Cross ICT-18-2018 White Paper

5G Trials for CCAM along European 5G Cross-Border Corridors - Challenges and Opportunities

Part I

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5GPPP Webinar on 5G for CCAM, November 6th, 2020

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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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Introduction & Background

White Paper Background

- Three European IA projects (5G-CARMEN, 5G-CroCo & 5G-MOBIX) are currently investigating ***5G-enabled CCAM in cross-border scenarios*** under the EU-funded programme ICT-18-2018
- The three projects will realize ***real-life trials in major European cross-border areas (corridors)*** using 5G connectivity and state-of-the-art autonomous vehicles (up to SAE L4)
- Trials are about to start, after a thorough requirements analysis, design, implementation and deployment process
- This WP presents the joint understanding of the three projects regarding the ***key challenges*** that need to be addressed in order to successfully ***provision CCAM services at cross-border environments over 5G networks*** and the most promising ***technological enablers*** that the projects are investigating

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Problem statement: Why is it hard to provision CCAM over 5G at cross-border conditions?

- Currently all telecommunication/industrial/business procedures and operations have been designed to work on a ***national level***, with no or minimal considerations for cross-border functionality
  - User mobility is almost exclusively treated with a network reselection (complete (long) interruption of communication and establishment of a new connection towards the visiting network), while ***CCAM applications require minimal to no interruption of service and very high throughput and extreme reliability***!
  - Different ***communication laws and obligations*** apply in different countries
  - Network configuration is not/scarcely shared with foreign MNOs leading to ***uncoordinated approaches***

- Original Equipment Manufacturers (OEMs) also face difficulties supporting CCAM functionalities across borders
  - ***No clear business model*** with significant ***additional costs*** (chipsets, antennas, validation costs, diagnosis/repair, calibration, etc.)
  - Potentially different national ***homologation*** rules and ***configuration requirements*** (e.g. supported frequency bands) for On Board equipment
  - Differentiated ***regulations & liability*** rules

White Paper Objectives

- Provide an ***overview of the goals*** and work being carried out within the three ICT-18 projects
- Provide an ***overview of the most prominent CCAM applications expected in cross-border environments*** and their respective requirements
- ***Analyse the key challenges*** that have to be addressed for CCAM support in cross-border environments, based on the work of the three projects
- ***Provide a list of candidate technological enablers and solutions*** that are/will be investigated within the projects and may potentially mitigate or resolve the identified challenges
- ***Increase visibility*** and ***engage the appropriate stakeholders*** as well as assist further research in the field (e.g. ICT-53 projects) by sharing currently available insights

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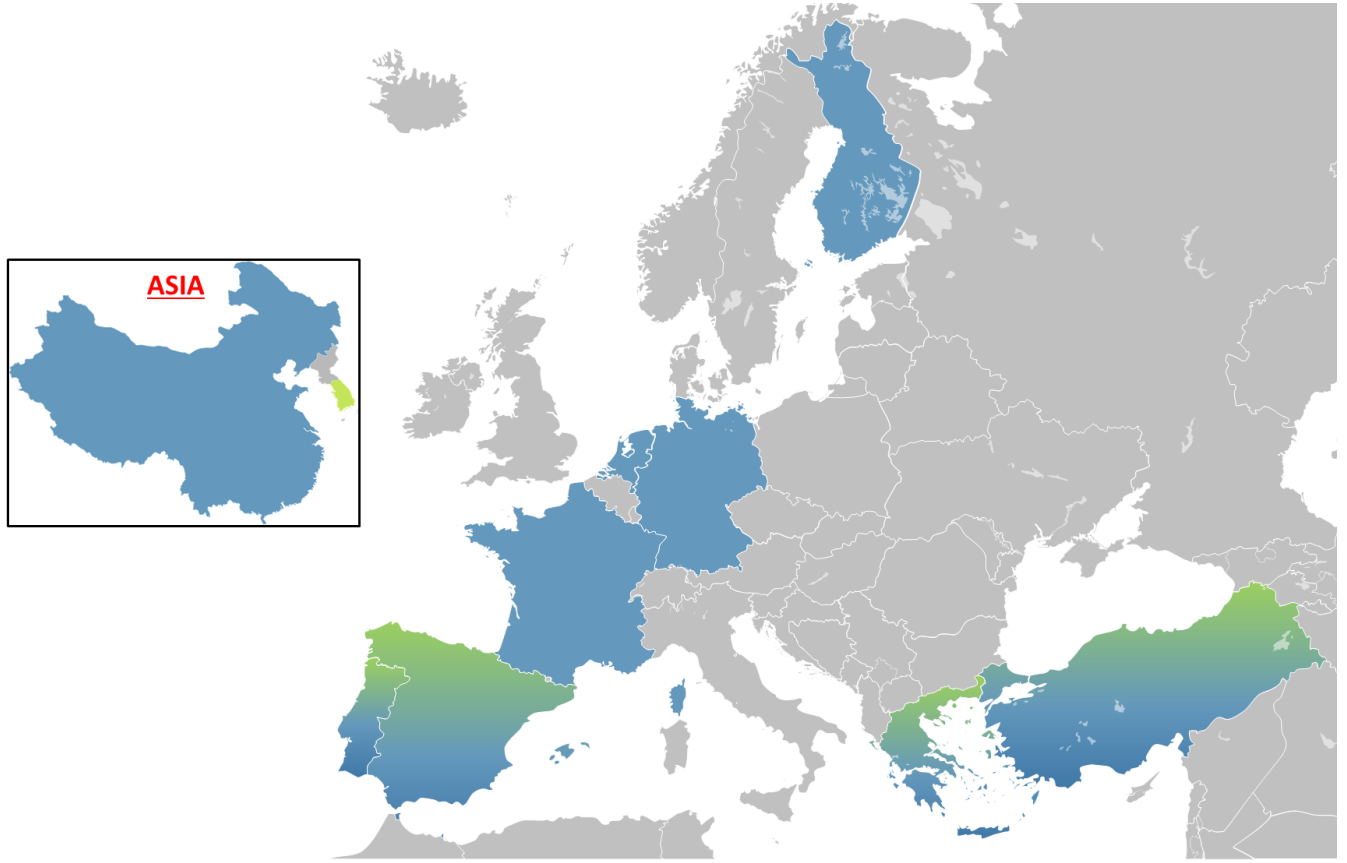
Challenges Overview

- ***Five high-level challenge categories*** have been defined, namely:
  - ***Cellular coverage and radio access aspects***
  - ***Service and Session continuity aspects***
  - ***MNO collaboration & Data Plane routing***
  - ***Data management & protection***
  - ***Non-functional aspects & business enablers***
- The challenges cover technical, business, regulatory/legal and data management aspects
- Each Challenge ([Ch.#]) category is further broken down into specific issues/components and their impact and relevance is analysed
- A match between the identified challenges and the potential solutions that could mitigate their effect is presented at the end of the WP

5G-MOBIX overview

Overview of 5G-MOBIX CBCs / TSs

- ***2*** Cross-Border Corridors (CBC), i.e. ES-PT & GR-TR
- ***4*** complementary European Trial Sites (TS), i.e. DE, FI, FR, NL
- ***2*** complementary Asian Trial Sites (TS), i.e. CH, KR
- ***5*** Use case categories based on 3GPP TS 22.186, focusing on x-border operation
- ***24*** SAE L4 automated vehicles
- ***30*** 5G gNBs
- ***NSA*** Architecture + SA in national Trial Sites (FI, DE, NL)



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5G-MOBIX UCC/US overview & TS contributions

- Different architecture / technology may be used at different sites evaluating their performance
- Focus on cross-border operation at the two CBC
  - Spain-Portugal (ES-PT)
  - Greece-Turkey (GR-TR)
- Local TS have been selected to ***contribute and enable*** the CBC trials (providing SW, components, alternatives, etc.)
- Extended evaluations requiring controlled environments also performed at the TS

Trial site	Advanced Driving	Vehicles Platooning	Extended Sensors	Remote Driving	Vehicle QoS Support
ES-PT	Complex manoeuvres in cross-border settings			Automated shuttle remote driving across borders	Public transport with HD media services and video surveillance
GR-TR		Platooning with "see what I see" functionality in cross-border settings	Extended sensors for assisted border-crossing		
DE		eRSU-assisted platooning	EDM-enabled extended sensors with surround view generation		
FI			Extended sensors with redundant Edge processing	Remote driving in a redundant network environment	
FR	Infrastructure-assisted advanced driving				QoS adaptation for Security Check in hybrid V2X environment
NL	Cooperative Collision Avoidance		Extended sensors with CPM messages	Remote driving using 5G positioning	
CN	Cloud-assisted advanced driving	Cloud-assisted platooning		Remote driving with data ownership focus	
KR				Remote driving using mmWave communication	Tethering via Vehicle using mmWave communication

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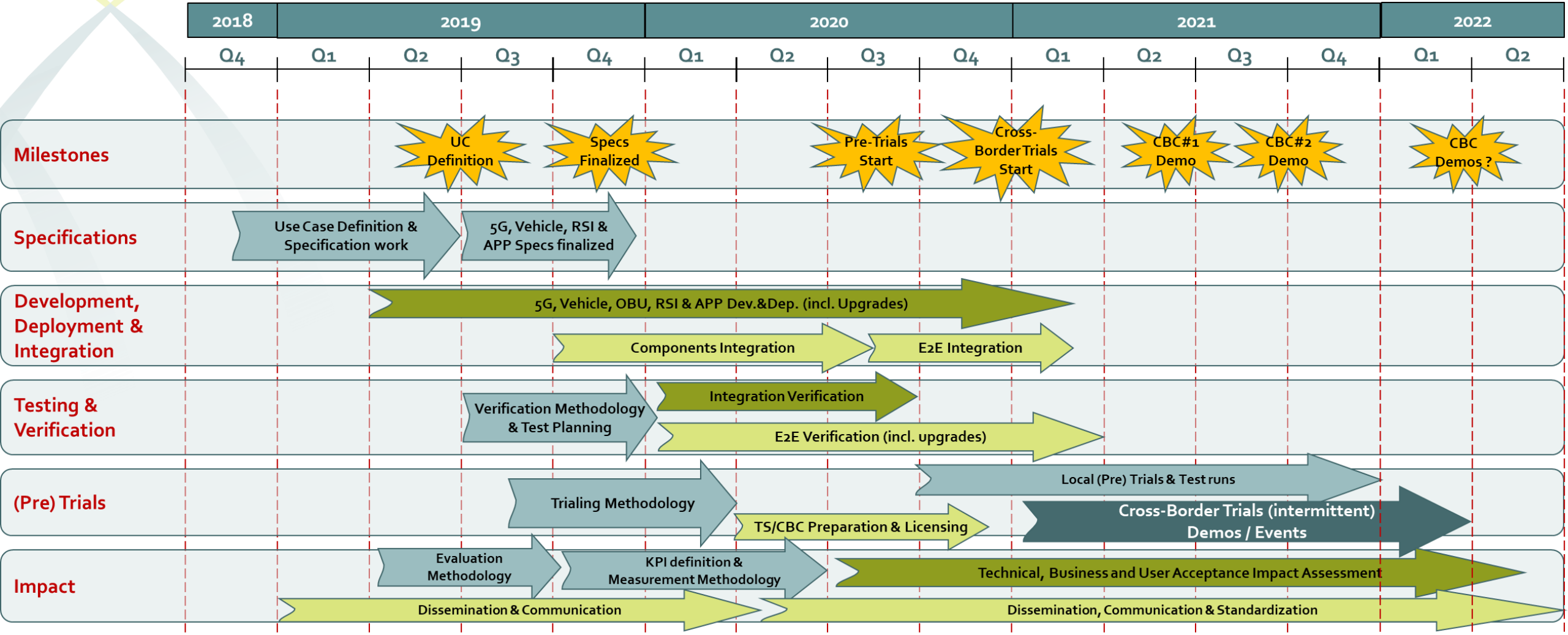
5G-MOBIX Roadmap

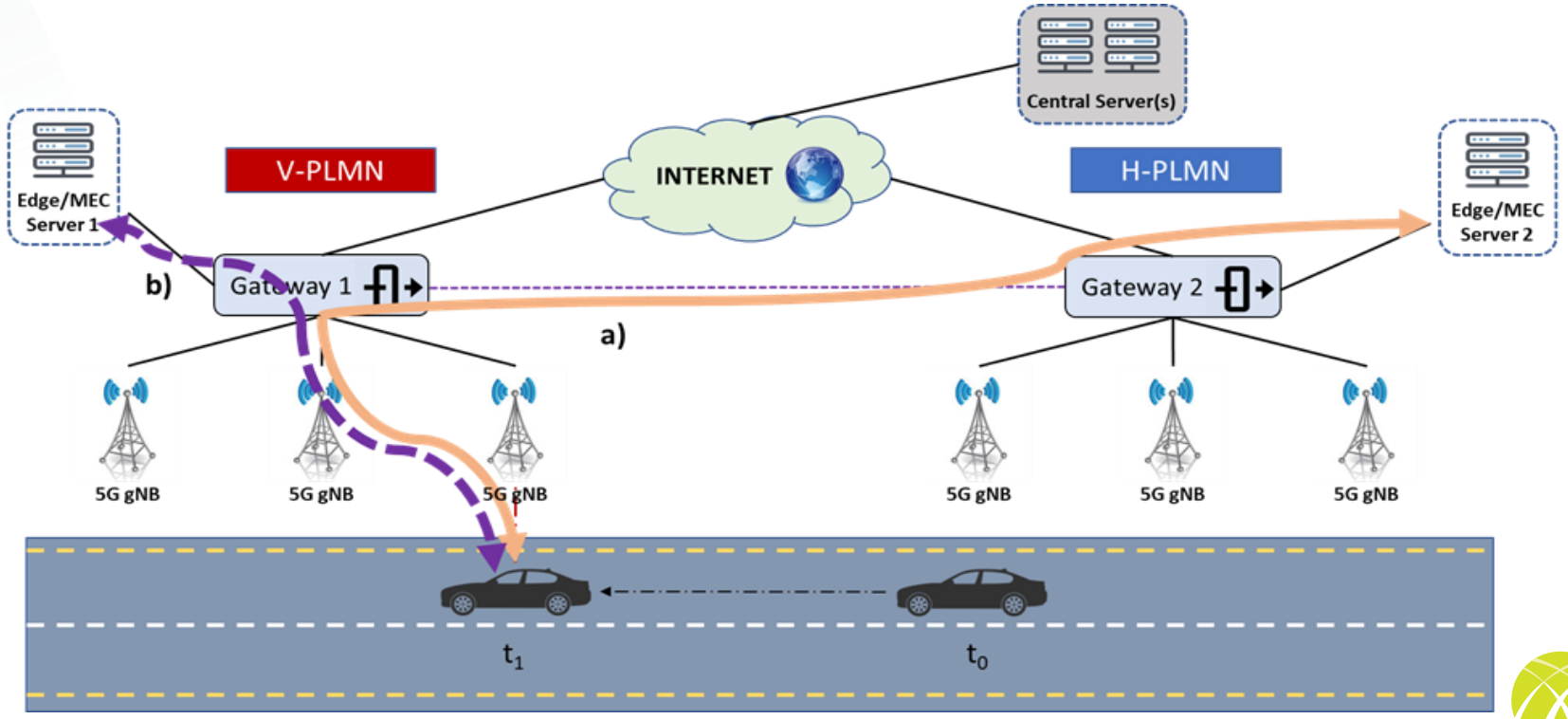


1st set of Challenges & potential solutions

(Service & Session Continuity, Data Plane Routing)

SSC Definitions & terminology

- **Session continuity**: The challenge of changing the attached gateway while maintaining the session (TS 23.501)
- **Service continuity**: The challenge of seamlessly switching the application server and host providing it



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Service & Session Continuity

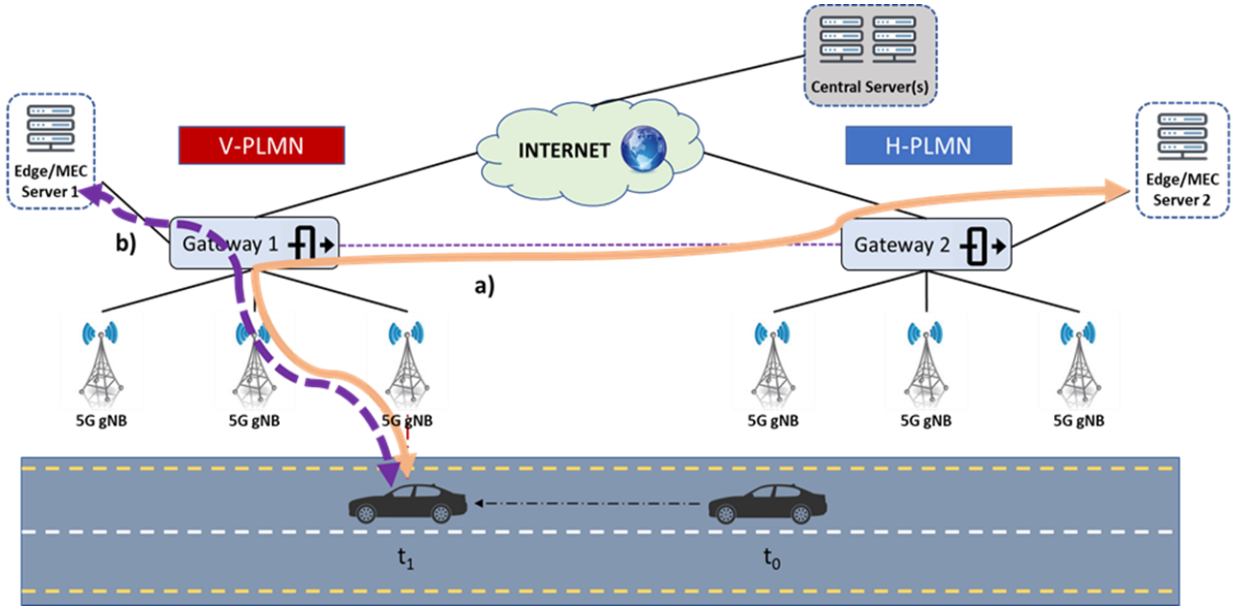
- Mobility events between neighbouring networks, require efficient gateway and edge/application server switches (under the mobility control plane)

- Session & Service Continuity (SSC) provides different levels of continuity for stateful applications → Very challenging for cross-border environments where ***both the network gateway and the edge/APP server need to be changed, while maintaining QoS/QoE based on SLA***
  - How to handle the IP address change?
  - How to transfer the state of the UE/vehicle between edge nodes for stateful applications? Especially in the case where NAT is used?
  - How to maintain the agreed QoS/QoE during the transition without increasing the cost (e.g. double SIM solutions, SSC mode 3)?
  - What provisions need to be taken from the Application side (state transfer, communication of different instances across different networks)?

Data Plane routing

- ***Home Routing (HR)*** is the standard procedure, i.e. the anchor gateway remains at the Home network, even after the mobility event
  - HR allows for easier session continuity
  - Long routes created for the data transfer, which introduces additional delays
  - Not scalable through multiple networks

- ***Local Break-Out (LBO)*** may be used where the anchor gateway switches to the visiting network after the mobility event
  - Optimal smaller routes for data transfer
  - Switching of gateways introduces connectivity interruptions (SSC issue)
  - Need for exchange of UE data (roaming UEs, ongoing sessions) between the MNOs



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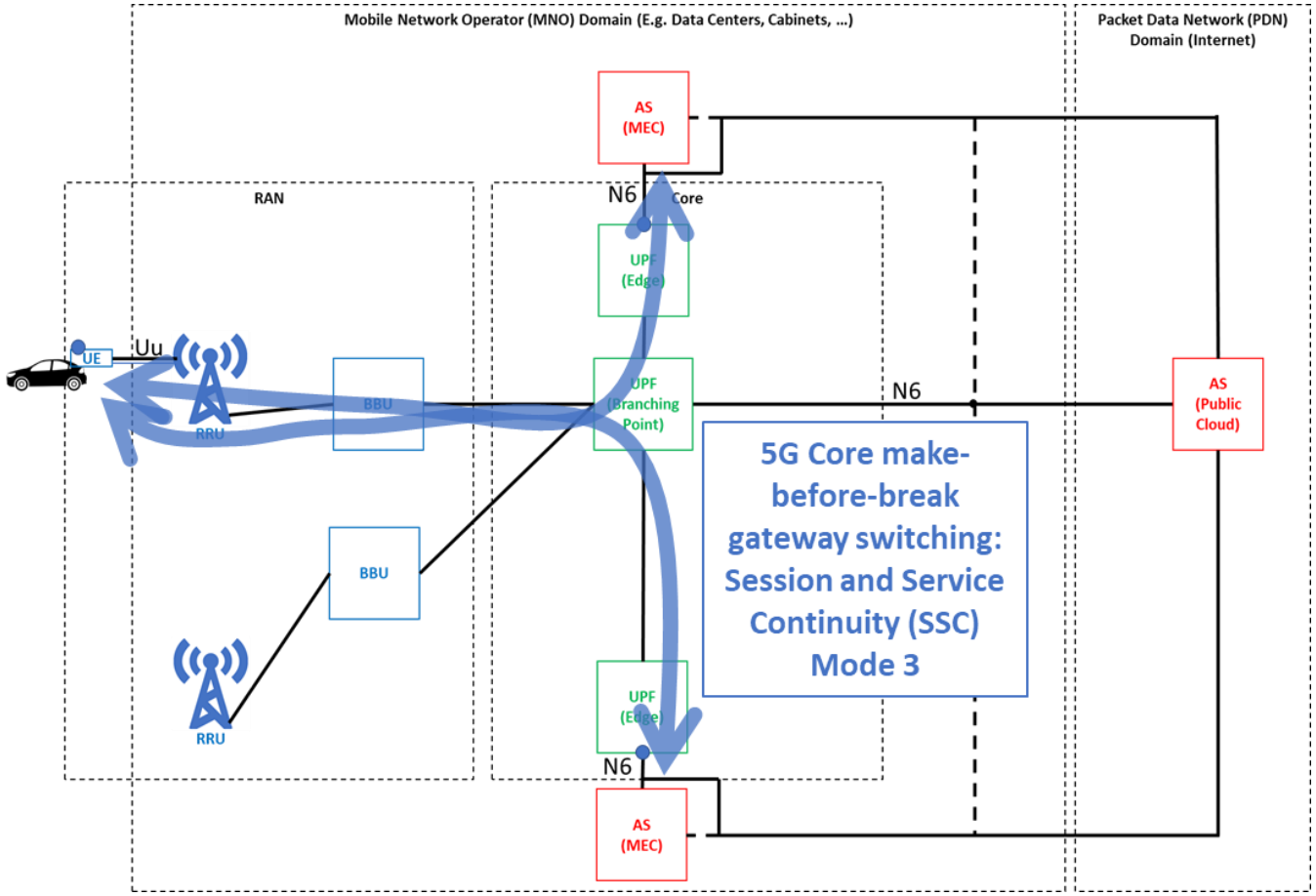
Technological Enablers for SSC & Data Plane Routing

- Extensive use of Edge servers (MEC) benefits CAM applications with smaller data routes and reduced latencies. Variations of SSC approaches exist
- ***SSC mode 3*** allows for a change of anchor gateway without temporary loss of connectivity but requires more advanced HW/UEs (promising but not available for testing)
- ***Cross-border / -MNO handover has already been standardized in 3GPP*** however not currently used by MNOs due to business, overhead/workload and legal/regulatory complexity



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Technological Enablers for SSC & Data Plane Routing

- Standalone 5G New Radio with 5G Core allows to change the connection from Home- to Local Breakout Roaming without service interruption
- The Application Function (AF) may facilitate communication between the core and the application in order to ***trigger the change of Edge/Application servers correctly*** (on time)
- IP change of the vehicle & state transfer still needs to be addressed at the application level
  - Vehicle state may also be stored in-vehicle and communicated with new server instance
  - Context transfer between application servers (IP and DNS addressing may create complications)

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Thank you

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