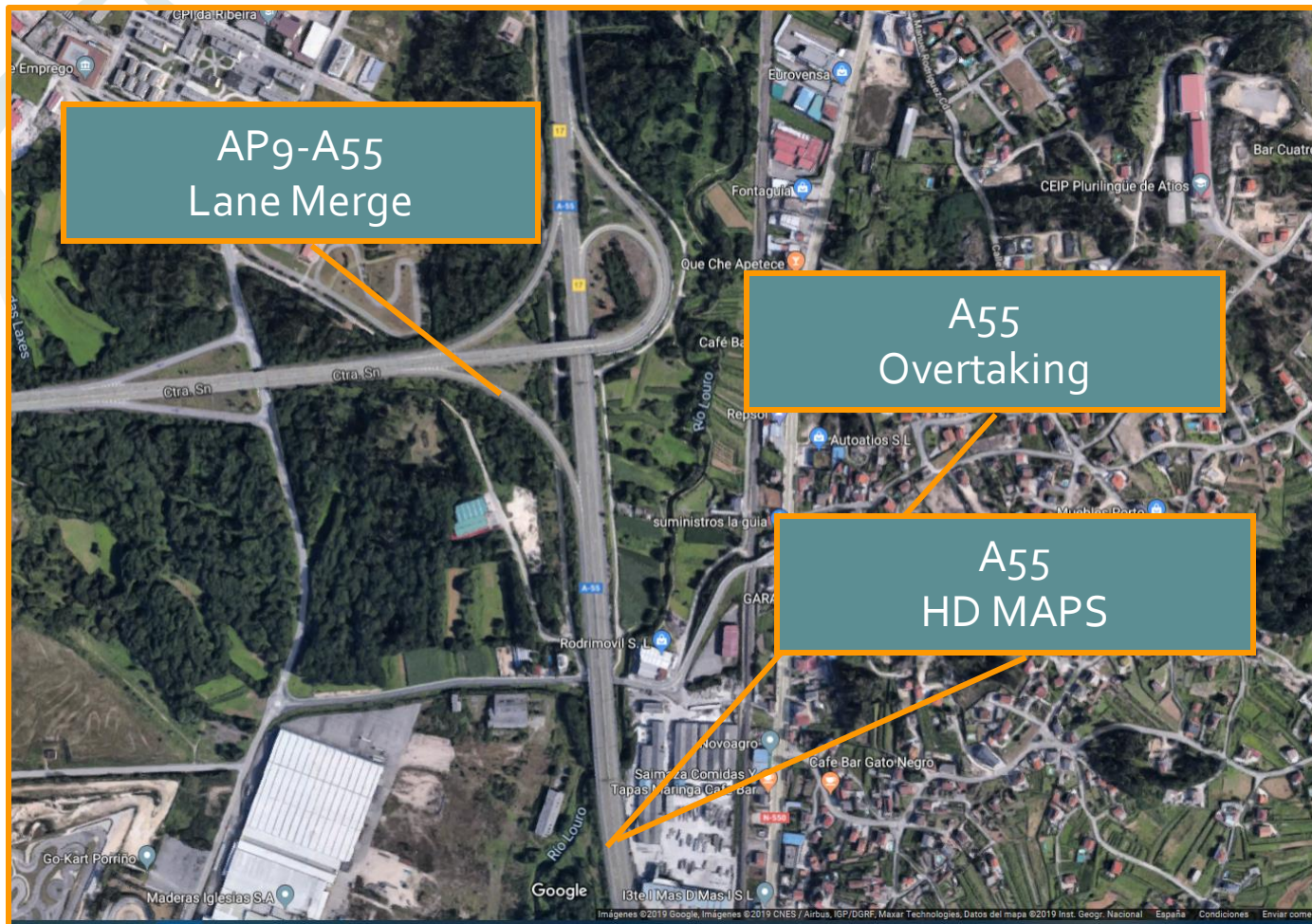
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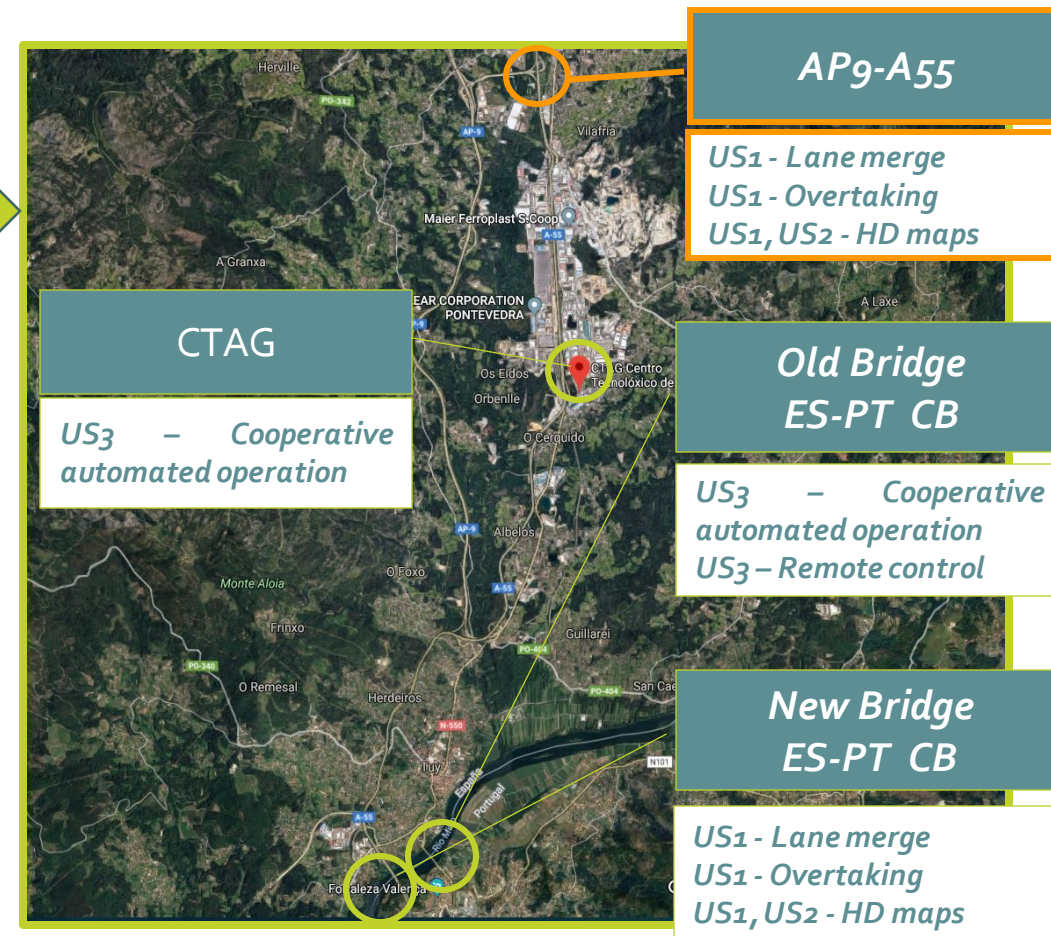
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Trials Location



- *US2 – Multimedia service for passengers*



AP9-A55

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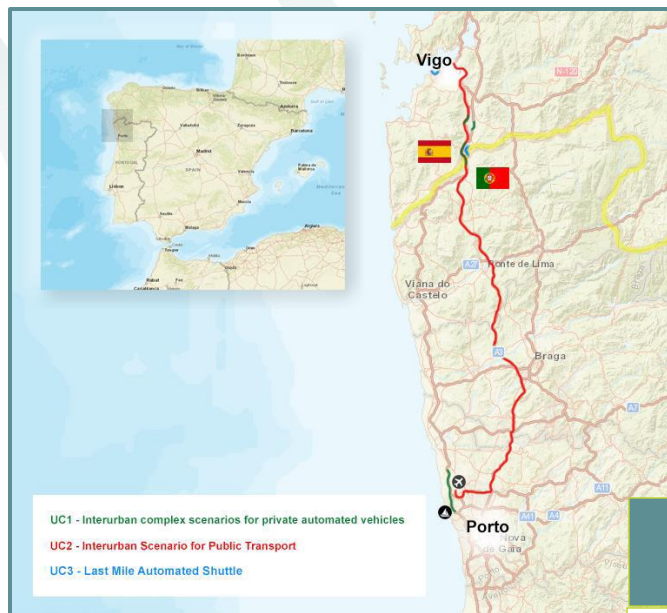
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ES-PT CB

US3 – Cooperative
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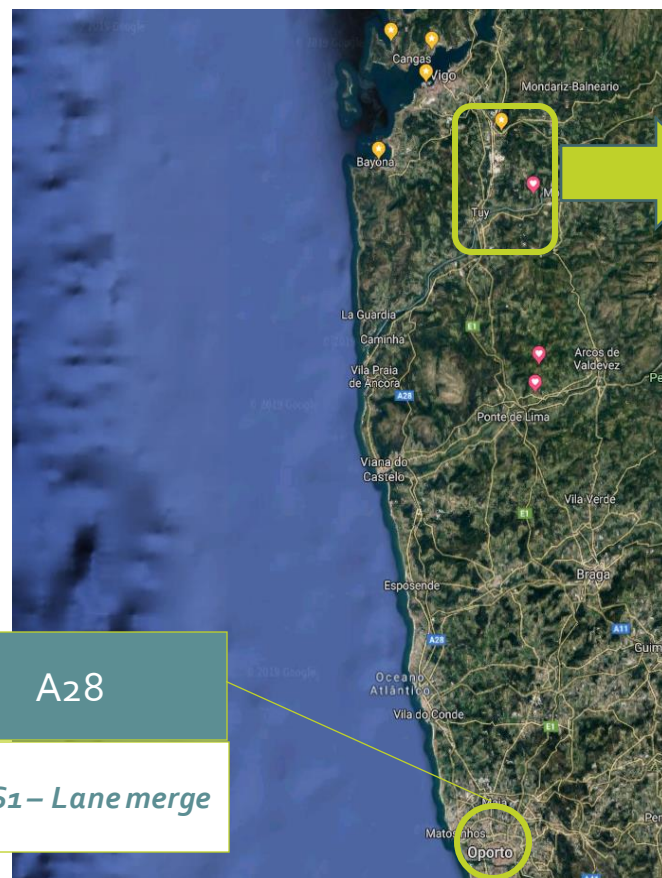
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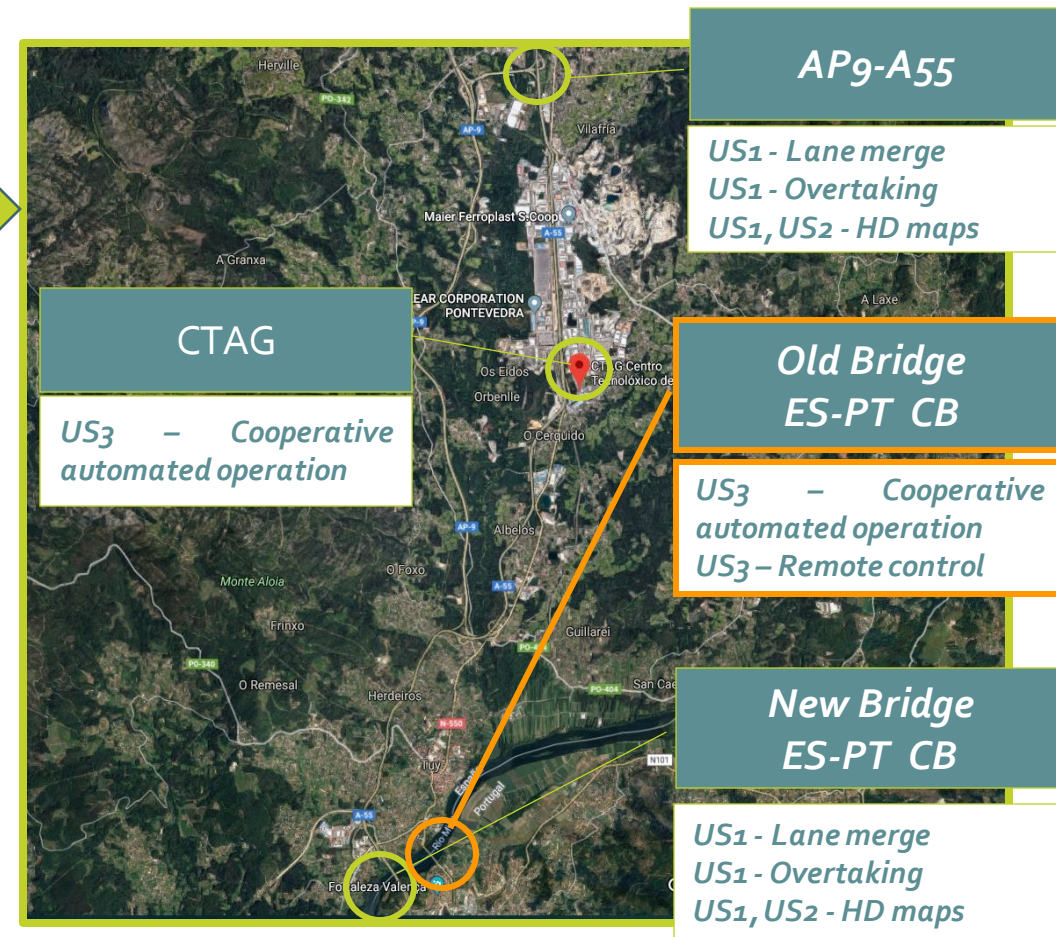
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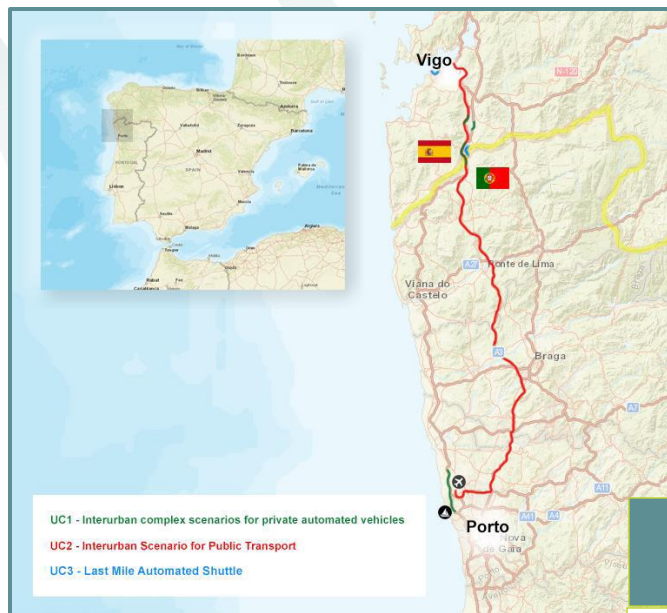
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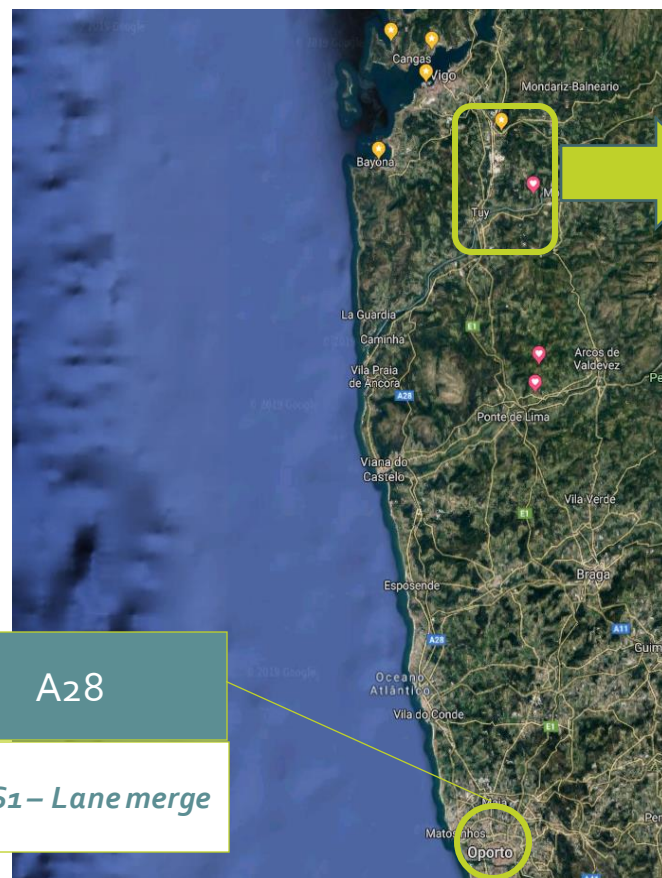


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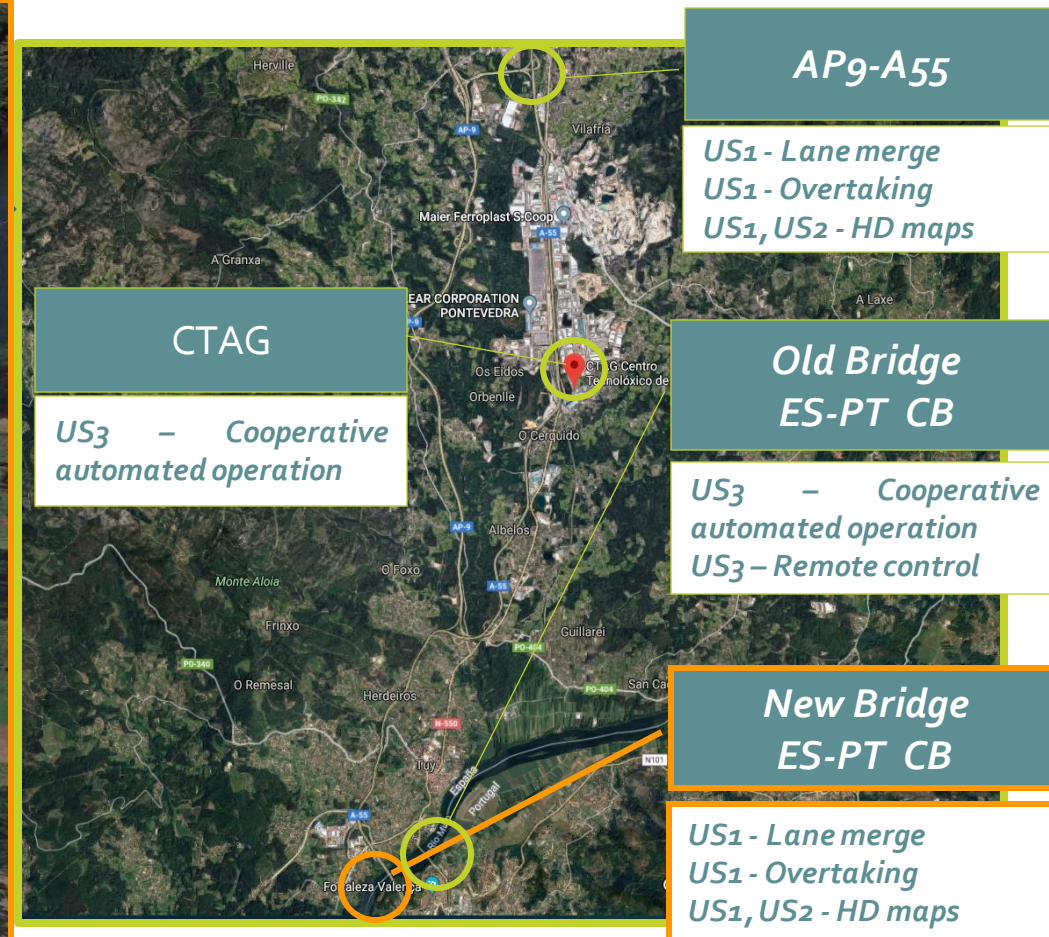
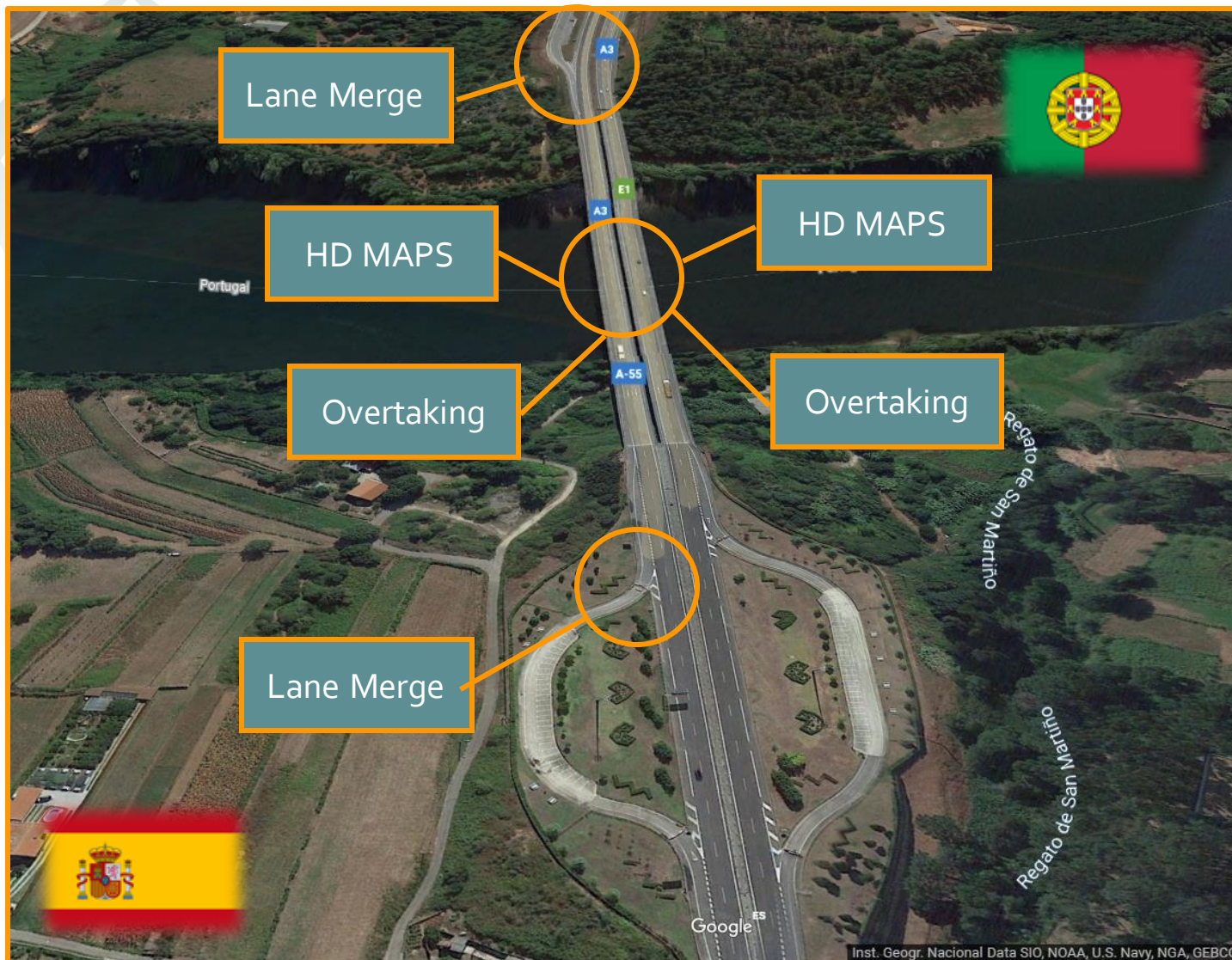
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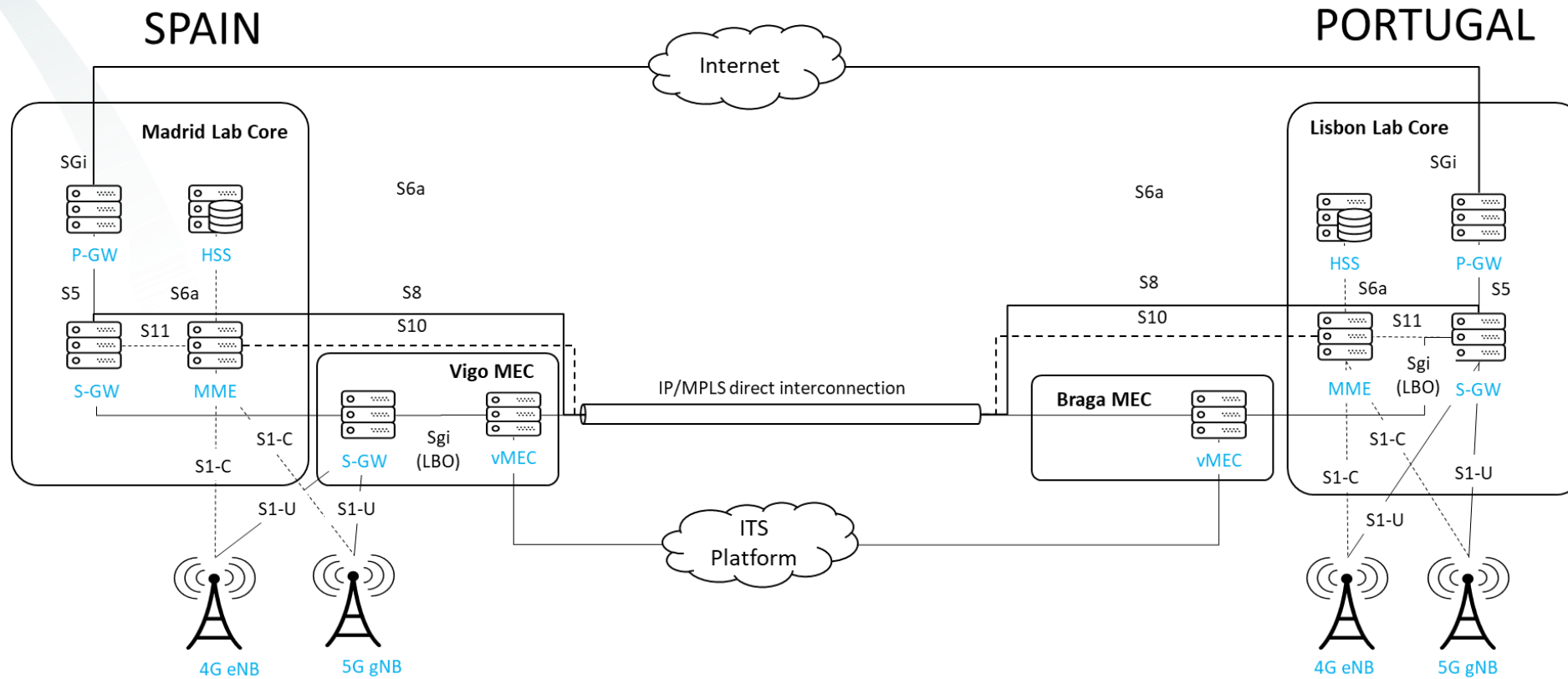


5G Network



5G Network Overview

3GPP Deployment Option	gNBs	Experimentation Frequency	MEC	Roaming
1 st Phase - NSA Option 3x 2 nd Phase - SA Option 2 (to be confirmed)	8	4G - 1800 MHz (B3) ES 4G - 2600 MHz (B7) PT 5G - 3.5 GHz (n78)	Distributed (Far edge & central)	HR/LBO

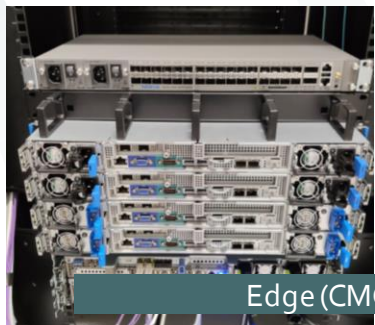


5G NSA Option 3x
ETSI MEC deployed with distributed SGW with Local Breakout (SGW-LBO)

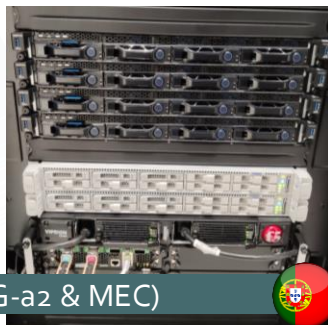
5G Network

Core & MEC

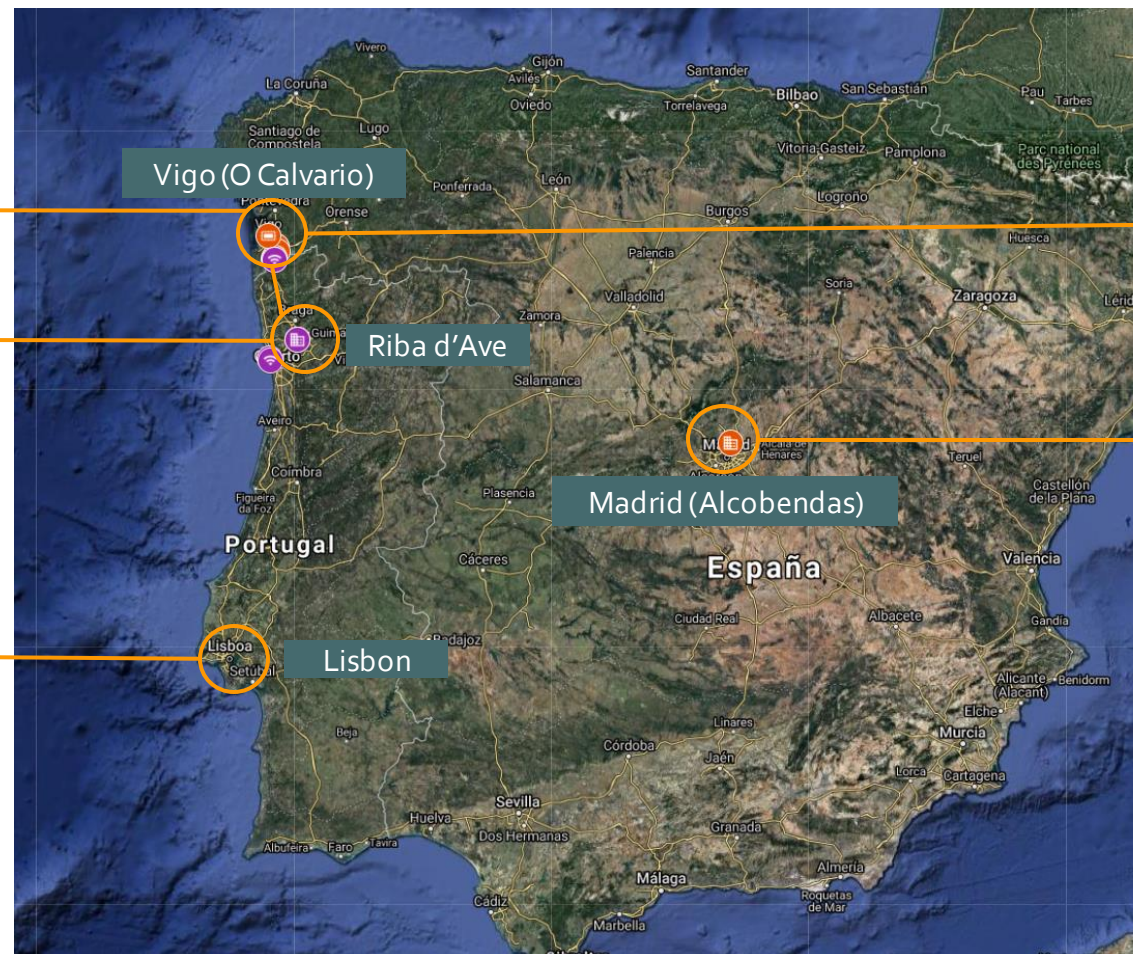
MECs Interconnection



Edge (CMG-a2 & MEC)



Central Core



Vigo (O Calvario)

Riba d'Ave

Madrid (Alcobendas)

Lisbon



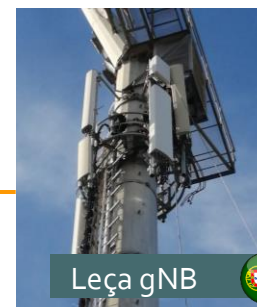
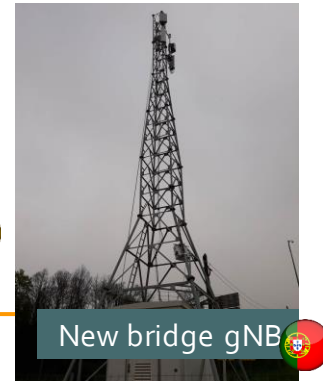
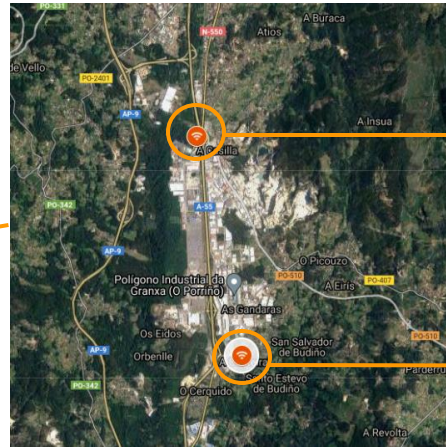
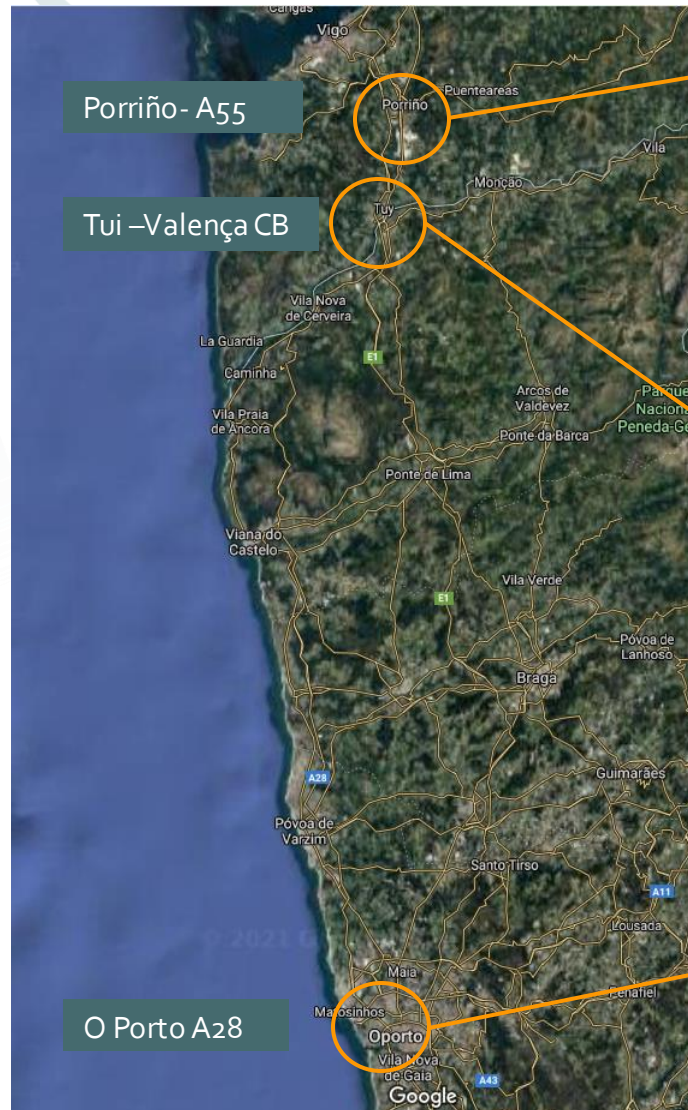
CMG-a2 & MEC



Central Core

5G Network

Antennas



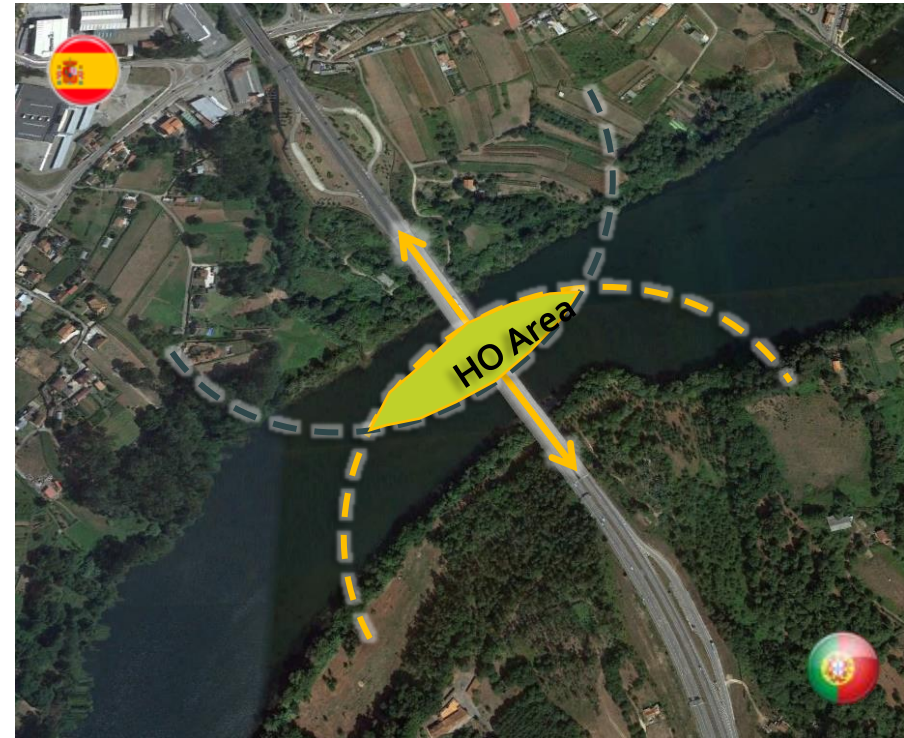
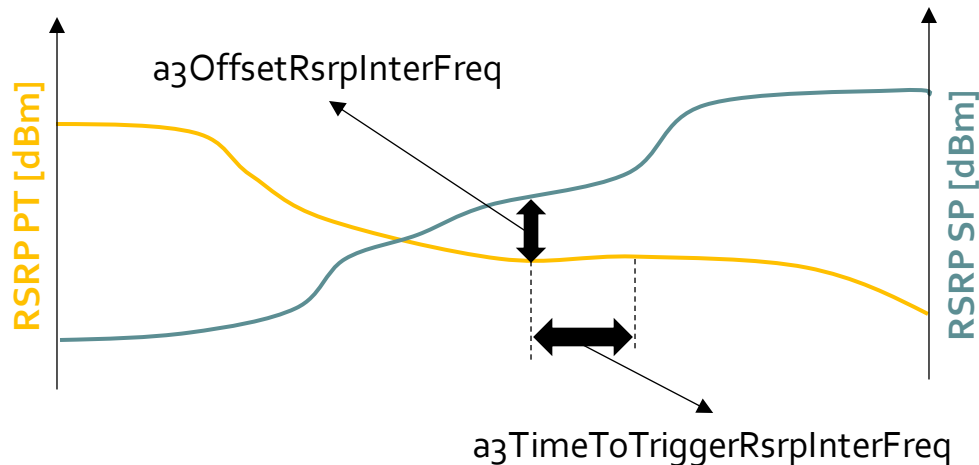
5G Network

5G roaming scenarios & handover

- **Roaming scenarios:** two possibilities are going to be tested in order to clarify the best option for V2X services: **Local Breakout and Home Routing.**

- **The HO area :**

- Initial adjusted by changing cell power and antenna electrical tilts.
- Fine tuning of HO area through adjustment of A3 event offset and time to trigger.



5G Network

CB Issues and TS Collaboration.

Telecom

NSA Roaming interruption

SA Roaming interruption

Inter-PLMN interconnection latency

Low coverage Areas

Session & Service Continuity

Data routing

Telecom& Application

Insufficient Accuracy of GPS Positioning

Application

Dynamic QoS Continuity

Data and Protocol Stack Interoperability

Geo-Constrained Information Dissemination

Regulation

Law enforcement interaction



Discovery service protocol (DNS-like name resolution service).

Benchmark in-vehicle decision-making (ES-PT) vs infrastructure decision-making (NL).

Deployment of "EDM-enabled extended sensors with surround view generation"

Dual-SIM OBU solution

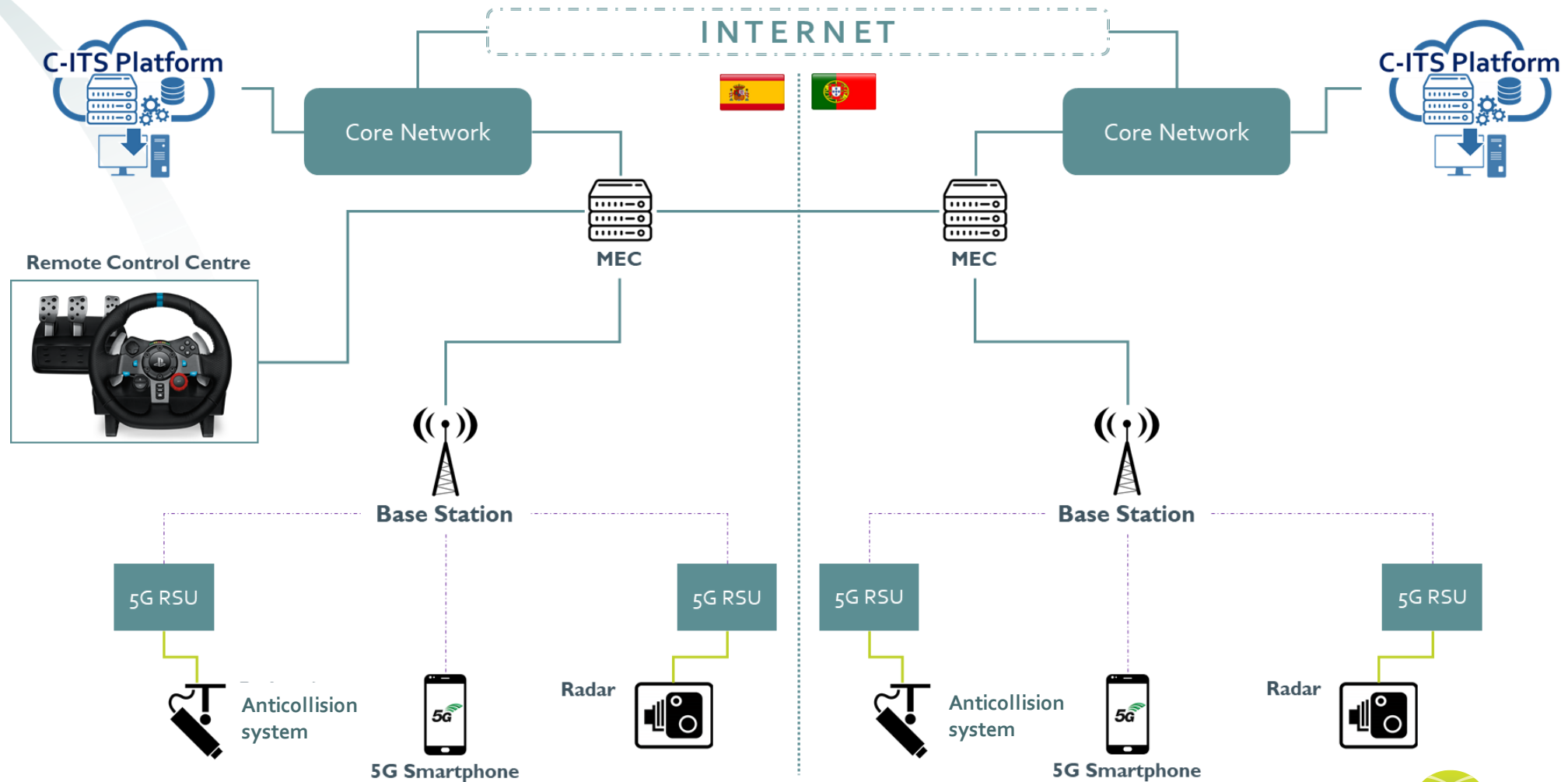


Roadside, Cloud & Remote Control Infrastructure



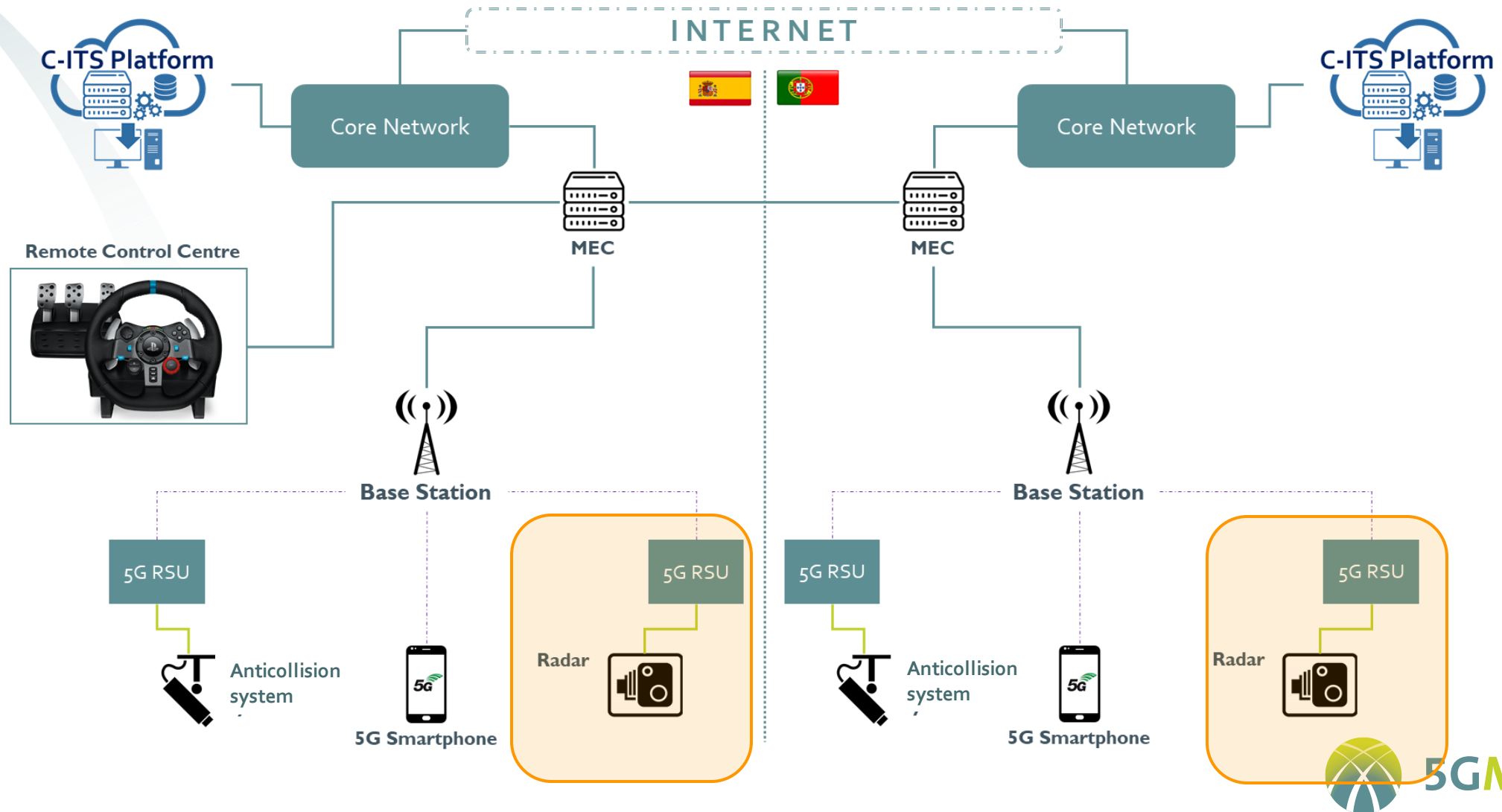
Roadside, Cloud & Remote Control Infrastructure

Infrastructure Architecture Overview



Roadside, Cloud & Remote Control Infrastructure

Infrastructure Architecture Overview



Roadside, Cloud & Remote Control Infrastructure

Roadside Infrastructure (I) – Vehicle detection

Traffic Radars

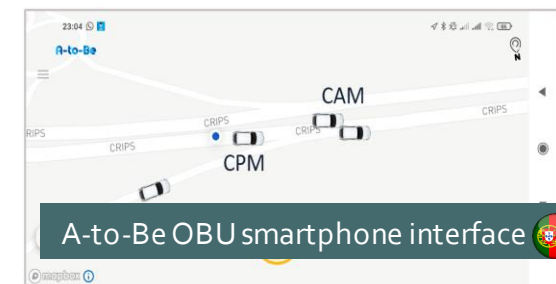
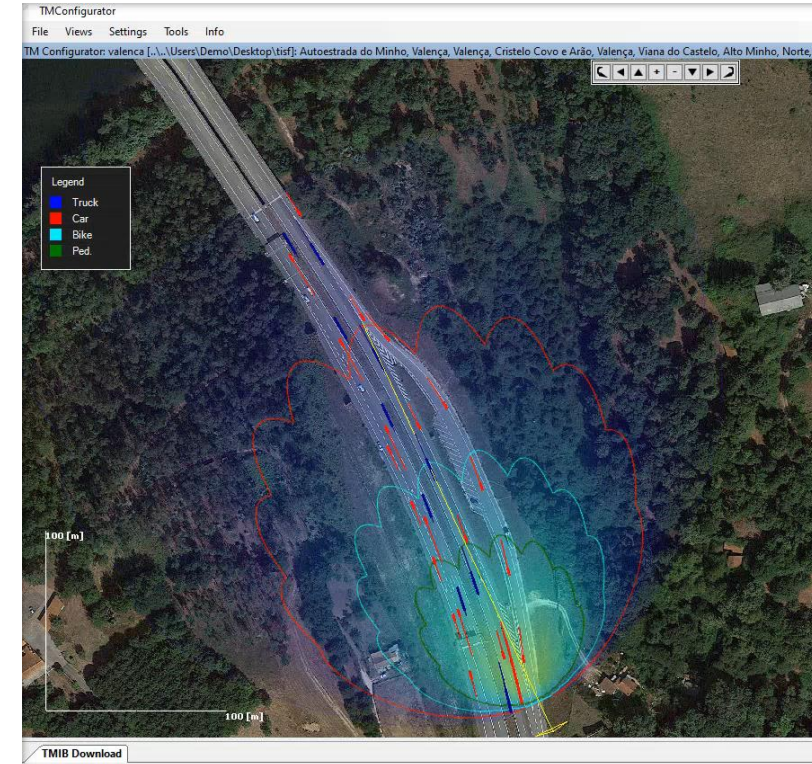
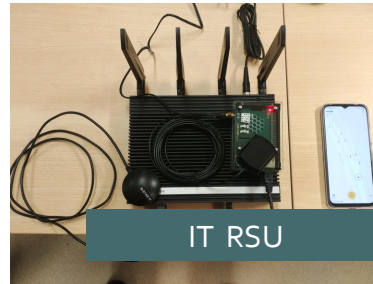


5G RSU



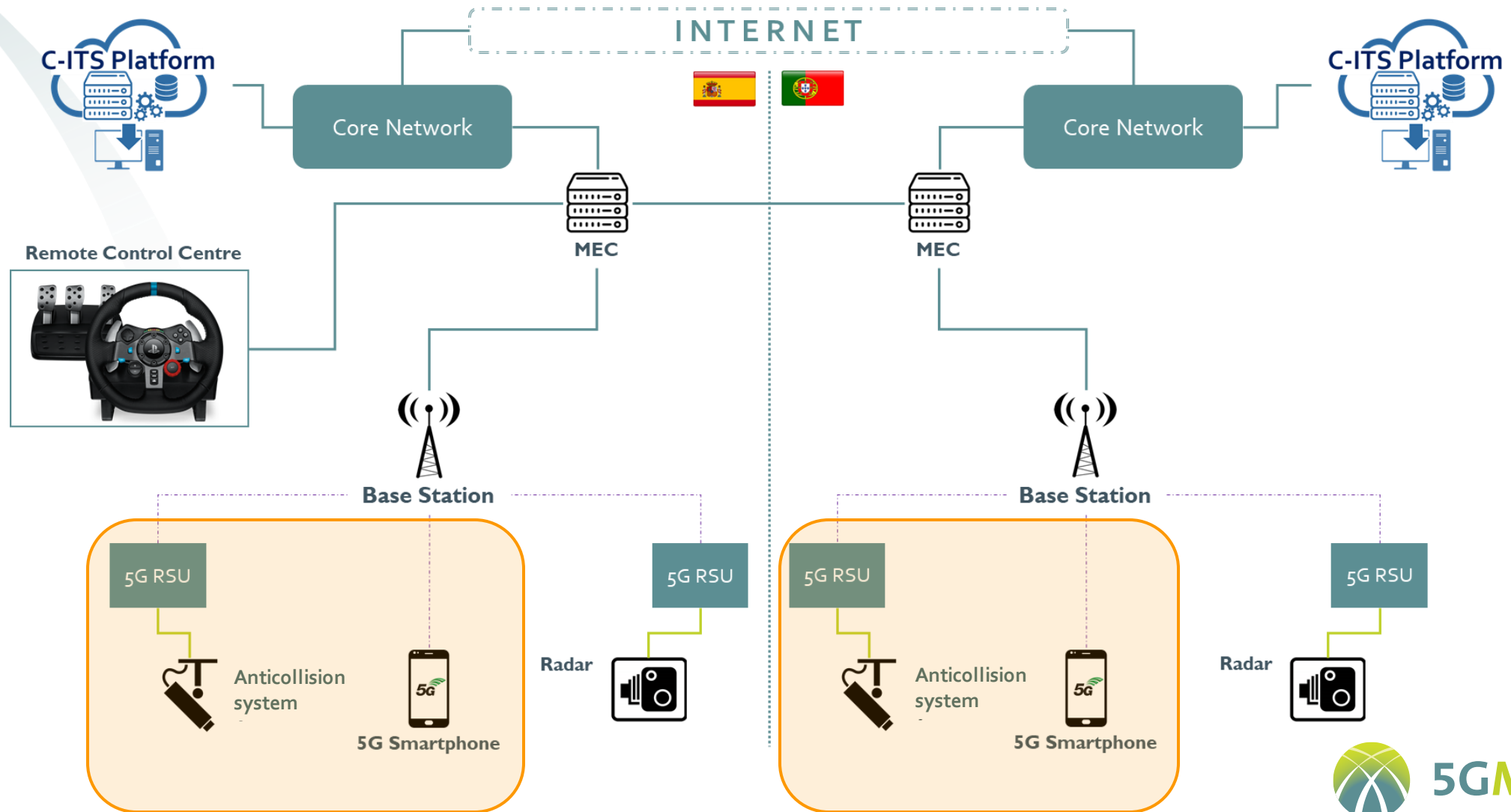
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Roadside, Cloud & Remote Control Infrastructure

Infrastructure Architecture Overview



Roadside, Cloud & Remote Control Infrastructure

Roadside Infrastructure (I) – Anticollision system

Anticollision system



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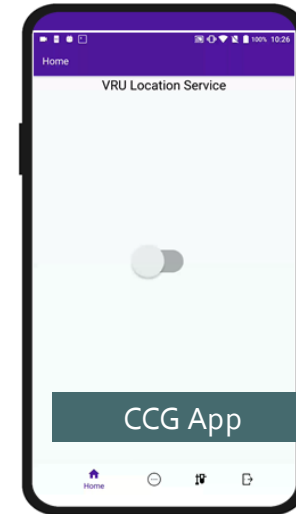
5G RSU



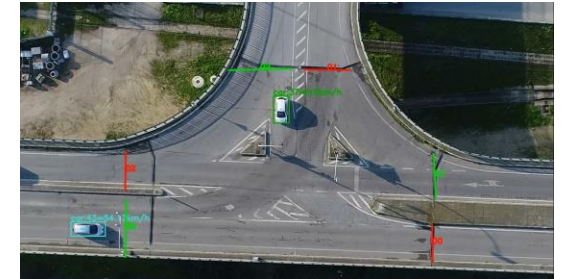
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Smartphone App



Drone

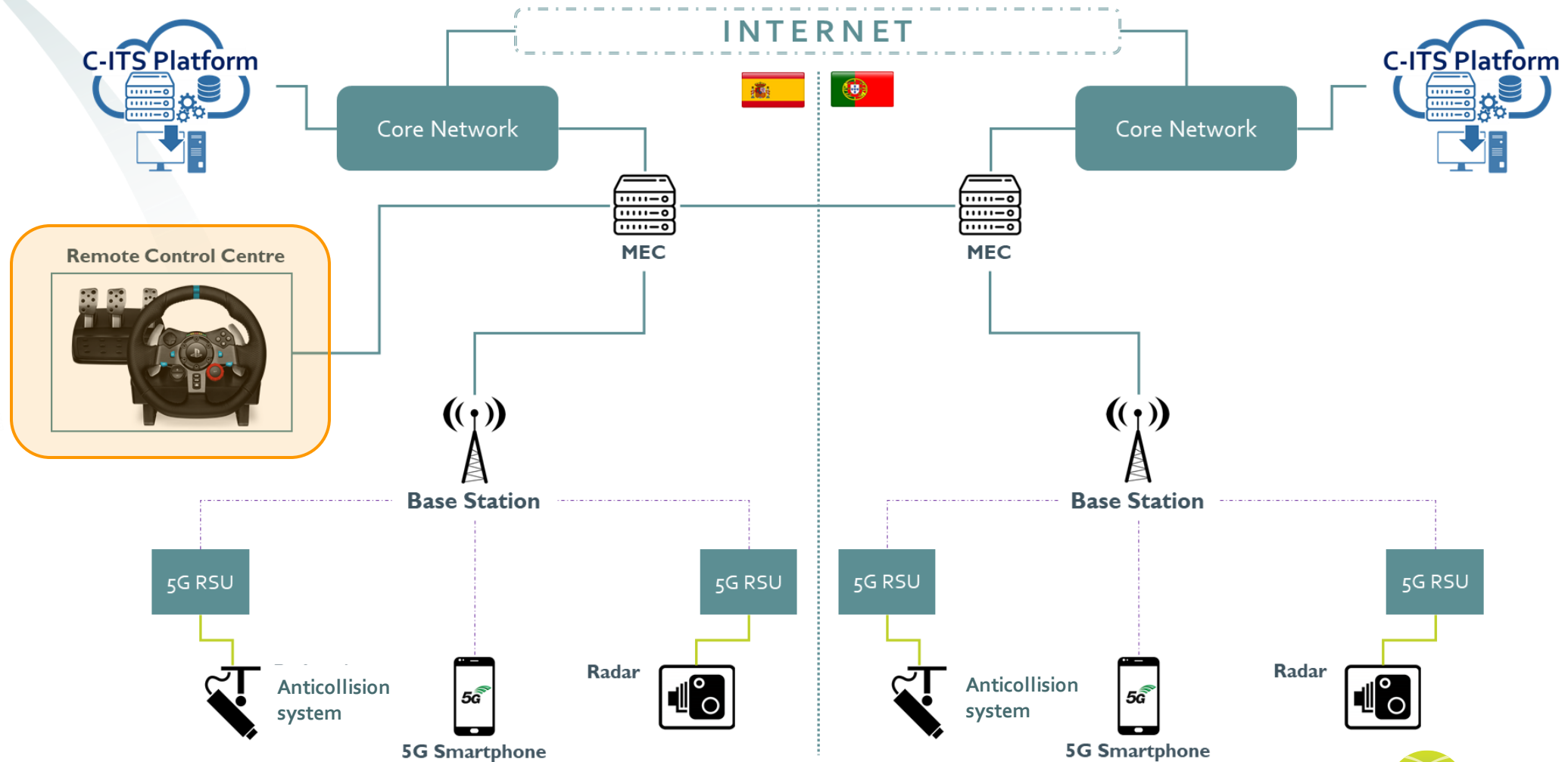


Siemens Drone



Roadside, Cloud & Remote Control Infrastructure

Infrastructure Architecture Overview



Roadside, Cloud & Remote Control Infrastructure

Remote Control Infrastructure

Remote Control Equipment

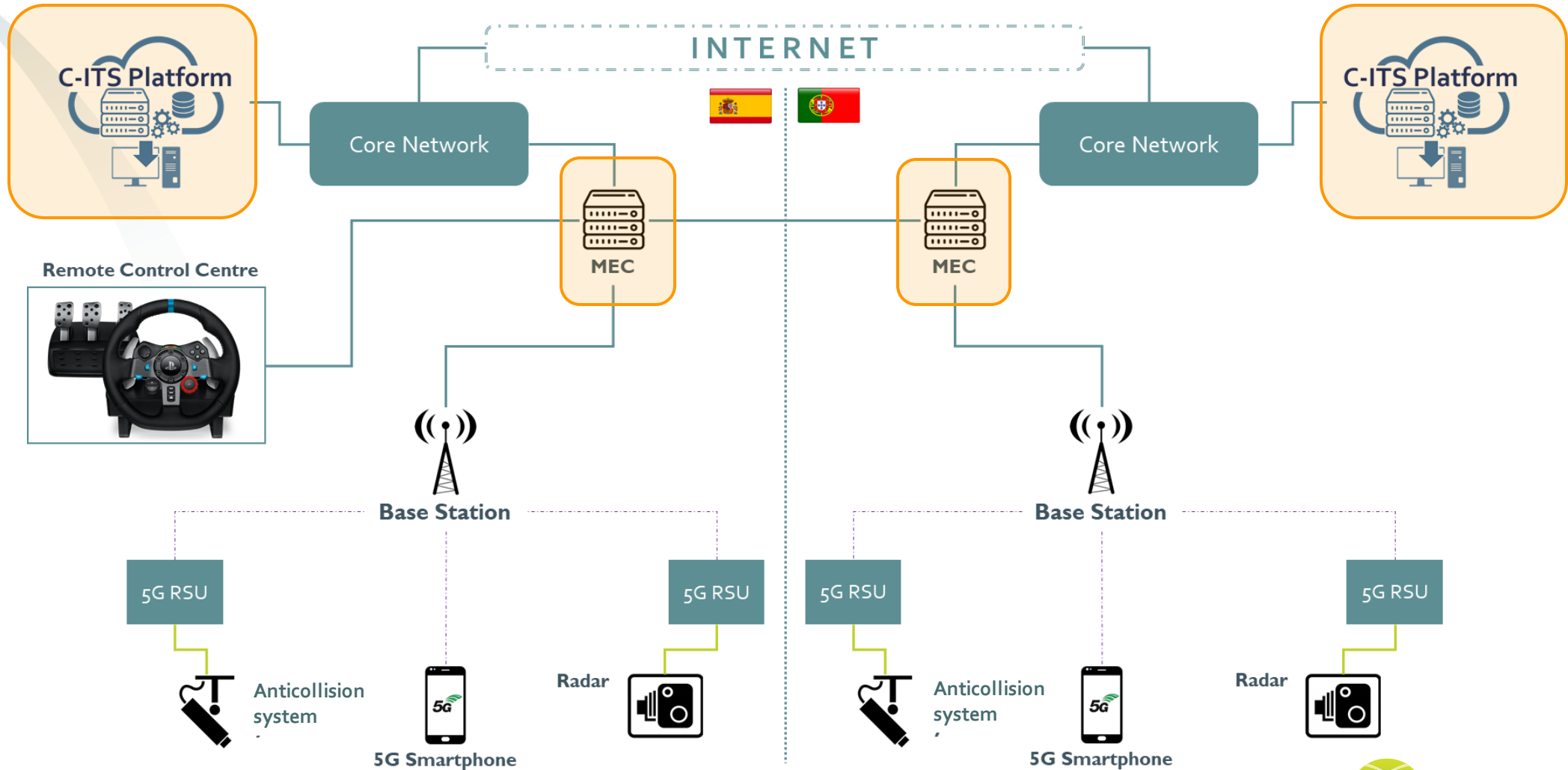


Direct connection
to the MEC



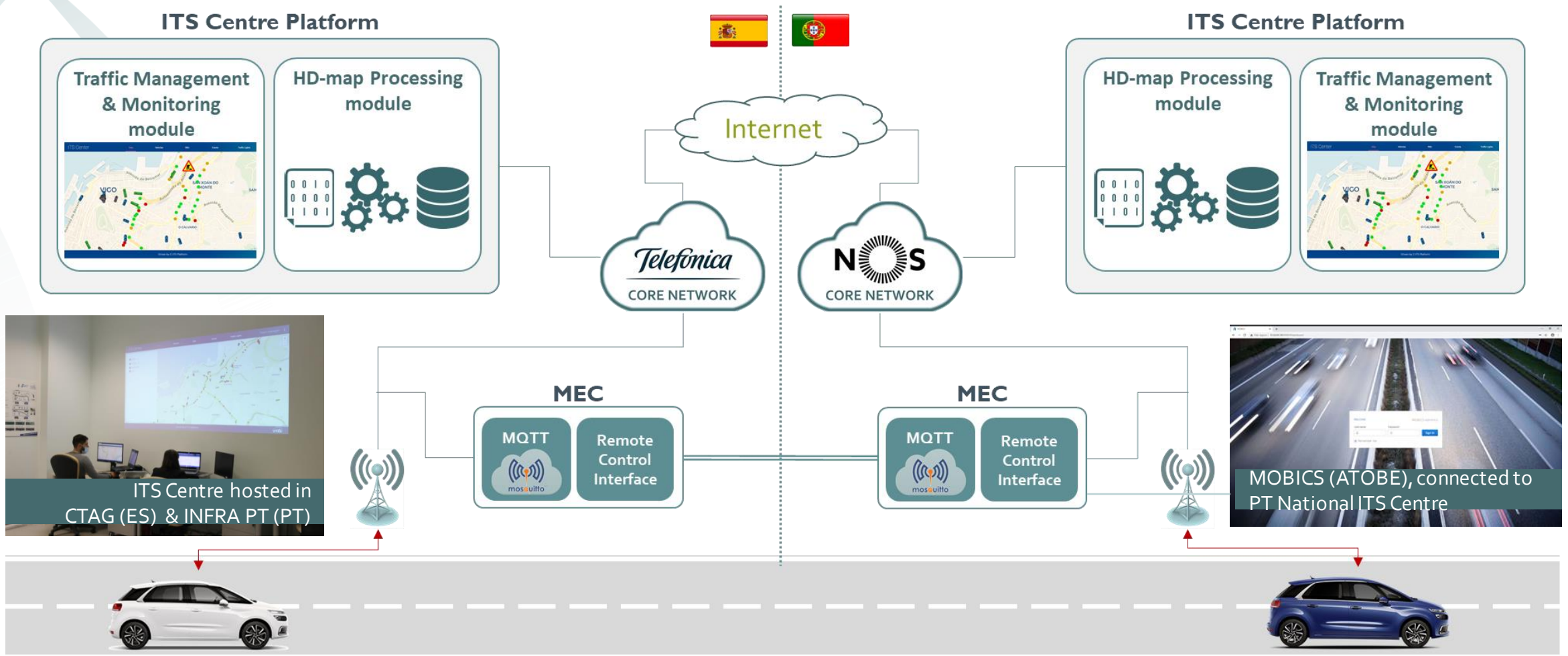
Roadside, Cloud & Remote Control Infrastructure

Infrastructure Architecture Overview



Roadside, Cloud & Remote Control Infrastructure

Cloud & Edge Infrastructure



Vehicles & OBUs



Vehicles & OBUs

Vehicles

Volkswagen Golf



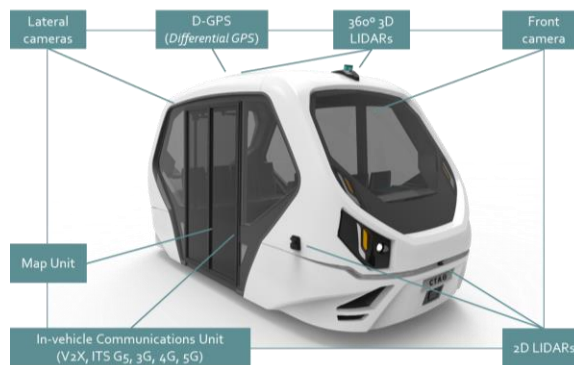
Citroën C4 Picasso



Renault Clio Station Wagon



CTAG Autonomous Shuttle

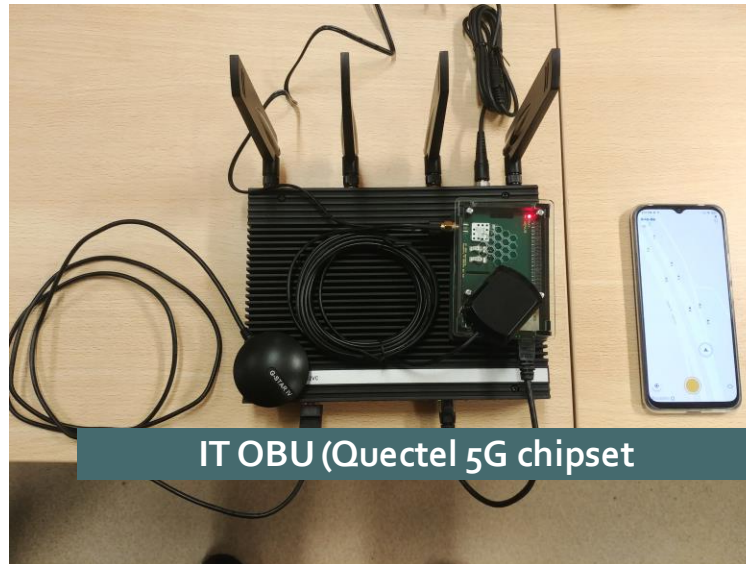


ALSA Commercial Bus



Vehicles & OBUs

OBUs



Technical Evaluation



Technical Evaluation

Technical Evaluation Purposes

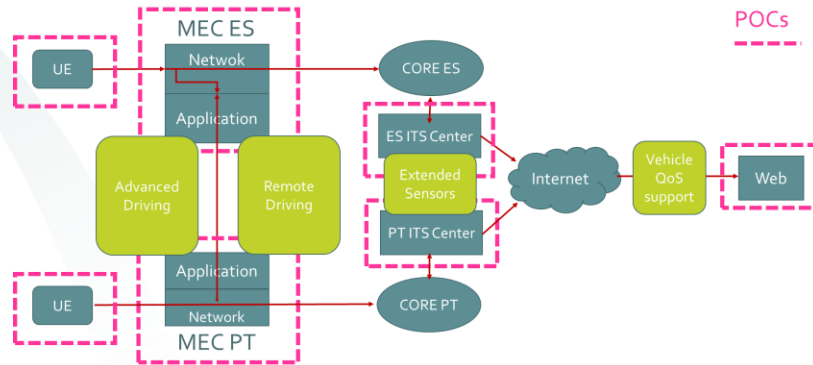
Objectives

- Analyse the difference between Home Routing and Local Break Out
- Analyse the impact of speed on roaming and handover
- Analyse the transition between MECs
- Analyse the difference between the infrastructure-decision and the in-vehicle-decision
- Analyse the interoperability between devices
- Analyse the cloud and MEC based operations
- Analyse the video streaming

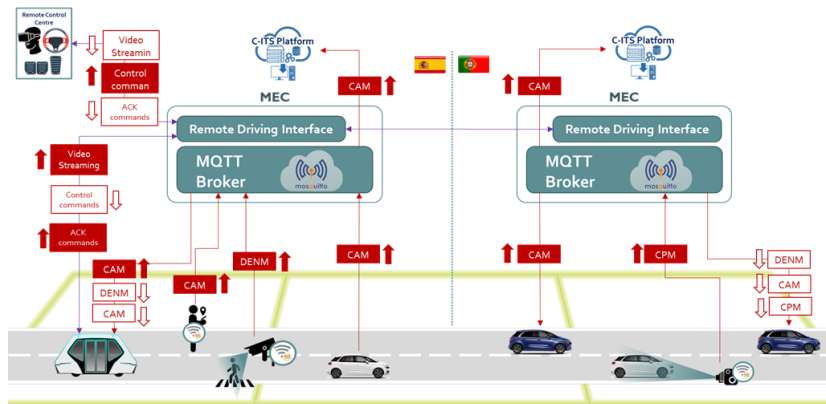
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Technical Evaluation

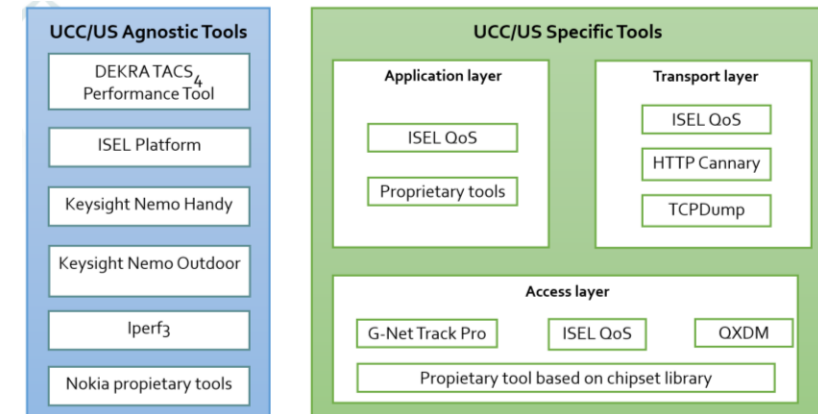
General Architecture and POCs



Data Flow



Measurement tools for ES-PT CBC



Test case description



Trial Site	Use Case Category	User Story	Scenario	Test Case
ES-PT	Advanced Driving	Complex manoeuvres in cross-border settings	ES-PT variant	ES ES A55 highway 100 km/h
				PT PT A28 highway 100 km/h
				ES-PT ES crossborder 100 km/h
			...	
			ES-PT variant stressing the network	
			NL variant	
...	

User Acceptance Evaluation



User Acceptance Evaluation

Motivation

- The acceptability of a technological concept, such as a CCAM use-case is affected by the implementation;
- Even a well-designed application will be perceived as bad if, for instance, the network communications fail frequently, hindering the user experience.

Objective

- Evaluate the impact of 5G connectivity on the acceptability of CCAM use-cases, on the boarder context.

Method

- Trials with users:
 - Simultaneous with technical evaluation;
 - Limited number of users.
- Online surveys:
 - Open to the community.

User Acceptance Evaluation

Methodology – Trials with users

Participants will be passengers of the vehicles but not drivers

We will also evaluate the acceptability of the professional/remote drivers

Evaluate in two contexts:

- **No connectivity breaks** – Local trials
- **With possible connectivity breaks** – On the border

Method

User enquiring

- Quantitative – validated psychometric scales
- Qualitative
 - Open answer questions – Interviews / Focus groups

Observation

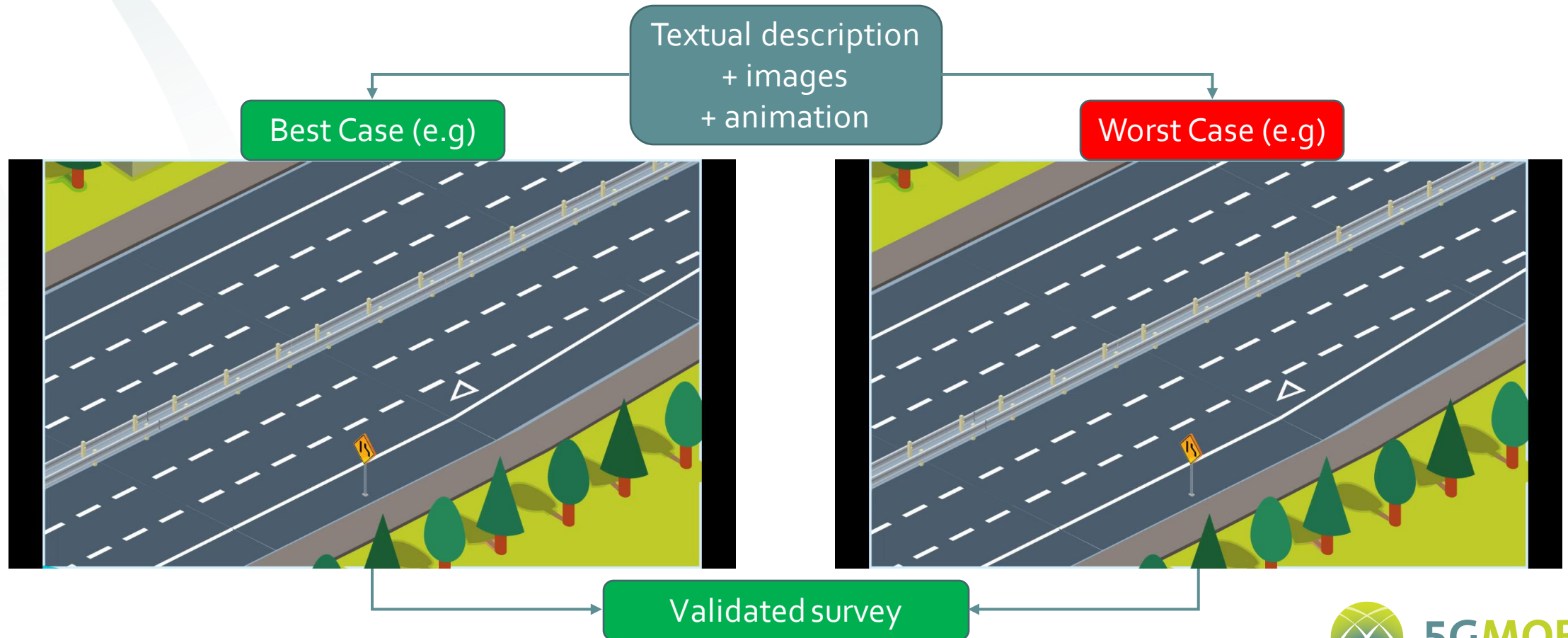
- Events (e.g. forced take-overs from automated system)
- Behavior (e.g. glances towards the road)

User Acceptance Evaluation

Methodology – Online survey 

Evaluate acceptability with a larger pool of respondents (online).

- Based on plausible scenarios of technology performance (best case scenarios and less than ideal scenarios)

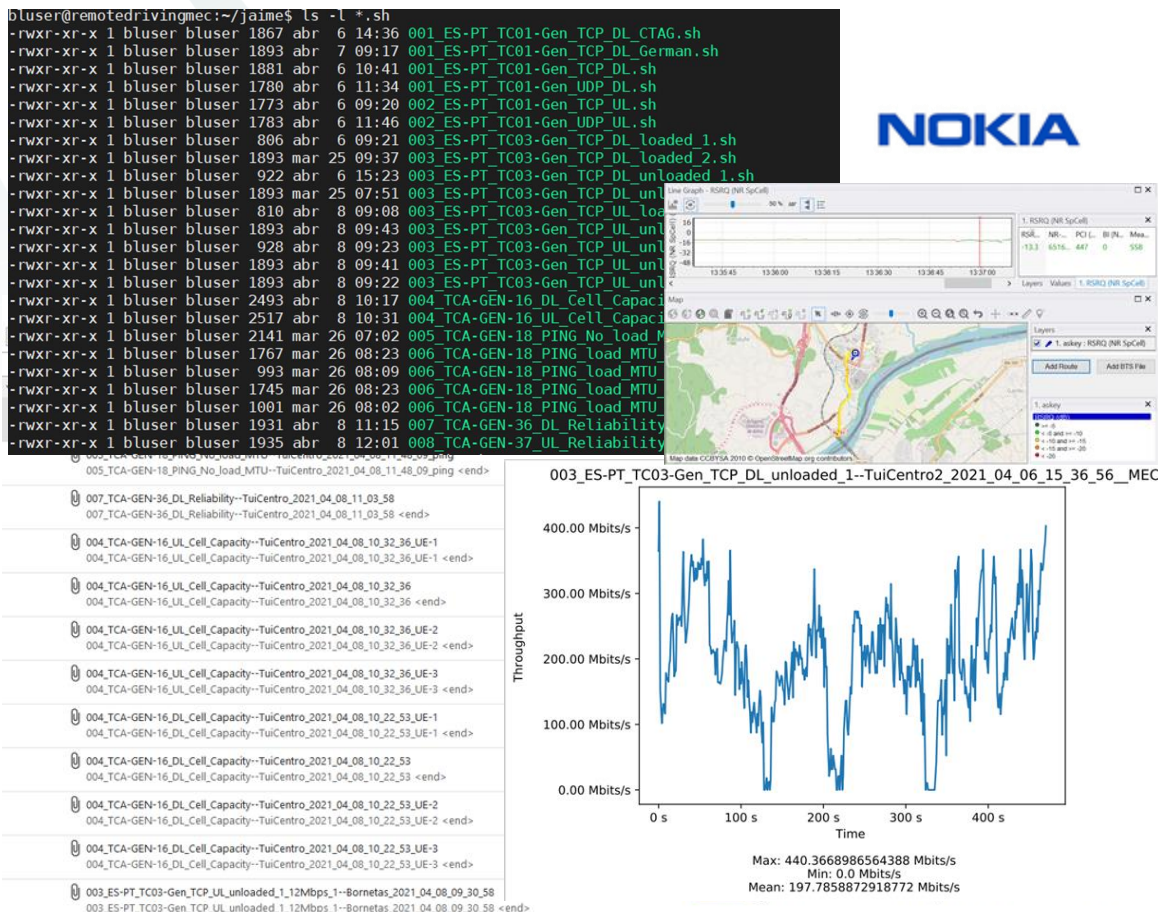


Preliminary results

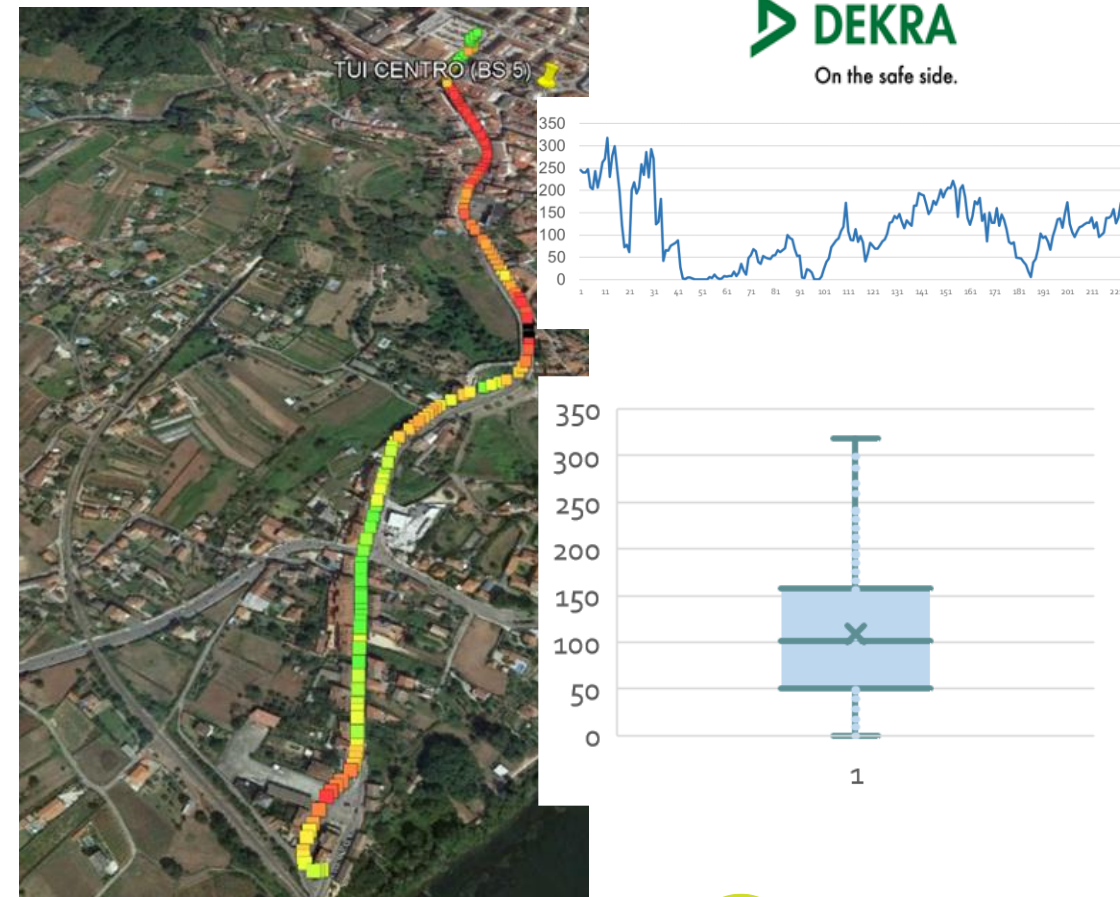


Agnostic tests

Agnostic test performed in April 2021.



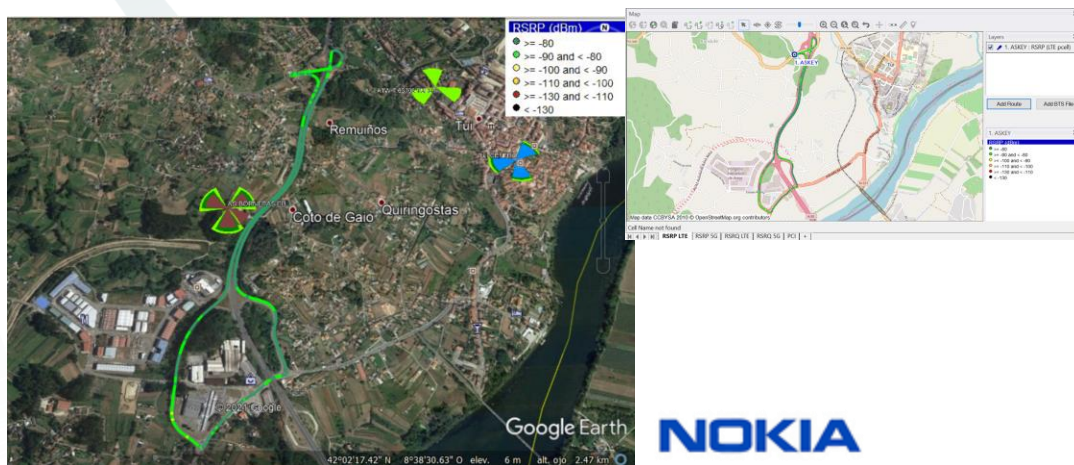
TCP DL Throughput. Old Bridge



Preliminary results

Agnostic tests

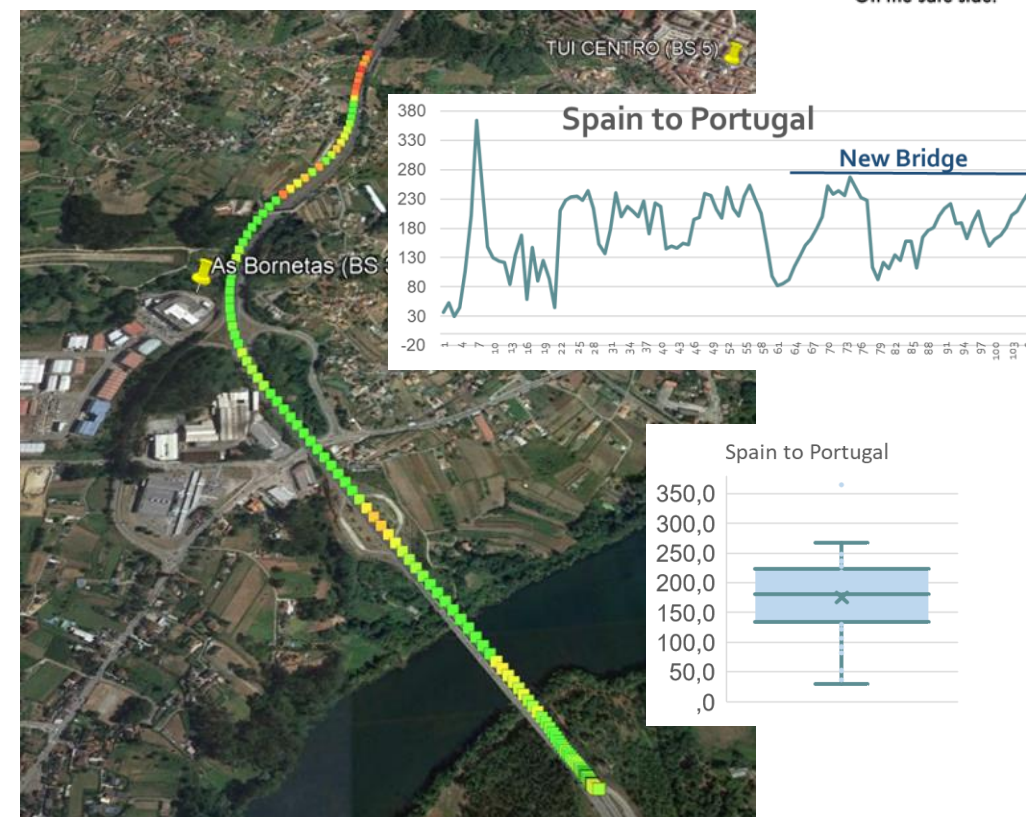
RSRP 5G New Bridge



TCP DL Throughput. New Bridge



On the safe side.



Trial Plan



Trial Plan

[illegible]

Conclusions



Conclusions

- **Diversity of scenarios**

- Highway and non-highway (open) borders (great for exploring a seamless transition between countries);
- The proximity of two nearby cities in each side of the border;
- Two different and MNOs in each side of the border.

- **Partner complementarity**

- Complementary stakeholders covering the complete value chain including car manufactures, telecom companies, public administrations and research institutions;
- The involvement of the countries' public road authorities in the project.

- **Open border with a strong relation between the two adjacent municipalities.**

Conclusions

A great contribution for the future of 5G CCAM in the region

The deployment of these 5G CCAM services and applications will provide a strong impulse in both countries towards the development of opportunities around 5G in the ITS sector.

- Partners from Portugal and Spain, together with the partners from all over Europe, are committed in preparing the future of CCAM using 5G-based technologies;
- The geographical, cultural and commercial context of this Cross Border provides great conditions to explore different use cases in the several dimensions to explore;
- The diversity of User Stories that are being explored will provide great insights about the way how 5G technology can lever CAM;
- Technical evaluation, user acceptance and impact assessment activities will provide valuable information that will support future decisions in this area;
- Some of the developments may turn into real applications in a near future.

Thank you



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