5G for Connected and Automated Road Mobility in the European union

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IEEE 5G Virtual Summit
IEEE 5G for CAM
CONNECTED AND AUTOMATED MOBILITY
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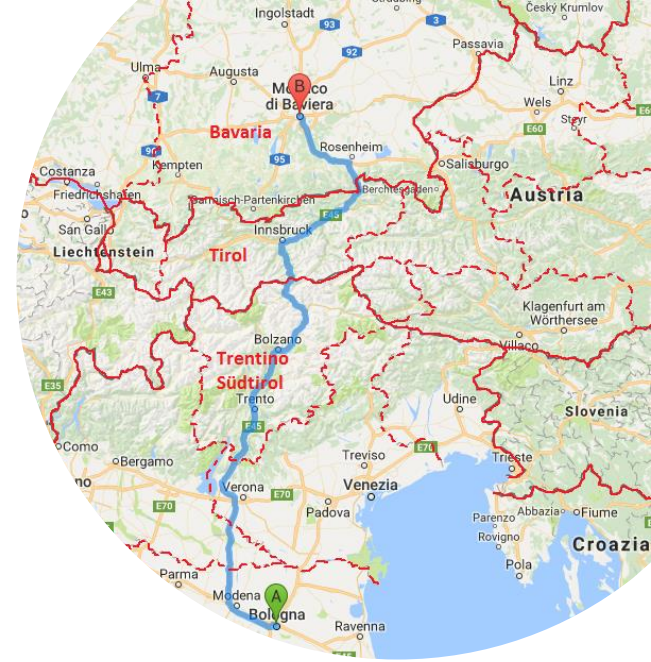
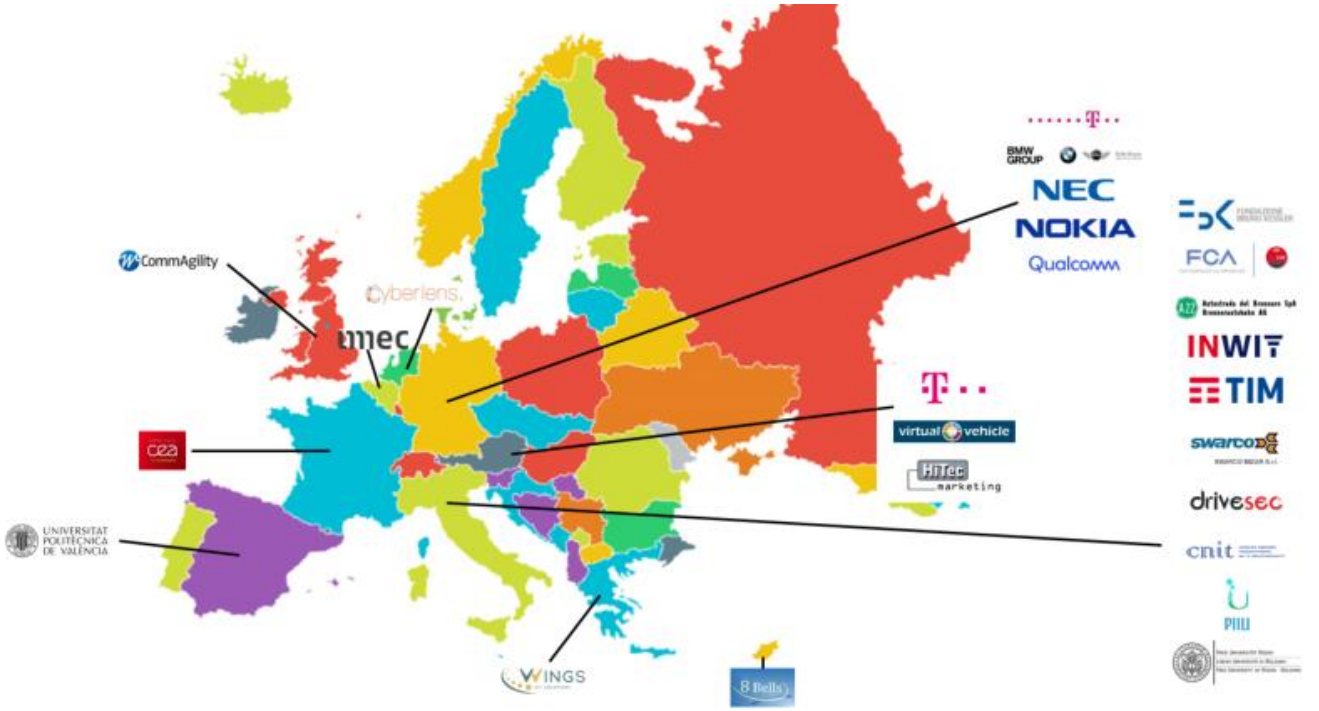
Agenda

- Project overview
- Use Cases and Trials
- Field measurements
- 5G Network assessment
- 5G Carmen solutions
- Q/A

Project Overview and Objectives



- The Bologna-Munich Corridor: ~600 Km across AT-AT-DE, interconnecting two-major industrial poles
- Elaborating and evaluating the **benefit of 5G and related Services for Automated Driving in real-world conditions**
- **Ensuring Service Continuity in different cross-border scenarios, enabling CCAM and SAE Level 4**
- Assessment of essential 5G KPIs for vehicle and MEC-based services **to pave the road for European Mobilitiy**



5G CARMEN

The 5G-CARMEN trials

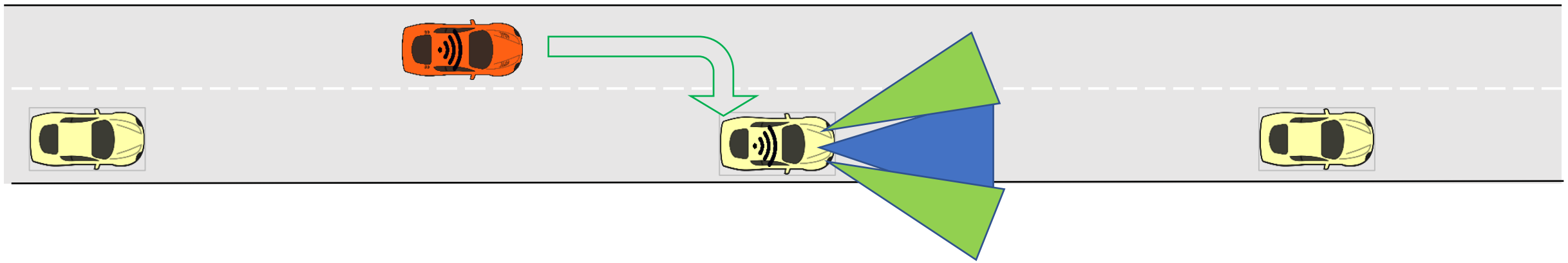
Demonstrating Level 4 Automated Driving

Two key use cases for connected and collaborative automated driving, targeting **5G connectivity to enable L4 automation**, thanks to improved awareness of the surroundings, integrated Edge Services a dynamic end-to-end Service Orchestration:

- **Cooperative and automated lane-change maneuvers**
  - Centralized approach (MEC-Service based) showing low-latency V2N Communication
  - Decentralized approach based on V2N2V communication (optionally including RSU message relay)
  - Edge-Orchestrated ad-hoc Emergency Vehicle clearance
- **Cooperative and automated in-lane maneuvers**
  - Situation-depending MEC-vehicle Local Dynamic Map synchronization for cruise control

The 5G-CARMEN trials
Cooperative and automated lane-change maneuvers

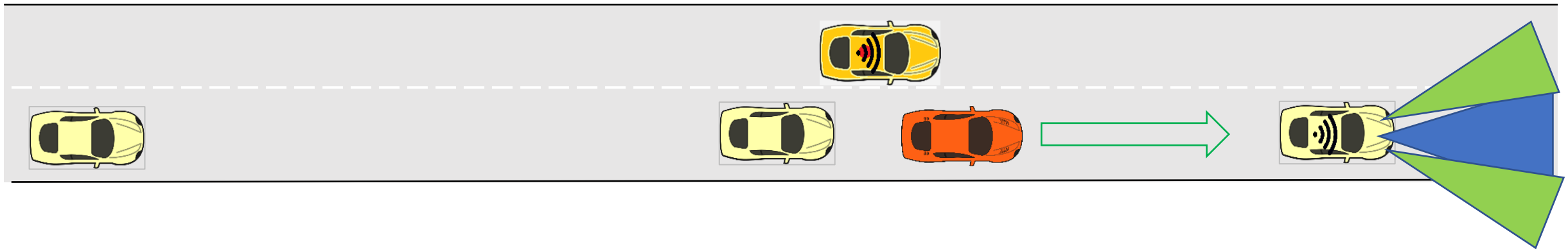
Clearance needed for emergency vehicle (known far in advance, through MEC)



A vehicle needs to change lane from overtaking to first lane or vice-versa. It performs lateral control in level 4 (L4) thanks to a very accurate and timely awareness of the surroundings, enabled by 5G. The use case includes two sub-use cases: the cooperative lane merge in the new lane as originally planned by the AD vehicle, and the lane change in presence of oncoming emergency vehicles.

The 5G-CARMEN trials
Cooperative and automated lane-change maneuvers

Lane keeping while emergency vehicle passes



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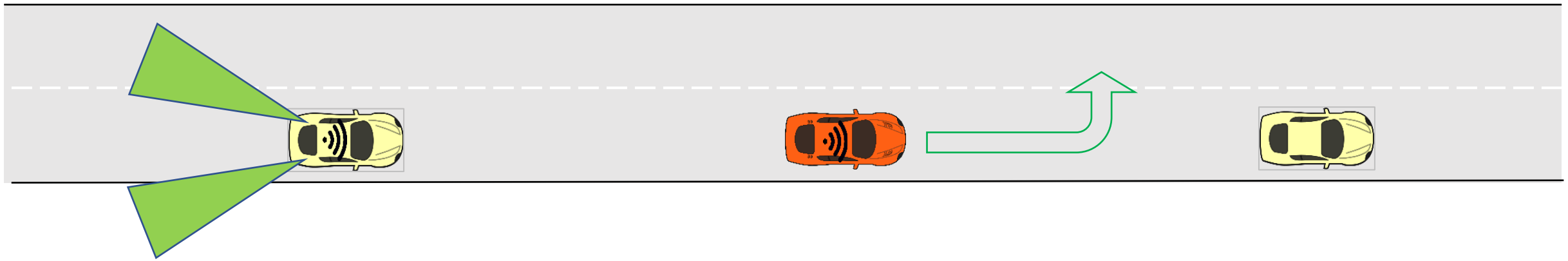
The 5G-CARMEN trials
Cooperative and automated lane-change maneuvers

Initial lane change intention (e.g. to overtake)



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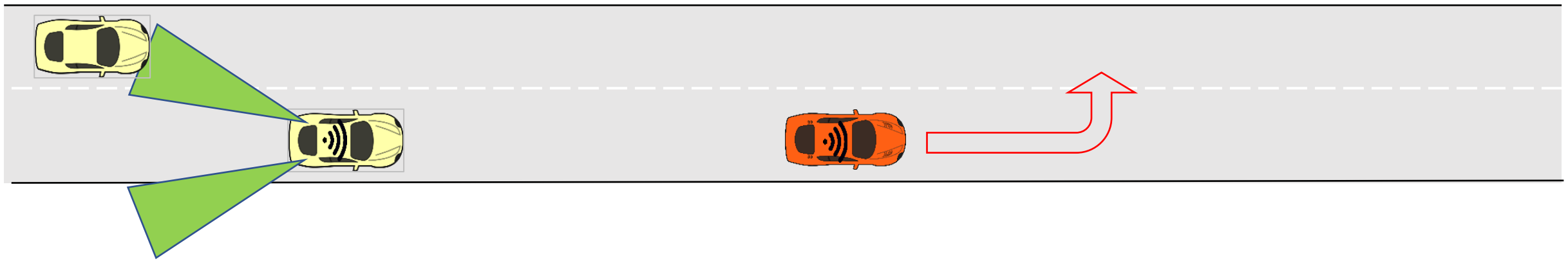
The 5G-CARMEN trials
Cooperative and automated lane-change maneuvers

Non-equipped vehicle detected far behind. It moves at very high speed.
Next lane change may fall outside ODD.



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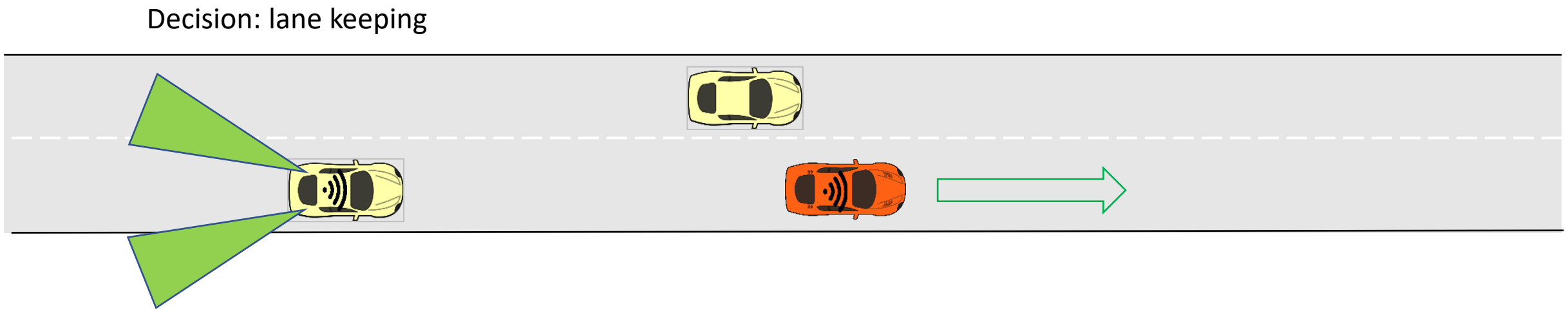
The 5G-CARMEN trials
Cooperative and automated lane-change maneuvers



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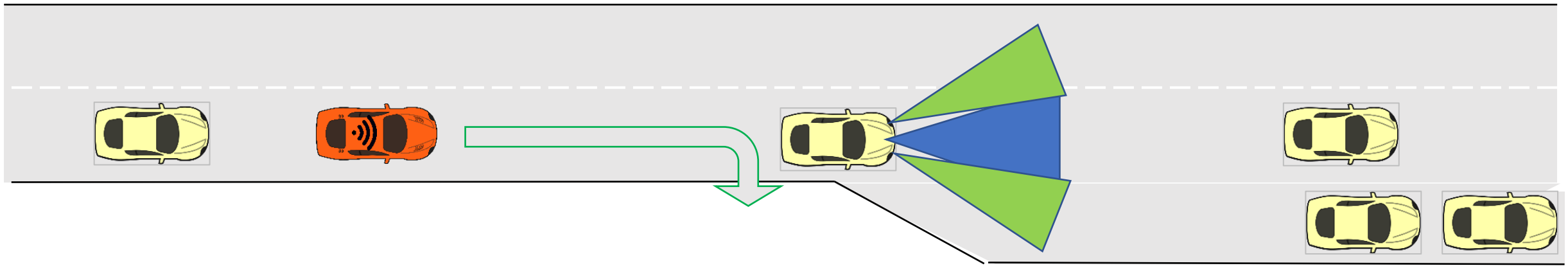
The 5G-CARMEN trials
Cooperative and automated In-lane maneuvers

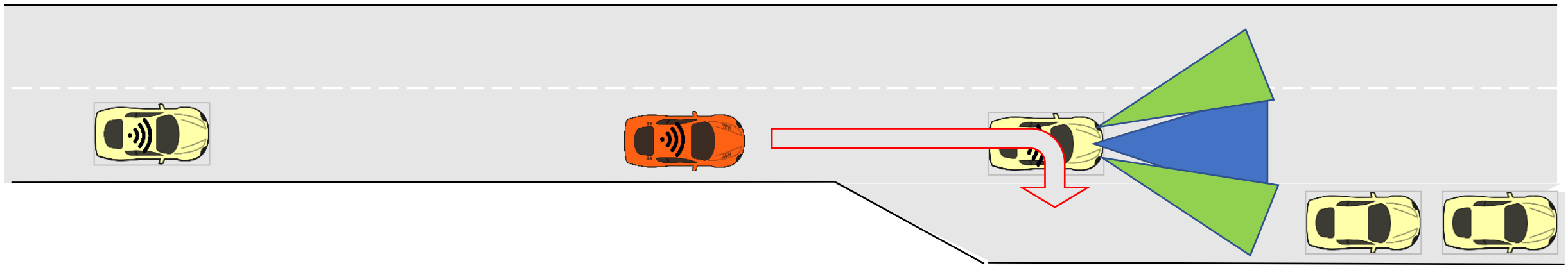
Exit/lane change intention



A vehicle is on the first lane and plans to exit the motorway in moderate-high traffic situation, with vehicles in front obstructing the view. A queue or obstacle on the exit lane would require the driver to take over. Thanks to 5G, however, the vehicle can sense what the vehicle in front senses and thus decide to keep L4, and stay in lane, re-planning the exit without disturbing the driver (in such situation, an autonomous vehicle is expected to go L3 if it is not sure about the lane conditions in advance).

The 5G-CARMEN trials
Cooperative and automated In-lane maneuvers

Exit/lane change plan would fall outside ODD (queue)



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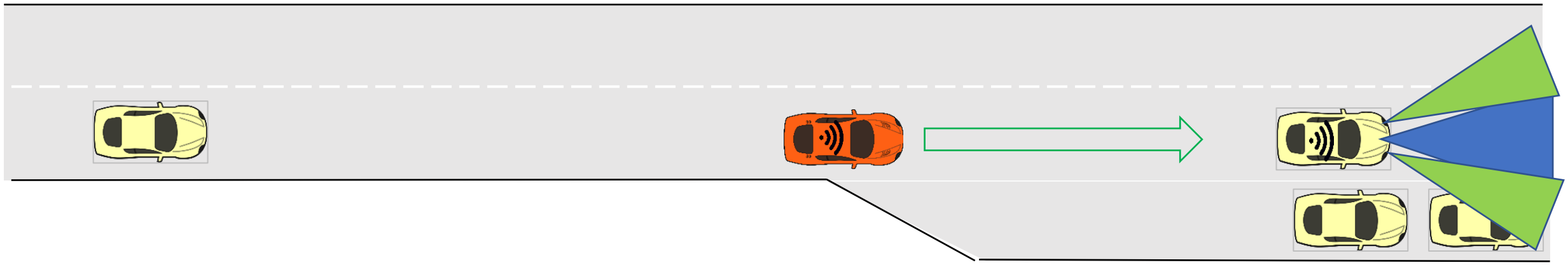
The 5G-CARMEN trials
Cooperative and automated In-lane maneuvers

Decision: keep going straight



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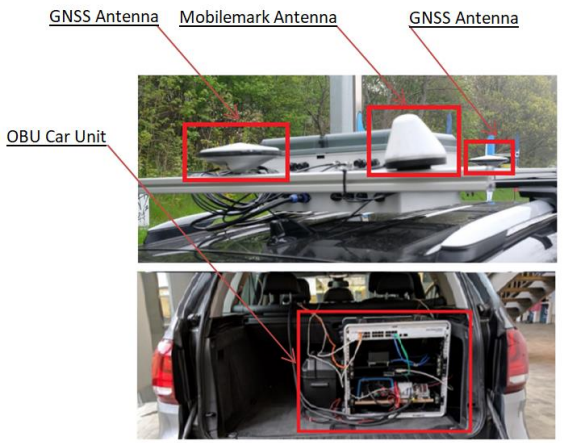
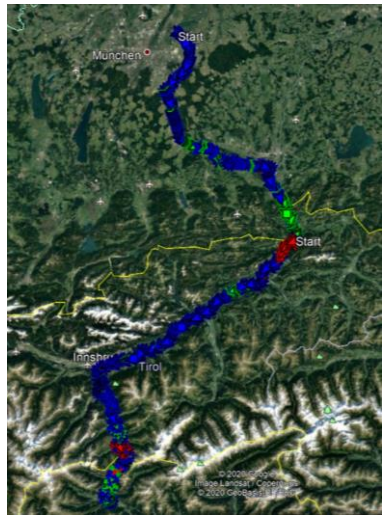
Tests and Trials

- **Field tests and 5G Rollout delayed** due to COVID-19 (e.g. Site access for MEC installation, Austrian borders temporarily closed…)
- **Integration and functionality/performance tests** for 5G/AD Enabler (e.g. V2X, **MEC Services AMQP, GeoService**, BSAF, S-LDM, Precise Positioning) ongoing
- Cross-border trials restarting (at the latest) **09/2021**





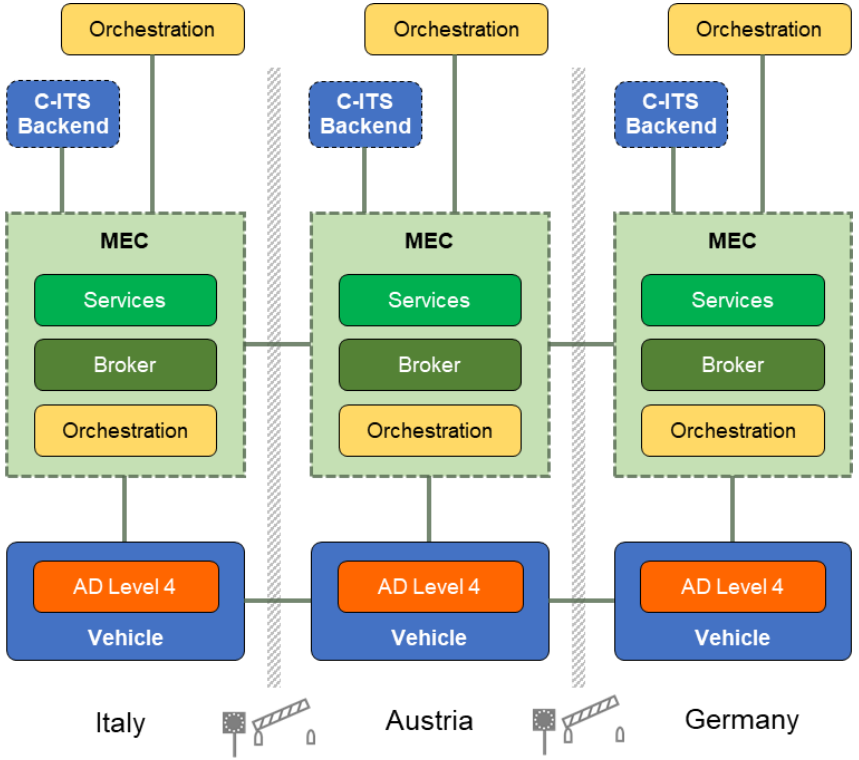
Precise Positioning Tests

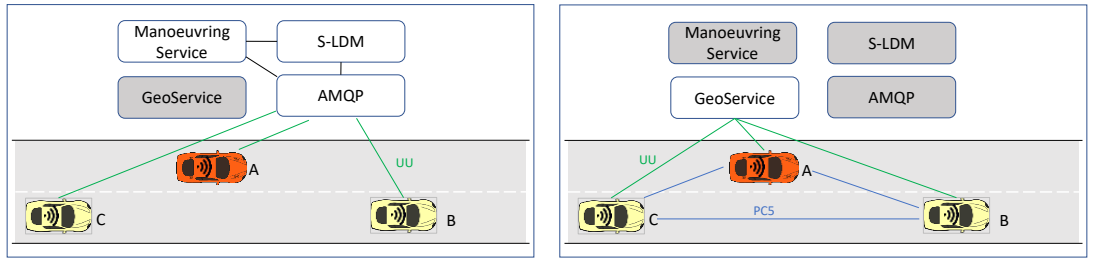
Main test sites (Munich, DE-AT border, AT-IT border, Trento)

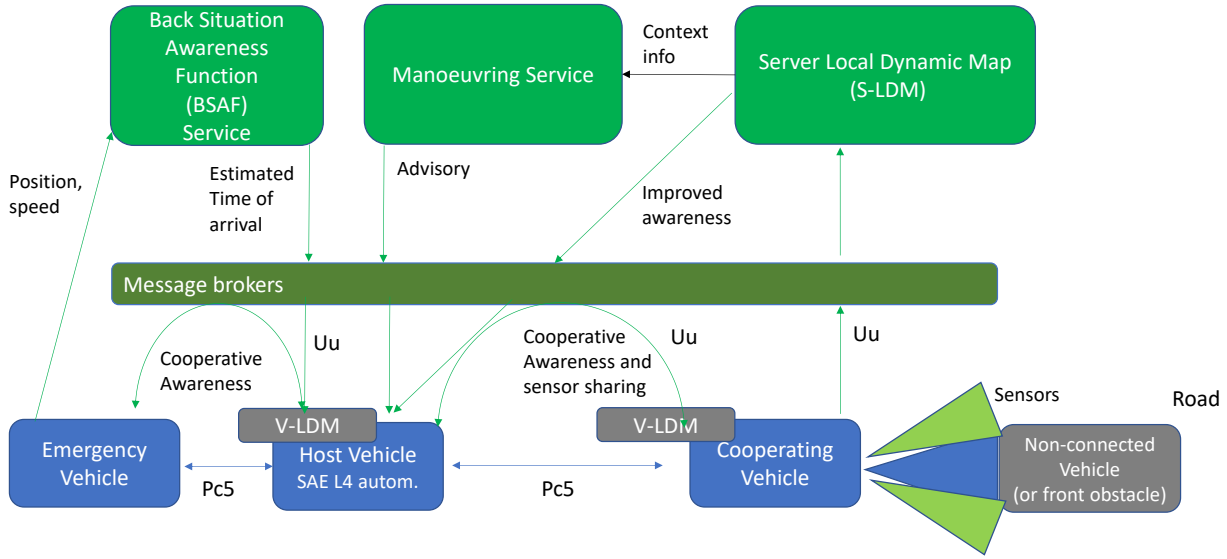
Architecture

E2E integration

- Use case specific Services
- **Harmonized cross-border**



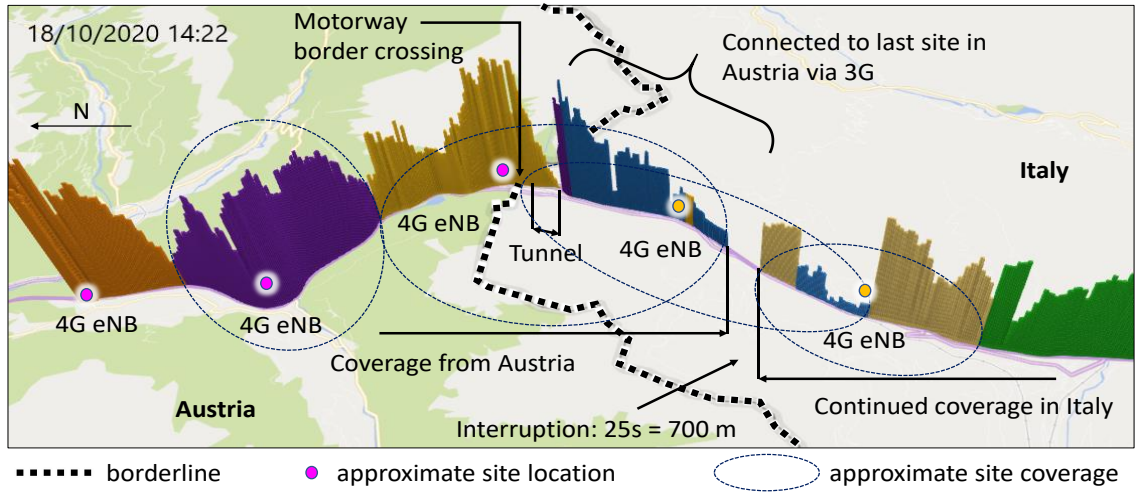




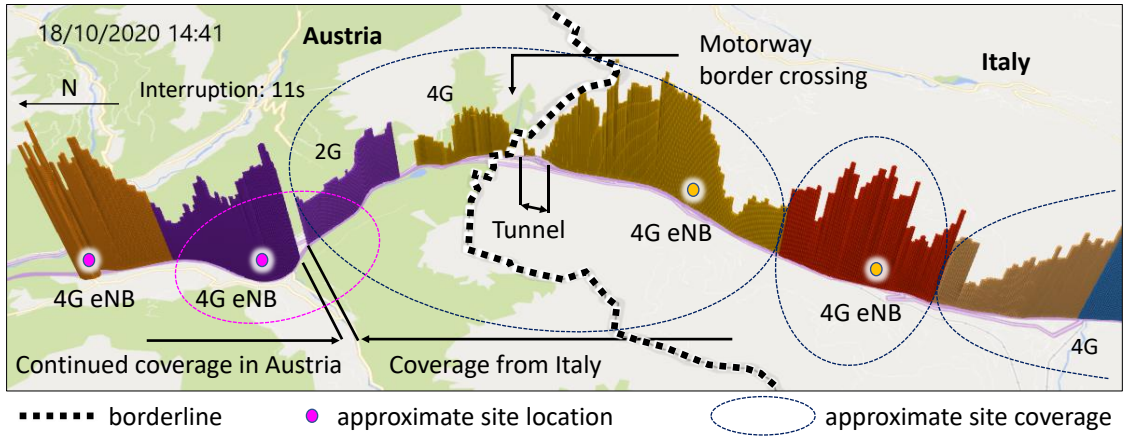
The current border situation
(similarly at most European borders)

- 5G NSA with 4G and 5G RAN at country borders (5G NR in Q3 2021)
- No inter-PLMN handover (required cross-border inter-MNO Core Network Interface not available)
- Network Re-selection:
  - **UEs stick to the Home Network as long as it is available** (down to lower bands/RATs)
  - UE get disconnected and scan frequencies to find any other network to re-attach
- **Connectivity gap of ~10s – 100s**

Driving from Italy to Austria



Driving from Austria to Italy

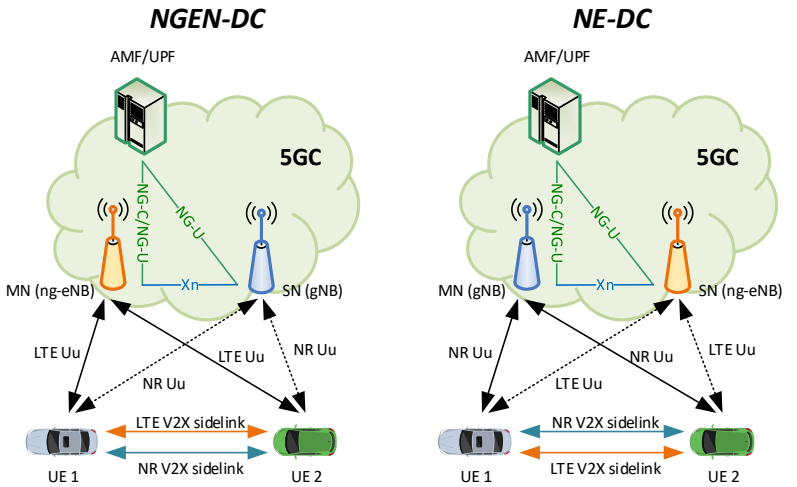


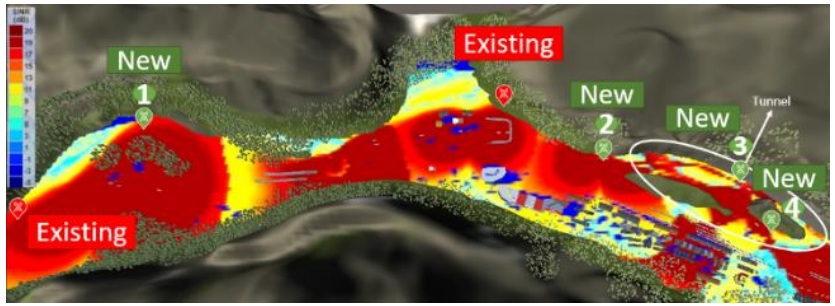
Local assessment (focus on 5G and invited paper)

Realistic deployment scenarios

Modelling of the Brennerpass area

- Applying **various traffic densities** (using real Road Operator data) and **radio propagation conditions**
- **Different deployment scenarios and RATs** (5GNR and V2N LTE, V2I and V2V PC5-Mode4), incl Multi-RAT
- Varying 5G settings and KPIs (e.g. message delay impact)
- Slice resource management: different data traffic requirements **coexisting on the same 5G resources**
- E2E scalability (e.g. manoeuver success rate) **depending on road traffic and penetration rate** (equipped vehicles)





Coverage Italian side

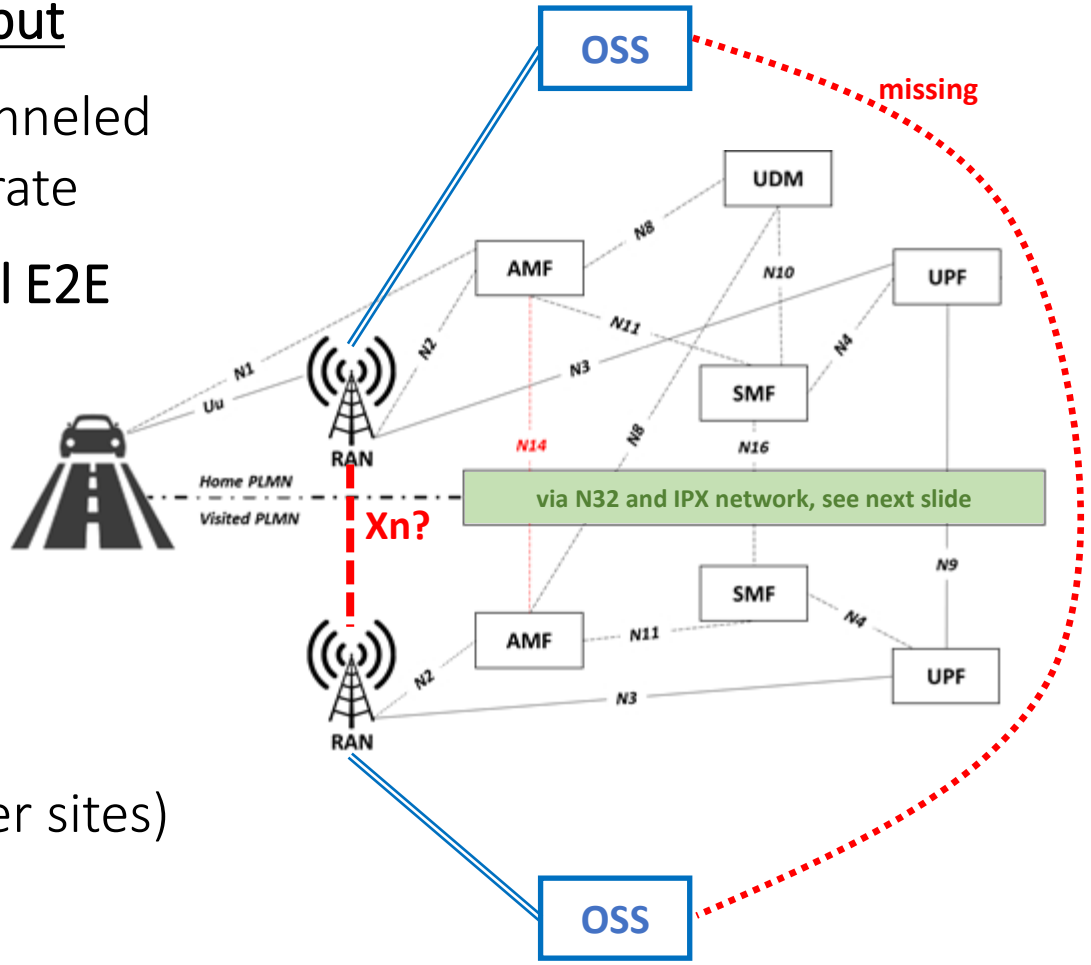
5G Globally: 3GPP Roaming Architecture, but…

RAN: cross-border inter-gNB (Xn) interfaces required, but

- Physical connections very expensive and (even if tunneled via N32) technically/operationally complex to integrate
- Anyways **not sufficient information for MNO-internal E2E Network Management (OSS)**

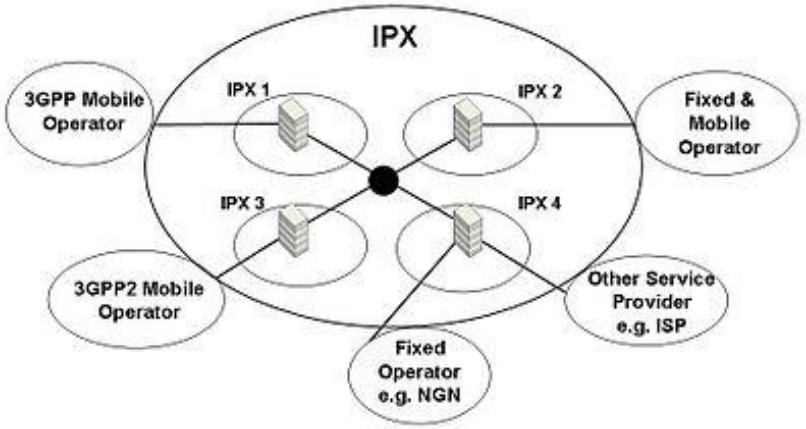
Network Management

- Governing **several technology generations** (2G-5G) and different equipment (vendors) in parallel
- Focus on radio planning/optimization (e.g. cell tower sites) and **seamless operations, both on a national level**



Network interconnections via IPX

- Dedicated backbone connections via IPX provider and peering points (e.g. AMS-IX, DE-CIX, LINX…)
- **Security: Trust between IPX provider and MNOs** (SEPP for N32, certificate handling etc WGs at GSMA)
- **E2E SLAs: guaranteed performance, quality and security** (recently standardized, implementation lengthy)
- **Latency:**
  - Optimized routing and traffic steering for better RTTs **(e.g via classification and regional prefixes, now standardized)**
  - Same discussion as for MEC: costs vs. need



	Amsterdam	Stockholm	Warsaw	Milan	Hong Kong	Istanbul	New York	Los Angeles
Amsterdam		30	31	27	178	47	71	135
Stockholm	30		36	37	201	70	108	171
Warsaw	32	39		32	196	58	107	174
Milan	28	39	32		184	48	98	162
Hong Kong	178	201	196	184		214	209	153
Istanbul	47	70	48	48	214		126	190
New York	71	108	107	98	209	126		62
Los Angeles	135	171	174	162	153	190	62	

Deutsche Telekom Global Carrier measurements Feb 2020

Practical cross-border improvements

5G for CCAM in Europe also depends on non-technical considerations

- The cross-border network situation will **often remain inter-RAT, thus hardly seamless**
- 5G-Carmen introduces an **accelerated network re-selection** (**<1s** in laboratory tests)
  - Foreign PLMN as "equivalent PLMN" -> **UE does not stick to the Home Network**
  - **Cell Neighbor Relations** with "foreign cells" and RAN **cell redirection procedures**
    -> **indicating (preferred) foreign cells directly to the UE** (discarding lengthy frequency scan)
  - **Shared, secure distributed database for inter-MNO RAN data sharing (cell PCIs, frequencies etc)**

- **RAN (Network Governance) data sharing is also required for the inter-PLMN handover**
  -> GSMA activity started for a non-discriminatory European (border area) database
- Pearse O'Donohue (DG CONNECT) statement on May 5th 2021 at the 6G Symposiom:
  "It's not just a digital interface – Europe must work together"

Thanks!

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Andreas Heider-Aviet, Deutsche Telekom

WWW: www.5gcarmen.eu

Twitter: @5g_carmen

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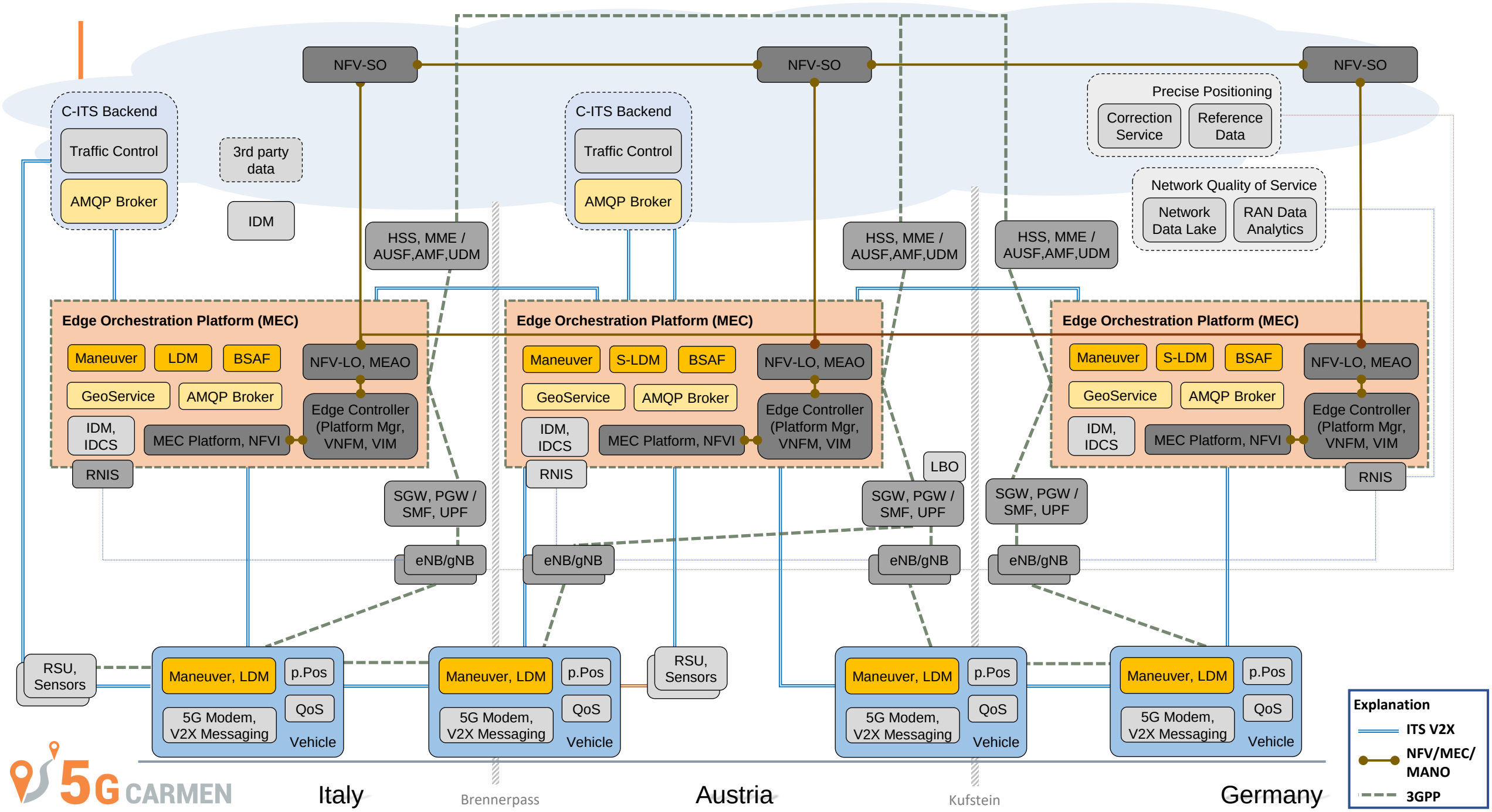
Backup


NFV-SO
NFV-SO
NFV-SO
C-ITS Backend
Traffic Control
AMQP Broker
3rd party data
IDM
C-ITS Backend
Traffic Control
AMQP Broker
Precise Positioning
Correction Service
Reference Data
Network Quality of Service
Network Data Lake
RAN Data Analytics
HSS, MME / AUSF,AMF,UDM
HSS, MME / AUSF,AMF,UDM
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Edge Orchestration Platform (MEC)
Maneuver
LDM
BSAF
NFV-LO, MEAO
GeoService
AMQP Broker
IDM, IDCS
MEC Platform, NFVI
Edge Controller (Platform Mgr, VNFM, VIM
RNIS
Edge Orchestration Platform (MEC)
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GeoService
AMQP Broker
IDM, IDCS
MEC Platform, NFVI
Edge Controller (Platform Mgr, VNFM, VIM
RNIS
LBO
SGW, PGW / SMF, UPF
SGW, PGW / SMF, UPF
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eNB/gNB
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eNB/gNB
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RSU, Sensors
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QoS
Vehicle
Explanation
ITS V2X
NFV/MEC/ MANO
3GPP
5G CARMEN
Italy
Brennerpass
Austria
Kufstein
Germany

Additional activities (non-exhaustive)

- **RNIS-based RAN control**: Managing UE priorities for ongoing Manoeuvers
- Inter-domain E2E Service Orchestration, **on-demand instantiation**
- Cross-border message broker (AMQP and location-based GeoService)
- **E2E security**: Combining Secure Elements, token-based authentication, **AI-based Intrusion Detection and Classification**
- Edge service continuity enablers (-> Technical Sessions)
  - Inter-MEC operations and demand prediction
  - Optimized application-context relocation approach

Simulation setup