Working Group gMEC4AUTO

MEC System Interoperability and Test Framework

5GAA Automotive Association
Technical Report

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Contents

Foreword

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The contents of the present document are subject to continuing work within the Working Groups (WG) and may change following formal WG approval. Should the WG modify the contents of the present document, it will be re-released by the WG with an identifying change of the consistent numbering that all WG meeting documents and files should follow (according to 5GAA Rules of Procedure):

x-nnzzzz

(1) This numbering system has six logical elements:
  (a) x: a single letter corresponding to the working group:
  where x =
  T (Use cases and Technical Requirements)
  A (System Architecture and Solution Development)
  P (Evaluation, Testbed and Pilots)
  S (Standards and Spectrum)
  B (Business Models and Go-To-Market Strategies)

  (b) nn: two digits to indicate the year. i.e. ,17,18 19, etc
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(2) No provision is made for the use of revision numbers. Documents which are a revision of a previous version should indicate the document number of that previous version

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Introduction

Global multi-access edge computing (MEC) deployments are characterised in real-life scenarios by multi-mobile network operator (MNO), multi-original equipment maker (OEM), and multi-vendor environments. In those scenarios, interoperability among all components is a key aspect. In this Technical Report (TR), and following the previous work in 5GAA MEC4AUTO, we have defined an updated and comprehensive architecture framework for MEC4AUTO, defining the different components and players within an automotive MEC deployment scenario. The present TR provides a technical analysis of MEC system interoperability requirements, for the definition a proper test object list (TOL) for testing on a global MEC perspective. For this purpose, the document discusses the main interoperability aspects in those scenarios of interest, and all related components of MEC interoperability; it also includes a selection of user cases (UC) for testing and key performance indicator (KPI) assessment, always with a focus on MEC from a UE perspective (service and network aspects) and from inter-MNO (network aspects) and inter-OEM perspective of MEC systems. Finally, the document conducts a review of latest developments in industry related to MEC test and interoperability, by considering recent activities from many organisations (e.g. ETSI MEC, 3GPP, GSMA/CAMARA, GCF, NGMN) who are making progress in terms of industry trails, Plugtests and developments for testing specifications.

1. Scope

The present document is continuing the previous work from 5GAA MEC4AUTO studies and reports. The previous work identified a set of possible use cases and related KPIs for evaluating MEC performance. In this document we take a more detailed look at the MEC deployment architecture and related interoperability and testing issues. Also, the selection of UCs and KPIs is reviewed and updated, and the current status of industry/ standards activities for interoperability and testing is also updated.

2. References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or nonspecific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] 5GAA Technical Report: MEC for Automotive in Multi-Operator Scenarios https://5gaa.org/content/uploads/2021/03/5GAA_A-200150_MEC4AUTO_Task2_TR_MEC-for-Automotive-in-Multi-Operator-Scenarios.pdf

[2] 5GAA NESQO TR200055 'Enhanced End-to-End Network Slicing and Predictive QoS' https://5gaa.org/content/uploads/2020/05/5GAA_A-200055_eNESQO_TR_final.pdf

[3] 5GAA gMEC4AUTO Technical Report "Global MEC technology to support automotive services; Technical Report on Cybersecurity for Edge Computing".

[4] 5GAA gMEC4AUTO Technical Report, "Moving toward federated MEC demos/trials (global MEC)", 5gaa.org/moving-toward-federated-mec-demos-trials

[5] ETSI GS MEC-IEG 006, 'MEC Metrics Best Practice and Guidelines', available at: https://www.etsi.org/deliver/etsi_gs/MEC-IEG/001_099/006/01.01.01_60/gs_ mec-ieg006v010101p.pdf

[6] 3GPP TS 23.501, 'System Architecture for the 5G System; Stage 2', Available at: https://www.3gpp.org/ftp/Specs/archive/23_series/23.501/

[7] ETSI GR MEC-DEC 025 Multi-access Edge Computing: MEC Testing Framework: https://www.etsi.org/deliver/etsi_gr/MEC-DEC/001_099/025/02.01.01_60/gr_mec-dec025v020101p.pdf

[8] TEC (Telco Edge Cloud) Forum: https://www.gsma.com/futurenetworks/telco-edge-cloud-forum/

[9] 5GAA Working Item MEC4AUTO Technical Report: "Use Cases and initial test specifications review", https://5gaa.org/content/uploads/2021/07/5GAA_MEC4AUTO.pdf

3. Abbreviations

For the purposes of the present document, the following abbreviations apply:

G3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5GC	5G Core
5GS	5G System
5QI	5G QoS Identifier
AC	Application Client
ACR	Application Context Relocation
AECC	Automotive Edge Computing Consortium
AF	Application Function
AMF	Access and Mobility Management function
API	Application Programming Interface
B2B	Business-to-Business
CN	Core Network
DN	Data Network
DNN	Data Network Name
DNS	Domain Name System
E2E	End-to-End
EDN	Edge Data Network
eMBB	Enhanced Mobile Broadband
eNB	evolved Node B
ETSI	European Telecommunications Standards Institute
GBR	Guaranteed Bit Rate
GFBR	Guaranteed Flow Bit Rate
gNB	Next Generation Node B
GNSS	Global Navigation Satellite Systems
GSMA OPG	GSM Association Operator Platform Group
KPI	Key Performance Indicator
MEC	Multi-access Edge Computing
MEC4AUTO	MEC for Automotive
MNO	Mobile Network Operator
NEF	Network Exposure Function
NEST	NEtwork Slice Type
NF	Network Function
NFV	Network Function Virtualisation
NFVI	Network Function Virtualisation Infrastructure
NG-RAN	Next Generation RAN
OAM	Operation and Maintenance
OEM	Original Equipment Manufacturer
OS	Operating System
PCF	Policy Control Function
PDB	Packet Delay Budget
PDU	Protocol Data Unit

PER	Packet Error Rate
P-QoS	Predictive Quality of Service
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RSU	Road Side Units
RTA	Road and Transport Authority
RV	Remote Vehicle
SDO	Standard Developing Organisation
SIM	Subscriber Identity Module
SLA	Service Level Agreement
S-NSSAI	Single Network Slice Selection Assistance Information
SoTA	State of The Art
SP	Service Provider
SST	Slice Service Type
TA	Tracking Area
TN	Transport Network
ToD	Tele-operated Driving
TOL	Test Object List
TR	Technical Report
TS	Technical Specification
UE	User Equipment
UL	Uplink
UPF	User Plane Function
uRLLC	Ultra Reliable Low Latency Communications
USRP	UE Route Selection Policy
V2X	Vehicle-to-Everything
VNF	Virtual Network Function
VPLMN	Visited Public Land Mobile Network
WI	Work Item

4. MEC system interoperability and test framework

4.1 Objectives

This work is continuing the previous work to examine MEC system analysis and interoperability requirements while considering complex scenarios where multiple applications with specific MEC requirements coexist and concurrently run in the car, input from SoTA, and standards. This TR will also focus on MEC from a user equipment (UE) perspective (service and network aspects) and from the inter-MNO (network aspects) and inter-OEM perspective of MEC systems.

The aim is to provide the following description and assessments:

- Selection of UCs for testing and KPI assessment (include UC with predictive QoS)
- Methodology setup including KPI and application with selected UCs
- Definition of a test object list (TOL) for testing on a Global MEC perspective (i.e. Multi-MNO/OEM scenarios)

4.2 MEC system testing recommendations and initial test object list

4.2.1 MEC system testing and interoperability requirements

Baseline from previous work MEC4AUTO

Inter-MEC interoperability topics were first covered in MEC4AUTO Task 2 TR [01]. One of the main objectives of that 5GAA report was to provide guidance on how to realise and manage the interoperability of automotive services in a multi-mobile network operator, multi-access edge computing, and multi-vehicle original equipment manufacturer environment. The TR examined the following multi-MNO scenarios:

- 1. Both MNO A and MNO B have MEC platform and MEC application X
- 2. Both MNO A and MNO B have MEC platform, but MEC application X is available only in MNO A
- 3. Only MNO A has MEC platform and MEC application X is available only in MNO A

These scenarios covered interoperability between two MEC systems, MEC platforms, or MEC application instances (thus we can talk about MEC-to-MEC interoperability), and where the end-device is mobile and requires switching between local MEC hosts. In this case, the MEC access or hosting entity is changed or re-routed.

Updated reference architecture

In the gMEC4AUTO project work, the reference architecture has been updated from the previous MEC4AUTO report, including the following main enhancements:

- support for edge resource sharing use cases (inspired by federated MEC trials experience),
- device roaming, in terms of different SIM options (MNO A, MNO B, roaming etc.), and
- different MEC host setups: local data network (DN inside the MNO domain), other DN (via MNO network) and setup in neutral host (NH) (thus, in shared DN).

The resulting reference architecture, with the above enhancements, is depicted in Figure 4.2.1-1, which captures the different MEC interoperability scenarios, identifying the possible combinations as part of gMEC4AUTO reference architecture. In fact, in order to have a compact view of all interoperability scenarios in one figure, the multiple options are captured/categorised in the architectural variants and classified based on the specific value assumed by the following attributes/dimensions (see also the related Tables 4.2.1-1 and 4.2.1-2 below):

1. **Presence of MEC application instance(s):** Here, multiple cases can occur; as an example, a host operator (MNO A) can provide not only the local RAN connection (to which the Vehicle 1 is attached), but also the edge resources to host the MEC application instance (called in the table as "MEC App A in MNO A"; this is the scenario corresponding to the case "1w"); or again, in another example, the MEC app instance (owned by MNO A) can run in other DNs (via MNO A), hence corresponding to the case "1c".
2. **Presence of MEC platform(s) to expose edge services:** The MEC platform used to host the MEC application instance can run on MNO A's premises, or MNO B, or again other DNs (via MNO or also in a shared datacentre).
3. **Network subscription of the end-user (vehicle (sub)system):** Here, the cars can be attached to different MNOs, thus with different SIM subscriptions (with some of them in network roaming); for example, the two-car scenario corresponding to the case "3a-3a" is when Vehicle 1 is with a SIM from MNO A, and Vehicle 2 with a SIM from MNO B).
4. **Available interconnection between MNOs:** A MEC deployment can exploit, for example, a controlled IP link to connect operators (case "4b"), or via N9 reference point (corresponding to the case "4a").
5. **Roaming options:** Here, some vehicles can be in their home network or in network roaming with the other network; data connection can be realised, for example, with local break-out (LBO) (which is the scenario corresponding to the case "5b" in the table).

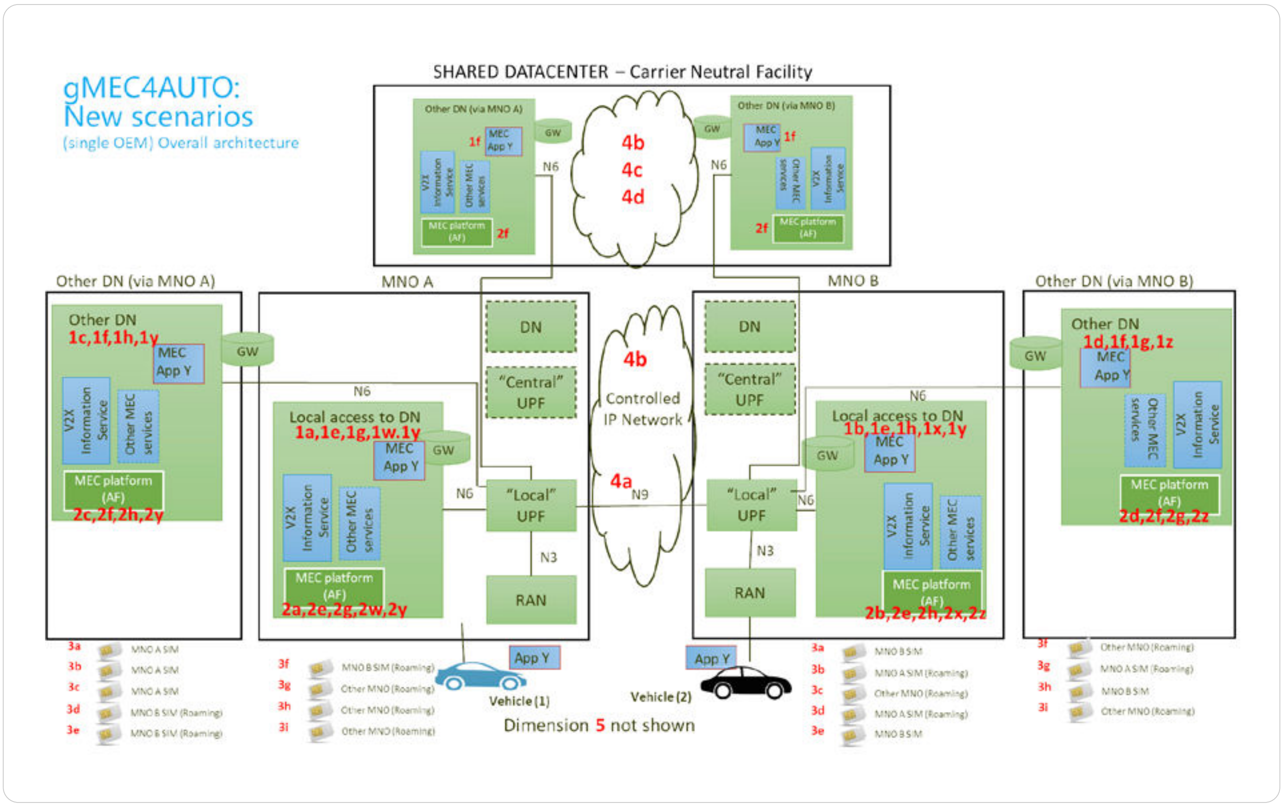

Figure 4.2.1-1: gMEC4AUTO updated reference architecture

Figure 4.2.1-1 thus provides a comprehensive view of all interoperability scenarios, and it includes both MEC setup options, i.e. in the MNO domain and NH scenario; the latter consisting of a shared datacentre where different physical MEC platforms (owned by different MNOs) are hosted in the same neutral facility, managed by a third party – the datacentre provider. This scenario provides additional interconnection capabilities, captured in the following tables for Dimension 1&2 and Dimension 4&5. One main benefit of this scenario is that all of the Dimension 4 options (b, c, d) could be provided by low latency (<1ms) interconnections, as both the MEC platforms will sit in the same room, same building or at least at the same campus.

Dimension	Attribute	Values											
		(*)	(*)	(*)	(*)	(**)	(**)	(**)	(**)	(***)	(***)	(***)	(***)
		a	b	c	d	e	f	g	h	w	x	y	z
1	Presence of **MEC Application instance**(s)	MEC App A in MNOA	MEC App B in MNOB	MEC App A in other DN via MNOA)	MEC App B in other DN (via MNOB)	MEC App A in MNOA	MEC App A in other DN (via MNOA)	MEC App A in MNO A	MEC App A in other DN (via MNO A)	MEC App A in MNO A	MEC App A hosted in MNO B	MEC App A in MNO A	MEC App A hosted in other DN via MNO B
						MEC App B in MNOB	MEC App B in other DN (via MNOB)	MEC App B in other DN (via MNOB)	MEC App B in MNCB	MEC App B hosted in MNO A	MEC App B in MNOB	MEC App B hosted in other DN via MNO A	MEC App B in MNOB
2	Presence of **MEC Platform(s) to expose edge services**, like predictions	MNO A	None	Other DN	None	MNO A	Other DN; Shared Data Center (Other DN)	MNOA	Other DN	MNO A	MNO B (MNO A uses MEC platform in MNO B)	MNO A	MNO B (MNO A uses MEC platform in other DN via MNOB)
		None	MNO B	None	Other DN	MNO B	Other DN	Other DN	MNOB	MNO A (MNO B uses MEC platform in MNO A)	MNO B	MNO A (MNO B uses MEC platform in other DN via MNO A)	MNO B

NOTE1: for all scenarios the assumption is MEC App instance 1 is owned by MNOA and MEC App instance 2 is owned by MNOB. For the sake of simplicity, we call them MEC AppA and MEC AppB
NOTE2: for all scenarios the assumption is that Vehicle 1 is connected to MNO A and Vehicle 2 to MNO B, and each Vehicle has a Client App running on the car
(*) these are cases of a single MEC App instance communicating with two Client Apps running on the two vehicles
(**) these are cases of two MEC App instances communicating with two Client Apps running on the two vehicles
(***) these are cases of edge resource sharing

Table 4.2.1-1: Dimensions 1 and 2 of Figure 4.2.1-1

			a	b	c	d	e	f	g	h	i
3	**Subscription** of end-user (vehicle (sub) system) according to SIM (instead of Global SIM)	Vehicle 1	MNO A	MNO A	MNO A	MNO B (roaming)	MNO B (roaming)	MNO B (roaming)	Other MNO (roaming)	Other MNO (roaming)	Other MNO (roaming)
		Vehicle 2	MNO B	MNO A (roaming)	Other MNO (roaming)	MNO A (roaming)	MNO B	Other MNO (roaming)	MNO A (roaming)	MNO B	Other MNO (roaming)

		a	b	c	d
4	Available **interconnection** between MNOs	N9	Controlled IP network	Local IXP	Private Network Interconnect
5	when in **Roaming**	Home routed	LBO		

Table 4.2.1-2: Dimensions 3, 4 and 5 of Figure 4.2.1-1

An important clarification for the table is that it covers only the owner of the MEC physical resources, and not the logical owner of the MEC app/service resources, which in many cases could be different hosted services supporting different business cases. As an example, the physical MEC platform which resides at MNO A in the figure may host the auto OEM as the logical owner of the MEC platform. The table does not reflect this valid business use case, simply to avoid adding further complexity. Another example affecting the MEC platform would be MNO A hosting two different OEMs, and each of them manages its own logical MEC platform.

4.2.1.1 Outline of interoperability aspects

In this section we provide an outline of the interoperability requirements for complex scenarios where multiple MEC hosted applications may concurrently run in the car. Here, considering the scenario where a device (vehicle) should be able to move between different MNO networks/locations, then the app should maintain interoperability with the relevant locally provided MEC services. This requires dynamic establishment/re-configuration/release of individual data sessions as specific services are consumed, and as the vehicle moves through different locations. This will involve both the configuration and routing of user plane data, and the configuration information sent across the control plane to/from the vehicle.

The following two challenges are therefore considered in the context of MEC interoperability:

Challenge 1

How to configure a vehicle to support multiple use cases, defining what are the "simultaneous" requirements?

- Simultaneous MEC use cases, with different MEC routes for several MEC servers.
- Simultaneous "other" services/connections alongside MEC use cases.

Challenge 2

How to manage a vehicle for "global" deployment? What types of parameters need to be set for each location/region, and how to configure them? (e.g. MNO specific, MEC specific, app specific, etc.).

- Statically configured by OEM.
- Dynamically configured/updated during the vehicle movement; configuration/updates coming from MEC service provider.

4.2.1.2 Components of MEC interoperability

The global MEC interoperability has been segmented into three basic components:

- Interoperability related to MEC vendors/suppliers
- Interoperability related to MNOs
- Interoperability related to OEMs (applications)

The fundamental requirement (from the end-user of an OEM point of view) is that MEC app A should work in the same way when routing across either MNO A or MNO B. This kind of MEC app interoperability can be proven using interoperability testing with direct IP connections; however, the effect of using an MNO-operated random access network (RAN) to transfer the information – because it includes both UE/modem and RAN elements – must also be considered. This will include the subscription-based features, e.g. UE route selection policy (URSP) and network slicing, and app-dependant features, such as traffic steering and routing to local break-out, which all affect the quality of service (QoS) and, hence, app performance. "Basic connectivity" may be available across most MNO's RAN networks, but QoS functions and related user experience and app performance may vary significantly with different MNO networks. This means the interoperability needs to include MEC app portability across different MNOs' RAN configurations, the processes for managing QoS and optimising performance settings, as well as selecting the best MEC routing option considering related latency impacts.

A simple MEC interoperability scenario is when a vehicle connected to MNO B uses a MEC application that is hosted/operated by MNO A. This scenario requires inter-working between MNOs, to enable connection to the required MEC application/ platform.

We can also consider a scenario where MNO A has local break-out to a MEC platform with the required MEC app server, but MNO A does not have relevant configuration for the RAN features to provide preferred QoS for the user. Alternatively, MNO B does not have a MEC app server available in the MEC and is federated across to the MEC in MNO A (e.g. via an EWBI), but MNO B does have RAN configuration with preferred features for QoS.

Now, to look at each component and understand the detailed requirements and challenges.

- App – UE: OS in the UE "exposes" parameters to the app
- UE – RAN: Implementation of URSP settings and selection (QoS and DNN selection)
- RAN – UPF: Within single MNO, no external interoperability factors
- UPF – DN: DN hosted in serving MNO (no problem); other DNs...
- DN – DN: MEC layer interoperability
- End-to-end

Basic approach and methodology

A set of baseline scenarios has been defined where only a single aspect is changed in the system configuration, and then the related interoperability requirements can be specified. The details of the full set of baseline scenarios are shown in Annex 1, as additional details of the different interoperability aspects.

This main study has combined the parameters/configurations defined in reference architecture and defined "real world" configurations and scenarios to be studied and specified, to then create expected interoperability requirements.

The following three sections will now define the three scenarios which were chosen for defining interoperability aspects of MEC for automotive purposes.

4.2.1.3 Interoperability of MEC from UE (OEM) perspective (service and network aspects)

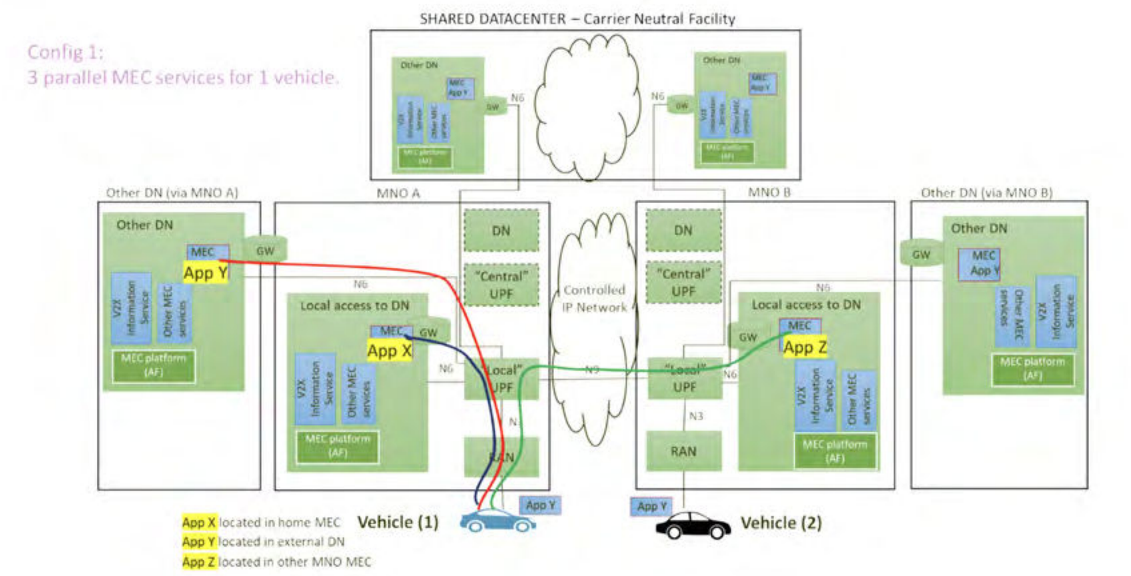

Figure 4.2.1.3-1: Interoperability of MEC from UE (OEM) perspective

The vehicle on-board unit (OBU) may be connected to multiple “services” in parallel (OEM backend server; road transport authority (RTA) backend server; service provider “marketplace” services; MNO backend server). This is depicted in Figure 4.2.1.3-1 using the updated reference architecture of Section 4.2.1.

In the 5G network deployment, we will need to consider if the network operator RAN will use the same URSP rules for all services (same latency, reliability, and RAN resources etc within a single PDU session), and the same physical routing to the data network (DN). The alternative is each MNO uses differentiated URSPs for different services (multiple protocol data unit (PDU) sessions with dedicated RAN resources/routing, and optimises QoS at the service level with separate RAN resources – on the basis of subscription-based access/quality for specific services. MEC4AUTO Task 2 TR (Section 8) indicates separate PDU sessions for each app to maintain service continuity, so this needs further study. The vehicle OBU may require connectivity to multiple MEC/local services, but not all AS may be co-located in same MEC entity, so multiple MEC connections may be required. Not all AS may be optimally located in MEC, other local (cloud system) servers may be available. Separate QoS prediction could be provided for different (individual) applications/services, so the ability to manage multiple PDU sessions with separate MEC routing and interoperability demands becomes important.

A scenario might be a car that has simultaneous connection to several running services (each with very different latency, reliability, and bandwidth requirements):

- OEM server connection for vehicle maintenance/monitoring (e.g. software update)
- OEM server connection for OEM AV service (e.g. HD map update)
- RTA server connection for local intersection information (hazard warning at intersection assist, VRU at intersection/crossing, etc.) hosted in local cloud system
- Service provider connection for infotainment streaming services
- Service provider connection for V2X services (e.g. valet parking, ToD, etc.)
- MNO server connection for specific services (e.g. road hazard warning, traffic jam warning, etc.)
- Data marketplace connection for value-added services (e.g. destination weather, points of interest, etc.)

From an interoperability point of view we need to consider the following questions: What types of parameters need to be specified/exchanged/agreed between OEM – MNO, and OEM – SP, and MNO – SP? What needs to be configured in the client-side app?

4.2.1.4 Inter-OEM perspective of MEC systems

We wish to understand what types of parameters need to be published/specified/configured by MNOs or SPs if they want different OEMs to have either the “same” or a “specific” user experience. How does an OEM (OBU) take this information and configure/update systems for this? Here, we speak about parameters specific to the app, OEM, MNO, etc.

To enable this, we first need to define what level of interoperability is required, and how to achieve it. So, the study has identified a series of different deployment scenarios and examined which of these would form the baseline for defining the interoperability parameters.

Figures 4.2.1.4-1 and 4.2.1.4-2 3 below show two examples of a simple inter-OEM MEC service, where two different OEM implementations are wanting to connect to the same MEC service.

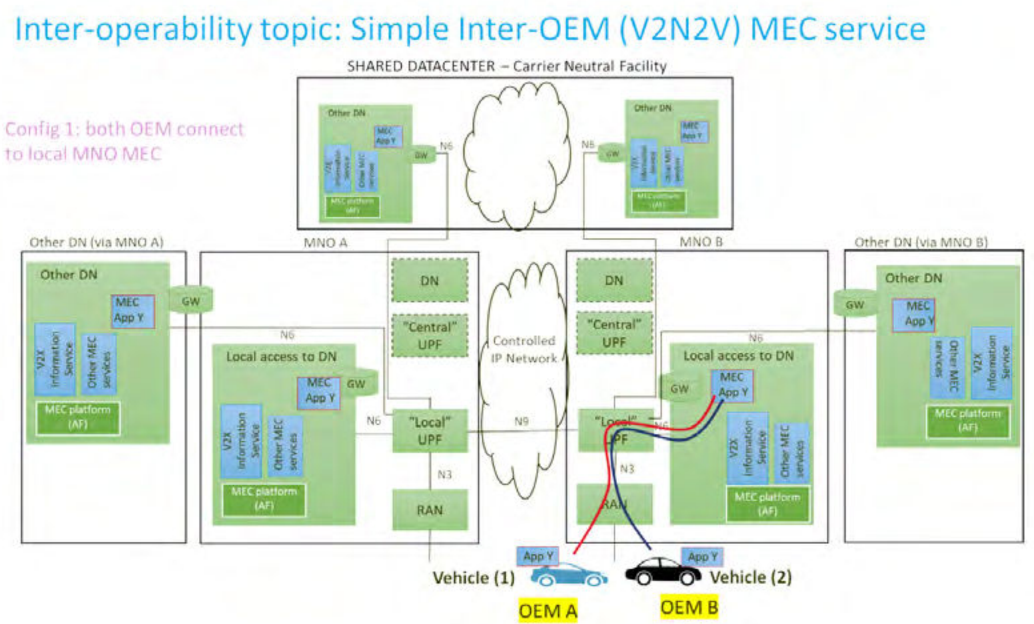

Figure 4.2.1.4-1: Interoperability of MEC, simple inter-OEM MEC service

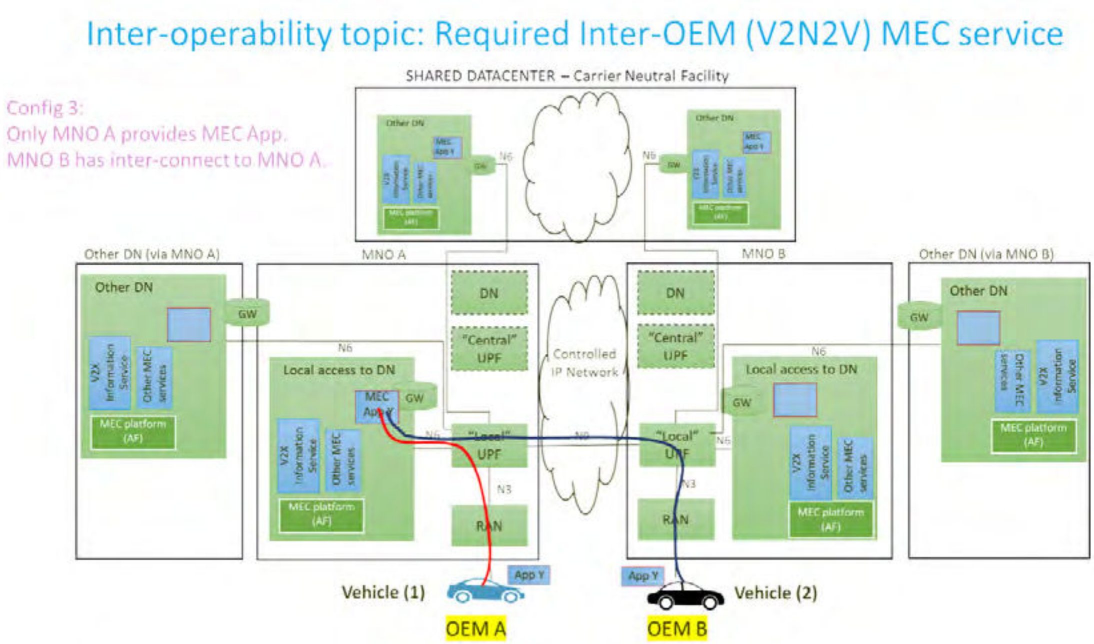

Figure 4.2.1.4-2: Interoperability of MEC, required inter-OEM MEC service

Figure 4.2.1.4-1 shows the simplest configuration, where both OEM vehicles are connected to the same MNO and MEC network. Figure 4.2.1.4-2 shows the required configuration to evaluate, as this represents a more real-world scenario where several MNO networks are available at the same location and two OEM vehicles may be connected to different MNO networks but need to access a MEC service that is only available in or on one MNO network.

4.2.1.5 Inter-MNO (network aspects) perspective of MEC systems

Figure 4.2.1.5-1 shows the inter-MNO aspect of MEC interoperability. Here, we wish to define the scenarios for inter-MNO interoperability of MEC, where a UE moves between two MNOs in a UE mobility scenario within the MEC system. The same vehicle, with same app installed, moves from MNO A to MNO B (e.g. in a roaming scenario). What are the handover/roaming/mobility interoperability parameters relevant to enable the end-to-end system to re-configure?

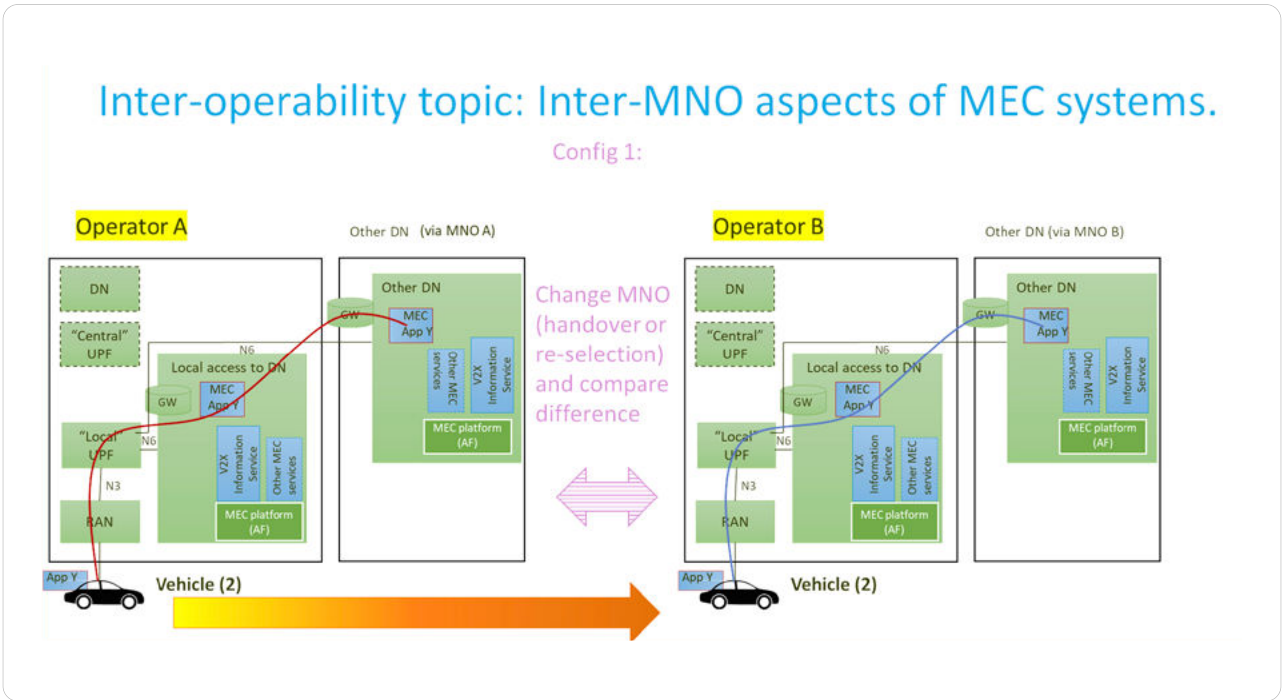

Figure 4.2.1.5-1: Interoperability of MEC, inter-MNO aspects

4.2.2 Selection of UCs for testing and KPI assessment

4.2.2.1 Selection of use cases for study

The selected use cases from the original MEC4AUTO Technical Report [9] are as follows:

- UC1: See-Through
- UC2: In-Vehicle Entertainment (IVE)
- UC3: Intersection Movement Assist (IMA)
- UC4: Vulnerable Road User (VRU), In-Vehicle Sensor-based Approach, Infrastructure Sensor-based Approach
- UC5: Vehicle Platooning (UC5 specifically discussed the prediction of QoS as an important parameter)

Other MEC-related UCs which have come to the market since the original MEC4AUTO report have also been considered for this new study (use cases requiring low latency and high reliability). In particular, the Automated Valet Parking (AVP) use case is of interest, taking input from the related 5GAA study for AVP (Work Item AVP Technology Assessment, which is developing a more detailed protocol description of this UC). The current study has looked to see if the use case would be suitable for detailed examination of the MEC requirements and required KPIs. Based on this work, and at the time of publishing, MEC4AUTO Technical Report TR is expected to be updated to include the AVP Type 2 Use Case evaluation as a candidate for MEC.

In addition, the following is the list of use cases that have been selected for Predictive Quality of Service (PQoS) according to the 5GAA NESQO TR (see Section 5.2 of A-190054) [02]:

- RT Situation Awareness and High Definition Map (Hazardous Location Warning)
- Software Update
- Tele-Operated Driving
- High-Density Platooning
- Advanced Safety (Lane Merge)
- In-Vehicle Entertainment

From the above candidate use cases, three have been recommended for further study: IVE, VRU, and AVP. The reasons for the selection are as follows:

- IVE has a relatively simple implementation architecture, and can more easily be defined and studied.
- VRU also includes the aspect of off-loading compute resources from vehicle-to-network, and represents a more complex set of interactions between different entities.
- AVP (Type 2) has an advanced definition of architecture and deployment within 5GAA and industry, which enables a real-world analysis of a use case with multiple actors involved in the scenario, and also has a complex architecture.

4.2.2.2 KPI assessment

The MEC4AUTO report [9] proposes a set of KPIs.

Metric/KPI	Description	Beneficiary
End-to-end latency	The latency definition in the scope of MEC4AUTO is referring to round-trip time (RTT), measured on the application level (see also [5]). Depending on the service type, the RTT might include heterogeneous paths (e.g. simple client-server applications, or multi-client communication through server, etc.).	End user, OEM
Bandwidth saving	A key benefit of MEC is a reduced load on the transport network [6]. This can be measured in terms of network throughput saving (i.e. user plane traffic at IP level) with respect to the usage of remote server applications.	MNO
Security and privacy	Security compliance can be a complex assessment and hard to perform in an exhaustive manner. The same considerations apply to privacy. Rather, a qualitative assessment of a use case for this metric can be performed.	All stakeholders
Energy efficiency	According to [5], energy efficiency can be defined at the UE side (terminals) and at the network side (infrastructure). Energy saving could be relevant in specific use cases for smartphones, and for certain RSU/small cell deployments.	MNO (e.g. RSU/ small cells) and End User (e.g. smartphones)
Bitrate guarantee	Besides latency, MEC can also have an impact on the capability to provide bitrate guarantees. This is not intended for quantitative evaluations but for qualitative one. Examples of such evaluations could be attributes such as “best effort/elastic”, “guarantee required – fixed bitrate”, “guarantee required – minimal bitrate”, “maximum bitrate (no benefit for application if higher one is provided)”, “event-triggered messages without fixed bitrate requirement”, etc.	End user

These KPIs are defining the key attributes to be ensured when using MEC to support a use case. So, any interoperability study or testing should ensure that these KPIs are not impacted or affected by different interoperability scenarios. While the actual measured value for any KPI may change with different interoperability scenarios, in each one it is required that the related service provider can still ensure and maintain a specified performance level for each KPI.

4.2.3 Definition of test object list for testing on a global MEC perspective (multi-MNO/OEM scenarios)

End-to-end latency was previously defined as RTT in previous MEC4AUTO studies [1], however for this study a more refined version is considered. Two key points that are now included in the latency requirement are (1) the traffic type (e.g. UDP packet size, packet rate), and (2) the asymmetric nature of many V2X use cases – different uplink (UL) and downlink (DL) data traffic loads – as defined in the 5GAA Use Case Description Document. The interoperability assessment should identify any impact on latency related mechanisms that arise from the different scenarios. So our TOL should be further refined to define uplink and downlink latency separately, with appropriate traffic types and the statistical nature of the latency distribution (e.g. 99% of downlink UDP packets to be within 20mS latency).

In terms of **bandwidth saving**, cellular networks are generally designed to manage a greater volume of downlink user plane data compared to uplink (for example, video streaming content distribution networks use a large volume of the data on 4G/5G). In addition, the 5G air interface is generally supporting larger downlink data rates than uplink data rates, leading to greater downlink capacity in networks. However, some automotive UCs may use higher uplink use plane data rates compared to downlink. So, the evaluation of MEC deployment-based bandwidth saving should evaluate the impact of different interoperability scenarios on the bandwidth of the specific use case, and the relative impact on related UL and DL transport network traffic.

Security and privacy is defined above as a qualitative metric for MEC KPIs. For the interoperability assessment, any possible impact on security and privacy should be identified in a qualitative manner for the different scenarios. The topic of MEC security is handled separately and in more detail in the gMEC4AUTO Task 4 [3] activity and report.

Energy efficiency savings from MEC are closely related to the bandwidth savings, as the reduced bandwidth required in the transport network and corresponding reduction in processing operations (e.g. central processing unit (CPU), switches and amplifiers, routings and inter-connects) directly leads to reduced power consumption by the network. In addition, the ability to provide services more locally from a roadside unit (RSU) or small cell, rather than a macro cell, can reduce the level of radio frequency (RF) power transmission required to support the service. For the different interoperability scenarios then the impact on the energy saving mechanisms above should be evaluated.

Bitrate guarantee is described above as a qualitative parameter in terms of KPI assessment. For the interoperability assessment, then, the possible impact on mechanisms used to deliver the bitrate should be identified for the different scenarios and use cases.

4.2.3.1 Define TOL related to each UC

Based upon the analysis above, the test object list can be reviewed in the context of each of the three deployment scenarios which were identified for study. The following bullets provide additional comments and observations regarding the KPIs and their application to each scenario.

- Multi services (MEC from OEM) scenario

E2E latency: Traffic data type (UL and DL), latency (UL and DL), availability (e.g. 99.9%).

Bandwidth saving: Multi-locations of AS may give multiple savings simultaneously.

Security and privacy: Multiple MEC locations and servers to be considered simultaneously.

Energy efficiency: Include offload of compute resources from vehicle to MEC/cloud.

Bitrate guarantee: Type of guarantee (e.g. best effort, minimum rate, fixed rate), availability (e.g. 99.9%).

- Inter-MNO scenario

E2E latency: Traffic data type (UL and DL), latency (UL and DL), availability (e.g. 99.9%).

Bandwidth saving: No extra comments.

Security and privacy: Change of MNO access route to MEC may imply change of security and privacy domain.

Energy efficiency: No extra comments.

Bitrate guarantee: Type of guarantee (e.g. best effort, minimum rate, fixed rate), availability (e.g. 99.9%).

- Inter-OEM scenario

E2E latency: Traffic data type (UL and DL), latency (UL and DL), availability (e.g. 99.9%).

Bandwidth saving: No extra comments.

Security and privacy: Different OEMs' implementations are connected simultaneously.

Energy efficiency: No extra comments.

Bitrate guarantee: Type of guarantee (e.g. best effort, minimum rate, fixed rate), availability (e.g. 99.9%).

4.3 Report of global MEC status: interoperability and system aspects

4.3.1 Current status of interoperability and systems aspects within industry trials and deployments

In this section we will describe the interoperability aspects that have been examined/ reported by industry trials for MEC. This covers the status of ETSI, GSMA, etc. trials and related interoperability activities available in the public domain. The status of 5GAA demos is handled separately in the gMEC4AUTO Task 1 report [04].

ETSI

ETSI MEC Plugfests (recent publications made during gMEC4AUTO project timescales).

June 2020: https://www.etsi.org/events/past-events/1683-nfv-mec-plugtests

The event included a wide range of test sessions covering:

- NFV interoperability and API conformance
- MEC and MEC-in-NFV interoperability and API conformance

Participation was open to organisations working on the following NFV and/or MEC solutions:

- Virtual, physical and containerised network functions, and element managers
- Management and orchestration solutions: NFVO, VNFM
- Network function virtualisation infrastructure, and virtual infrastructure managers
- Hardware solutions
- MEC platforms, platform managers and orchestrators (MEO, MEA, MEPM, MEPM-V)
- MEC applications
- Operations and business support systems: OSS, BSS
- Test tools and simulators implementing NFV and/or MEC APIs

February 2021 (remote) API Plugtests: https://www.etsi.org/events/past-events/1840-nfv-mec-remote-api-plugtests-2021

Allow participants to self-evaluate the conformance of their API server implementations with network function virtualisation and MEC API specifications. Validate and gather feedback on ETSI NFV and MEC API and conformance test specification and associated robot test suites.

October 2021 IOP Plugtests: https://www.etsi.org/events/past-events/1935-nfv-mec-iop-plugtests-2021

The MEC interoperability testing aimed at testing interoperability of MEC applications execution on different MEC platforms and in different deployment types (i.e. MEC standalone and MEC in NFV). The MEC Interoperability Track proposed four groups of interoperability tests covering application lifecycle management, traffic and DNS management, MEC service management, and MEC location service. The main interoperable interfaces were between MEC applications and MEC platforms (the Mp1 reference point). The test configurations were derived from the generic interoperability testing architecture reported in ETSI MEC025[7].

GSMA has organised a number of multi-MNO trials under the umbrella of the Telco Edge Cloud (TEC) forum [8]. These activities include industry trials or deployment activities related to MEC deployments. However, specific interoperability results have not been published yet.

4.3.2 Current status of interoperability and systems aspects within SDOs and industry forums

In this section we will outline the progress made in related standards organisations (SDO) – especially 3GPP and ETSI MEC – related to interoperability and testing aspects of MEC in 3GPP networks. It can be seen that ETSI MEC has published and updated a number of documents, and that 3GPP has made advances in the study of testing for URSP and network slicing from a "full stack" end-to-end point of view.

ETSI MEC

ETSI MEC-related document which focuses on interoperability between the different elements within the MEC system.

NFV interoperability testing methodology ETSI GS NFV-TST 002

- Multi-access Edge Computing (MEC); Guidelines on Interoperability testing ETSI GR MEC-DEC 042

Guidelines on the architecture, configurations, and Test Descriptions of testing MEC in a given set of test group scenarios.

Draft ETSI GS MEC 032-1, 032-2, 032-3, Multi-access Edge Computing (MEC); MEC API Conformance Test Specification Part I, II, III.

- Multi-access Edge Computing (MEC); API Conformance Test Specification; Part 1: Test Requirements and Implementation Conformance Statement (ICS)
- Multi-access Edge Computing (MEC); API Conformance Test Specification; Part 2: Test Purposes (TP)
- Multi-access Edge Computing (MEC); API Conformance Test Specification; Part 3: Abstract Test Suite (ATS)
- ETSI GR MEC 035 (June 2021)

Multi-access Edge Computing (MEC); Study on Inter-MEC systems and MEC-Cloud systems coordination

https://www.etsi.org/deliver/etsi_gr/MEC/001_099/035/03.01.01_60/gr_MEC035v030101p.pdf

3GPP

Focuses on interoperability between the device and network.

Study item on Enhancement of Network Slicing (UID-910099) eNS-UEConTest. This resulted in the update of UE protocol conformance test cases to cover test of network slicing.

Study item on 5G NR UE full stack testing for Network Slicing (UID-910095) FS_NR_Slice_Test, which resulted in TR 38.918 published in July 2022.

Study item on end to end performance methodology for 3GPP at a system level, resulting inTS28.554: 5G end-to-end Key Performance Indicators.

Other industry forums

GCF

The Global Certification Forum (GCF) previously created a task force GCF TF MEC (which is described in a previous MEC4AUTO report). No progress has been reported, and no further activity has been undertaken by GCF in this area. The work appears to be currently on hold.

GSMA/CAMARA

CAMARA is an open source project within Linux Foundation to define, develop and test the APIs for global telco deployments. CAMARA works in close collaboration with the GSMA Operator Platform Group to align API requirements and publish API definitions and APIs.

Availability across telco networks and countries is necessary:

- To ensure seamless customer experience
- To accelerate technology development and commercial adoption (minimise implementation effort)
- To accelerate education and promotion
- To support application portability

Sub-project to define the service API's for the Edge Cloud. Work has started in July 2022, but no results are publicly disclosed yet, and no update on any test or interoperability aspects are made public.

https://camaraproject.org/edge-cloud/

Sub-project to define Quality on Demand APIs, describe, develop and test API quality for a mobile connection (e.g. required latency, jitter, bitrate). This project started in October 2021, and has released an initial version of the definition and documentation. No reports yet on the testing aspects of the APIs.

https://camaraproject.org/quality-on-demand/

NGMN

NGMN has published a paper jointly with Global TDD Initiative (GTI) to consider the deployment and interoperability aspects of network slicing in user devices. The paper, entitled "Definition of the testing framework for 5G device network slicing pre-commercial trials", was first published in January 2022. It defines a testing framework to verify the interoperability of the network slicing mechanisms deployed in or on UE, including URSP for network routing selection. In addition, a set of conclusions from the first trials has been published, showing initial results of using the test methodology described.

www.ngmn.org/publications/definition-of-the-testing-framework-for-5g-device-network-slicing-pre-commercial-trials.html

www.ngmn.org/wp-content/uploads/221122-Pre-Commercial-Network-Slicing-Trials-Major-Conclusions-v1.0.pdf

5. Conclusions

In this study and report we have defined a new architecture framework for MEC4AUTO, outlining the different components and players within an automotive MEC deployment scenario. The work has then analysed the different combinations and scenarios and identified three leading scenarios for further interoperability analysis. These scenarios were selected based upon the actual trials and demonstrations being reported in 5GAA, to align the study with the trials work that is running in parallel.

The three leading scenarios were identified as:

- MEC interoperability from UE (OEM) perspective
- Inter-OEM perspective of MEC interoperability
- Inter-MNO perspective of MEC interoperability

The study has then reviewed the different automotive use cases relevant to MEC and interoperability issues. The previous study from MEC4AUTO was reviewed, together with more recent industry and 5GAA roadmap activities. From this, the use case of Automated Valet Parking was identified as a new candidate for study.

From the set of candidate use cases, the three were recommended for further study: In-Vehicle Entertainment, Vulnerable Road User, and Automated Valet Parking. The reasons for selection were explained, as follows:

- IVE was selected because it has a relatively simple implementation architecture, and can more easily be defined and studied.
- VRU was chosen because it also includes the aspect of off-loading compute resources from vehicle-to-network, and represents a more complex set of interactions between different entities.
- AVP (Type 2) was selected as it has an advanced definition of architecture and deployment within 5GAA and industry. This enables a real-world analysis of a use case that has multiple actors involved in the scenario, and also has a complex architecture.

The KPIs related to performance evaluation of MEC have then been analysed, with specific comments and observations on their relevance to interoperability and testing of MEC deployments. These have been analysed in the context of the three identified scenarios, and how these scenarios may affect the KPIs related to:

- E2E latency
- Bandwidth saving
- Security and privacy
- Energy efficiency
- Bitrate guarantee

Lastly, the latest MEC test and interoperability related developments in industry have been reviewed. This looked at ETSI MEC, 3GPP, GSMA/Camara, GCF, and NGMN organisations. We can see progress and new initiatives in the industry, with multiple trails, Plugtests, and testing specifications being developed.

Annex A:

Baseline scenarios for defining interoperability requirements (informative)

A.1. Baseline scenarios for interoperability study

Basic approach for “baseline scenarios”: use a common/defined reference configuration, and then change only one (or a selected set) of parameters to create two configurations. Then compare the two configurations to define the interoperability requirements needed to support the change of selected parameters.

Scenarios derived from Section 4.2.1.2.

Change of OEM: OEM-related aspects and parameters to define.

Change of MNO: MNO-related aspects and parameters to define.

Change of App: App-related aspects and parameters to define.

Compare OEM A + MNO A versus OEM B + MNO B configurations. OEM + MNO combination related aspects and parameters to define.

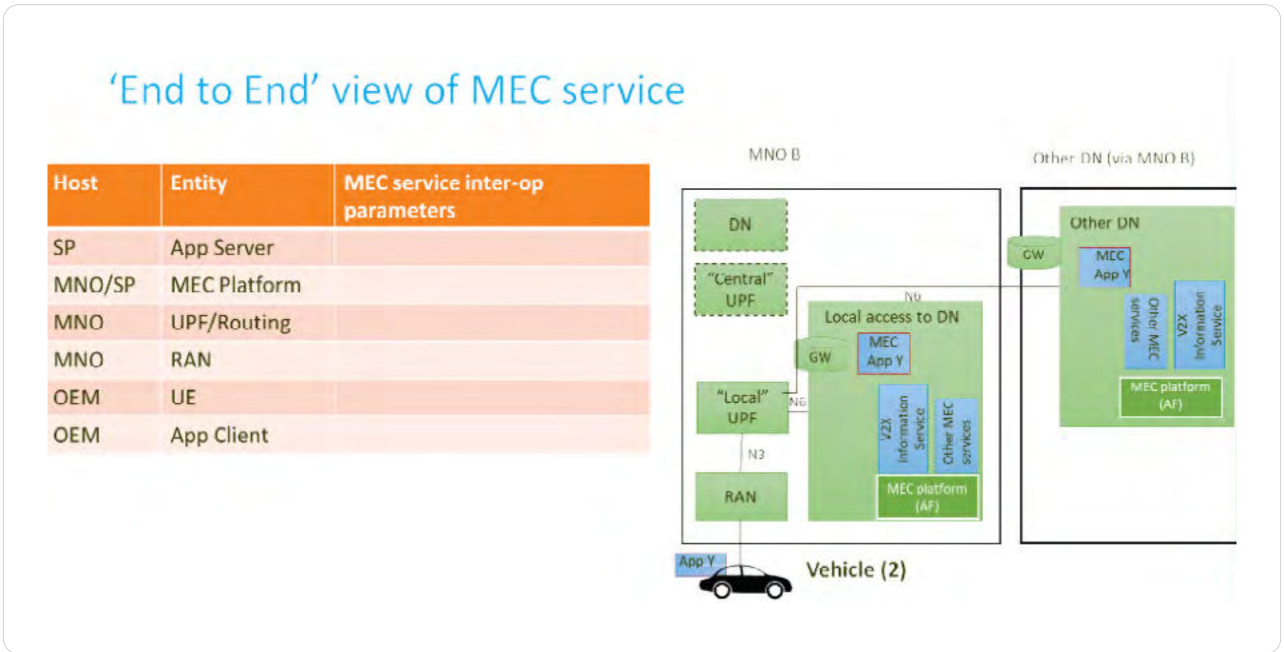

Figure A-1: End-to-end view of MEC service

Baseline 1

Different OEM (OEM A, OEM B) implementations.

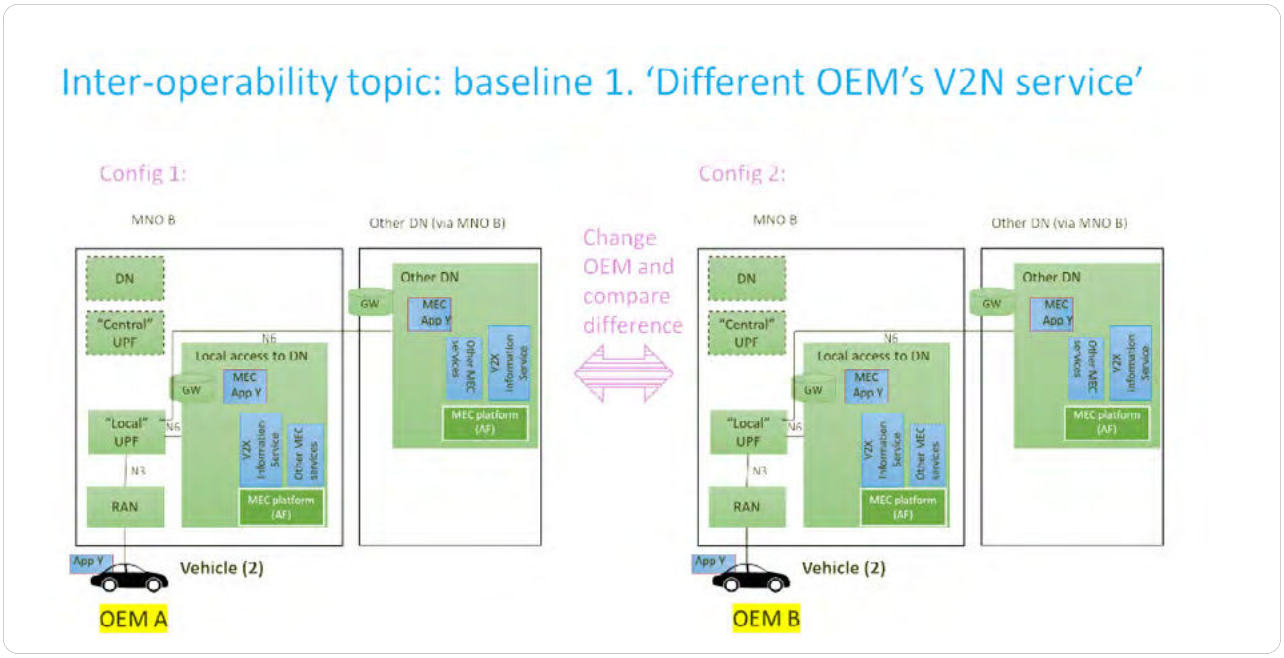

Figure A-2: Different OEM (OEM A, OEM B) implementations

Change of OEM: OEM-related aspects and parameters to define.

Baseline 2

Different MNO (Operator A, Operator B) implementations.

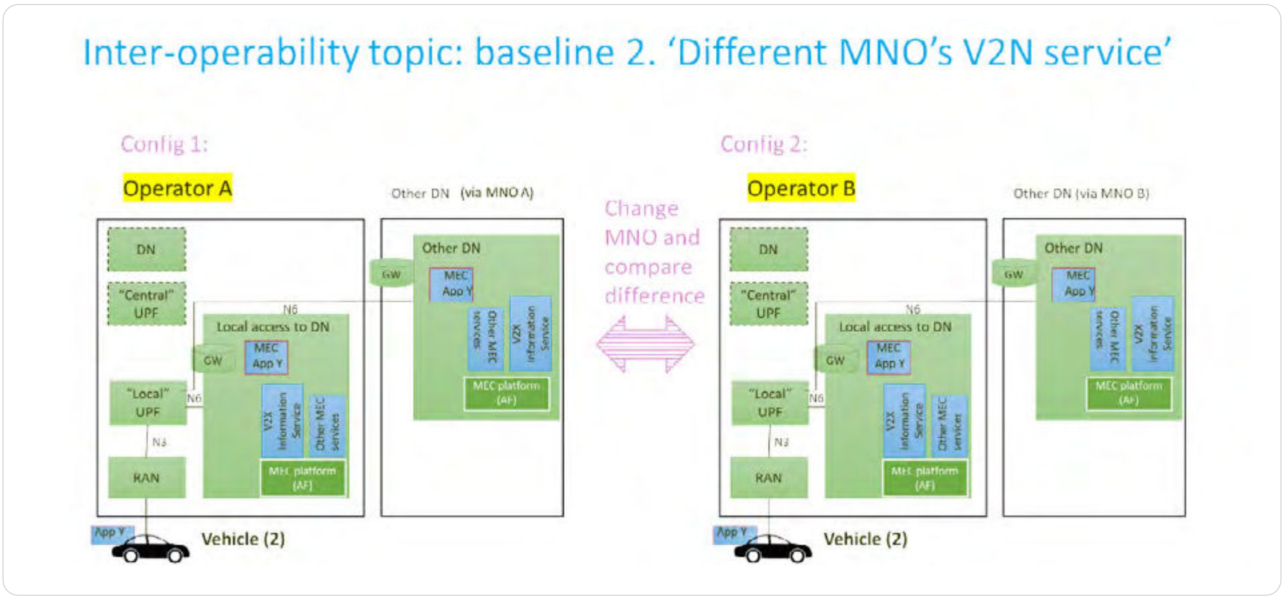

Figure A-3: Different MNO (Operator A, Operator B) implementations

Change of MNO: MNO-related aspects and parameters to define.

Baseline 3

Different Applications Services (App X, App Y) implementations.

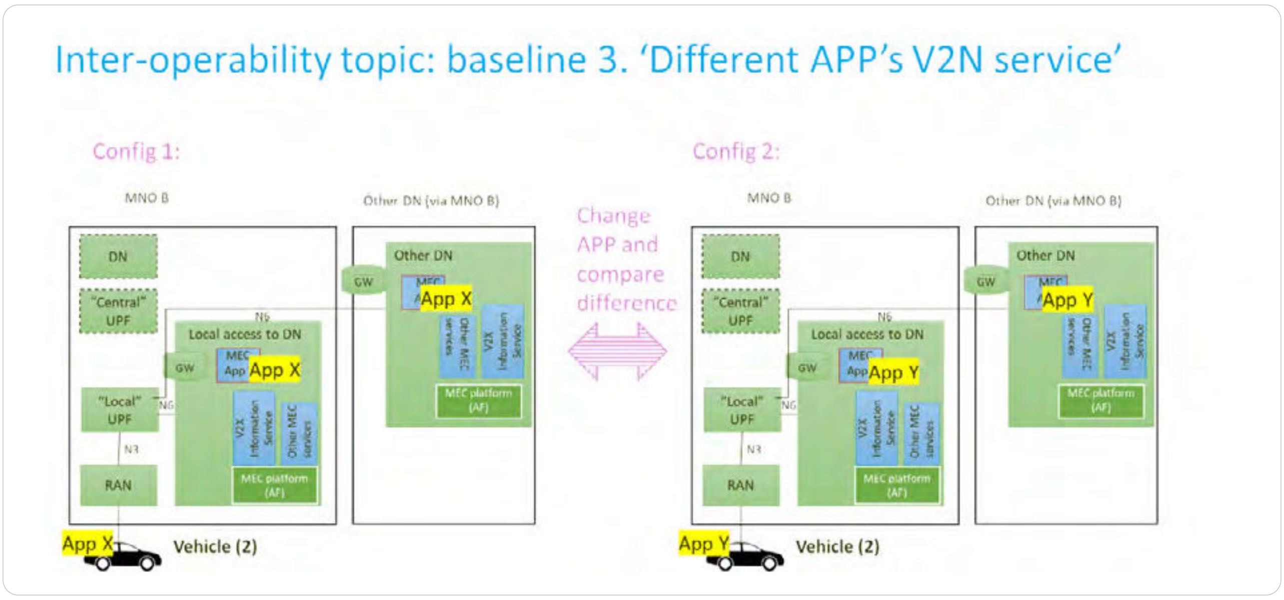

Figure A-4: Different application service (App X, App Y) implementations

Change of APP. APP related aspects and parameters to define.

Baseline 4

Expected real-world situation, different MNO and different OEM using same App.

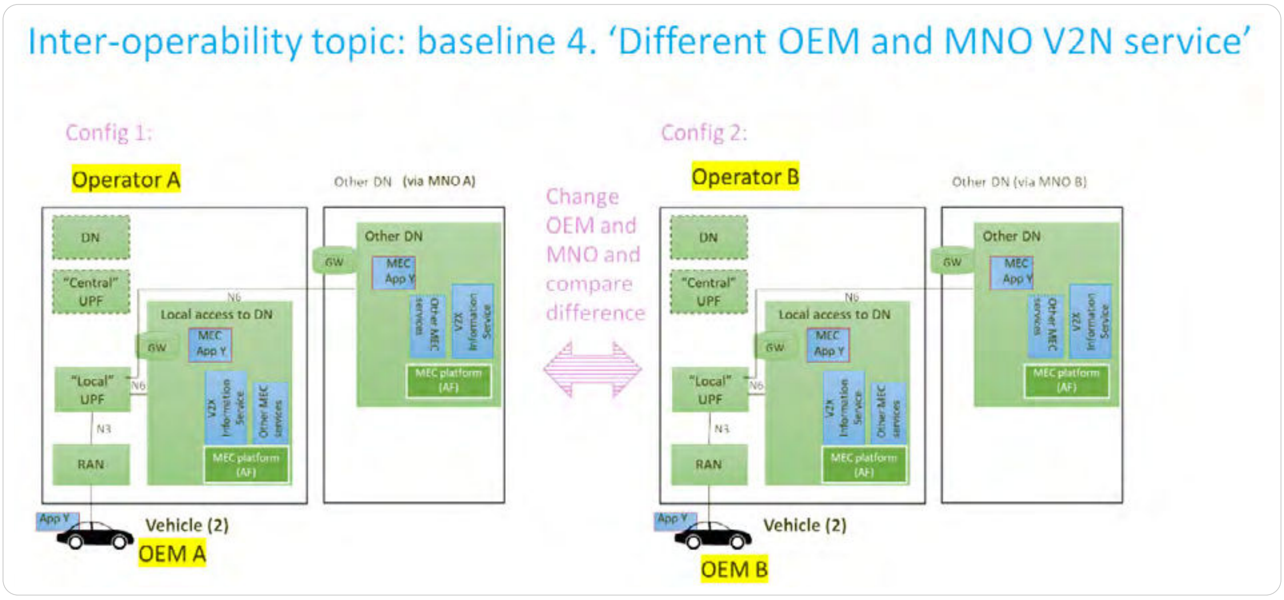

Figure A-5: Different MNO and different OEM using same App

Compare OEM A + MNO A versus OEM B + MNO B configurations. OEM + MNO combination related aspects and parameters to define.

Annex B:

Reference scenarios for analysis of interoperability requirements (informative)

B.1. Reference scenarios for interoperability study

Basic approach for “baseline scenarios”: using the defined architecture, create a range of different scenarios for interoperability based on:

- Inter-OEM
- MEC from UE (OEM)
- Inter-MNO

For the inter-OEM topic, a range of eight possible scenarios were identified and described.

B.1.1 Inter-OEM

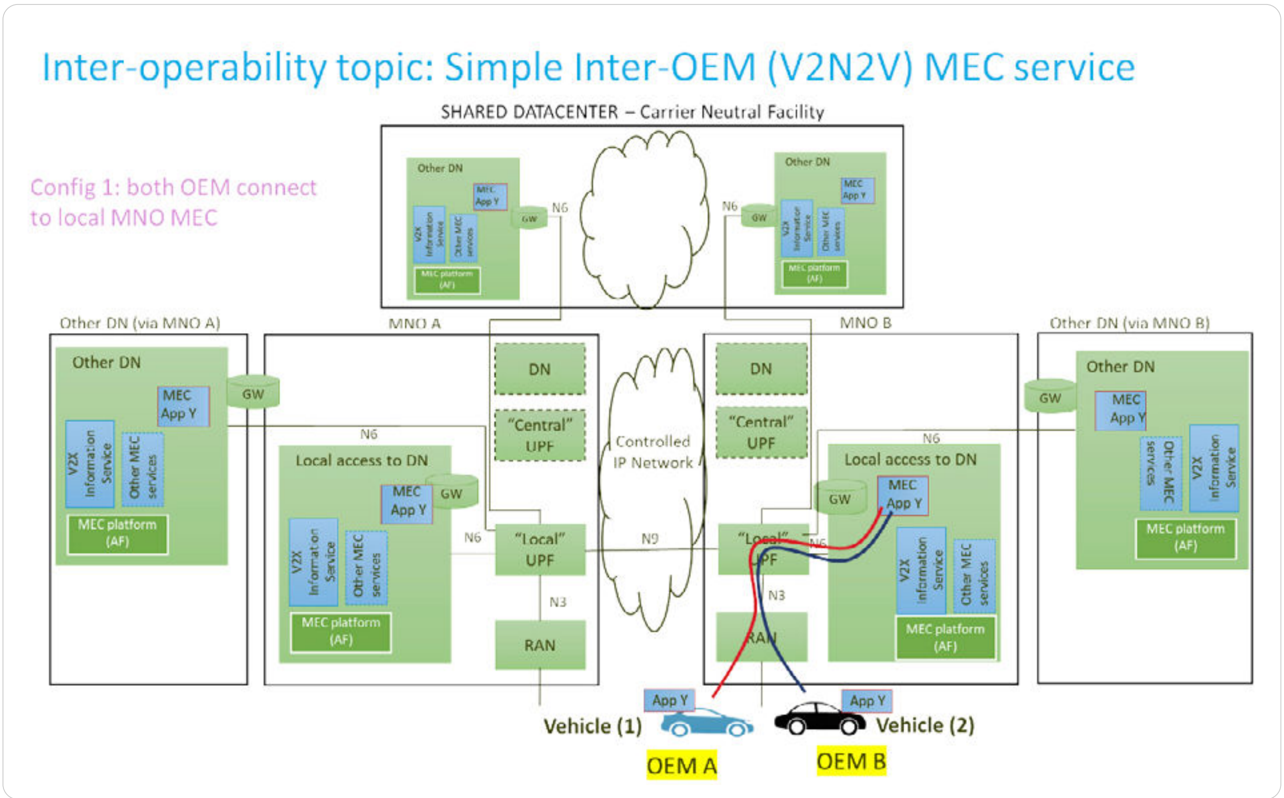

Figure B1.1-1: Simple inter-OEM MEC service local MNO MEC

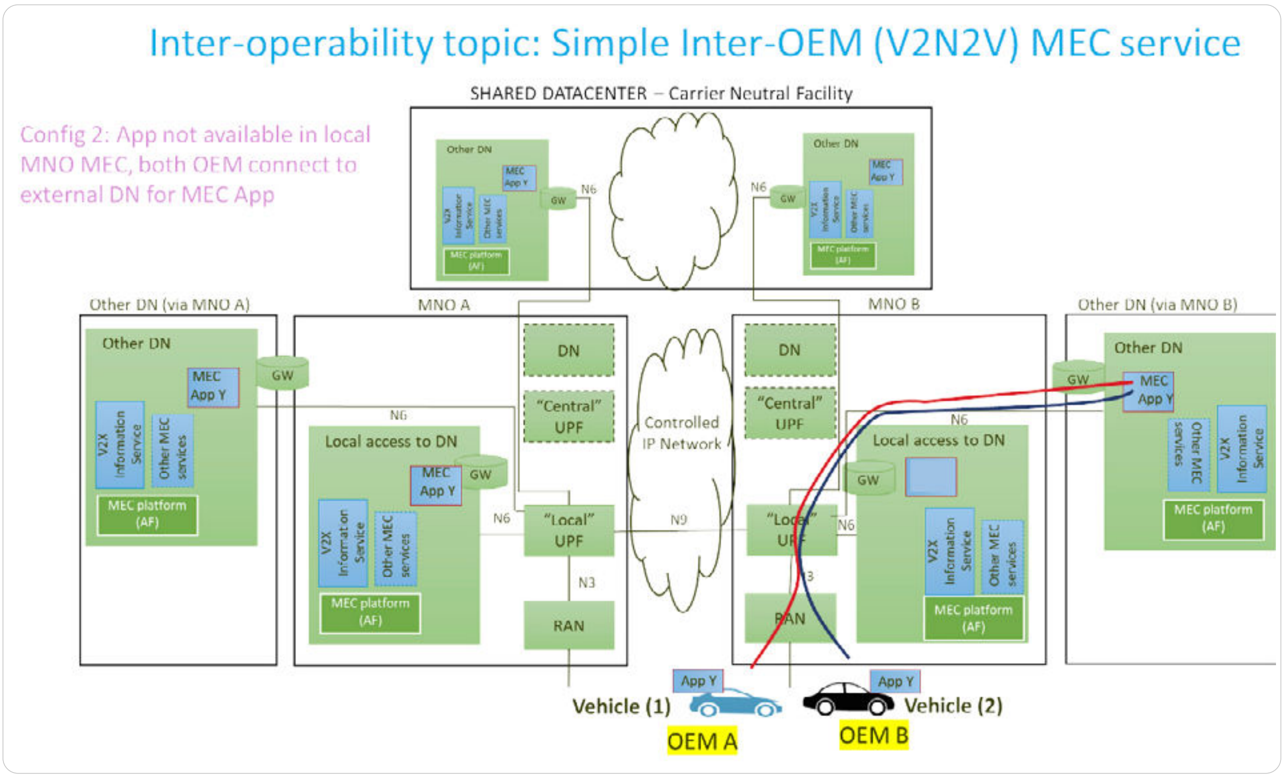

Figure B1.1-2: Simple inter-OEM MEC service (external DN MEC)

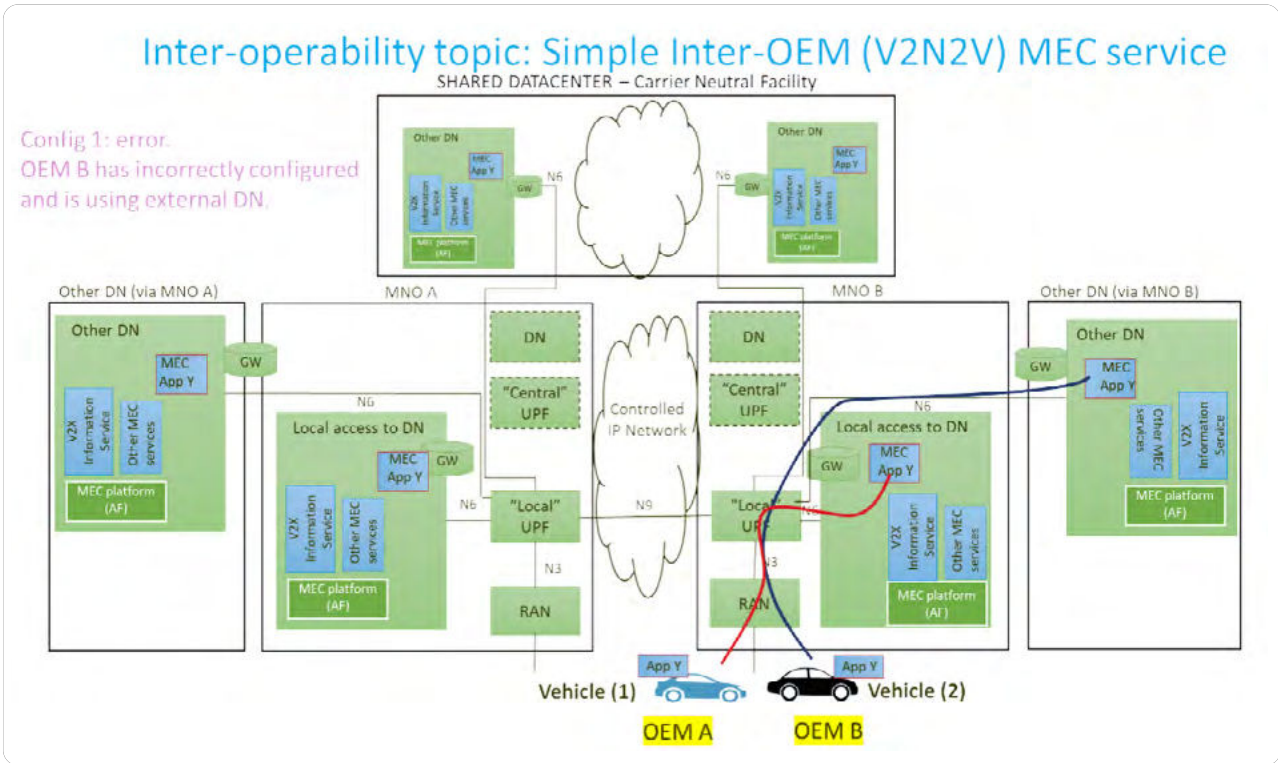

Figure B1.1-3: Simple inter-OEM MEC service with error

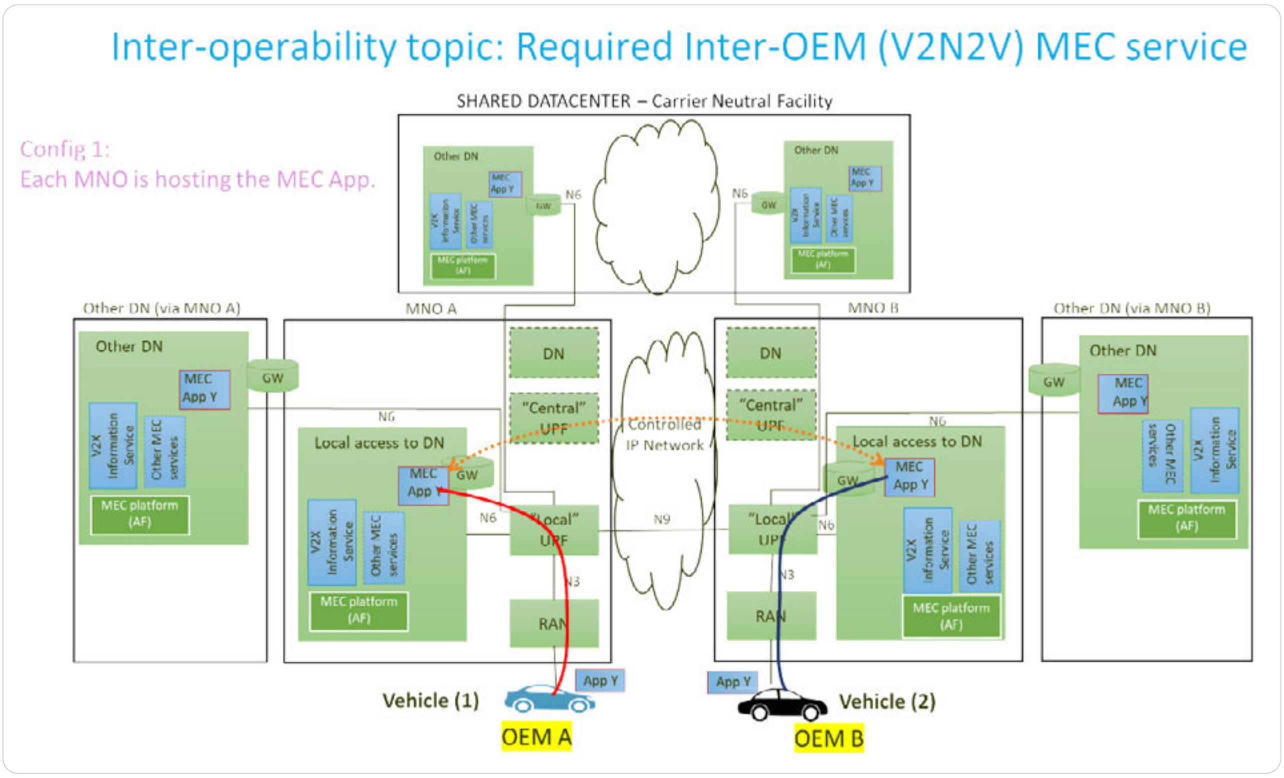

Figure B1.1-4: Required inter-OEM MEC service (separate MNO MECs)

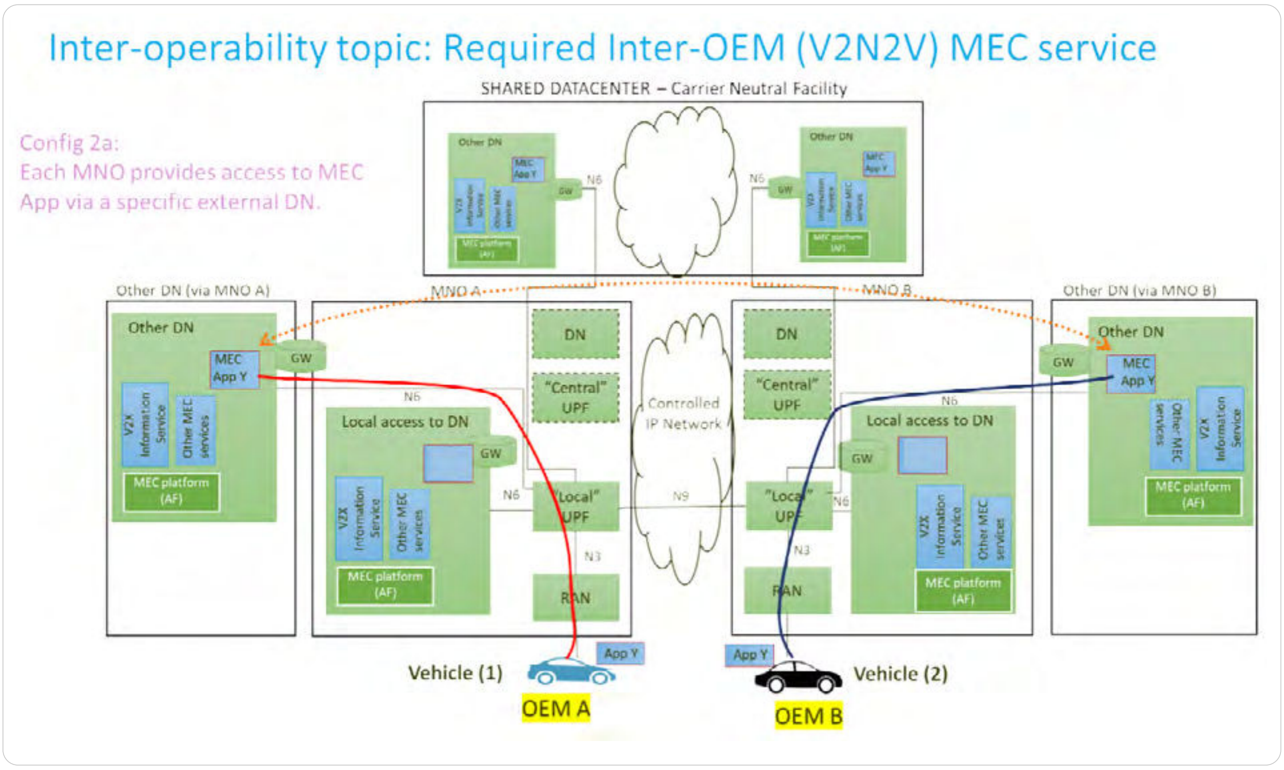

Figure B1.1-5: Required inter-OEM MEC service (separate external DNs)

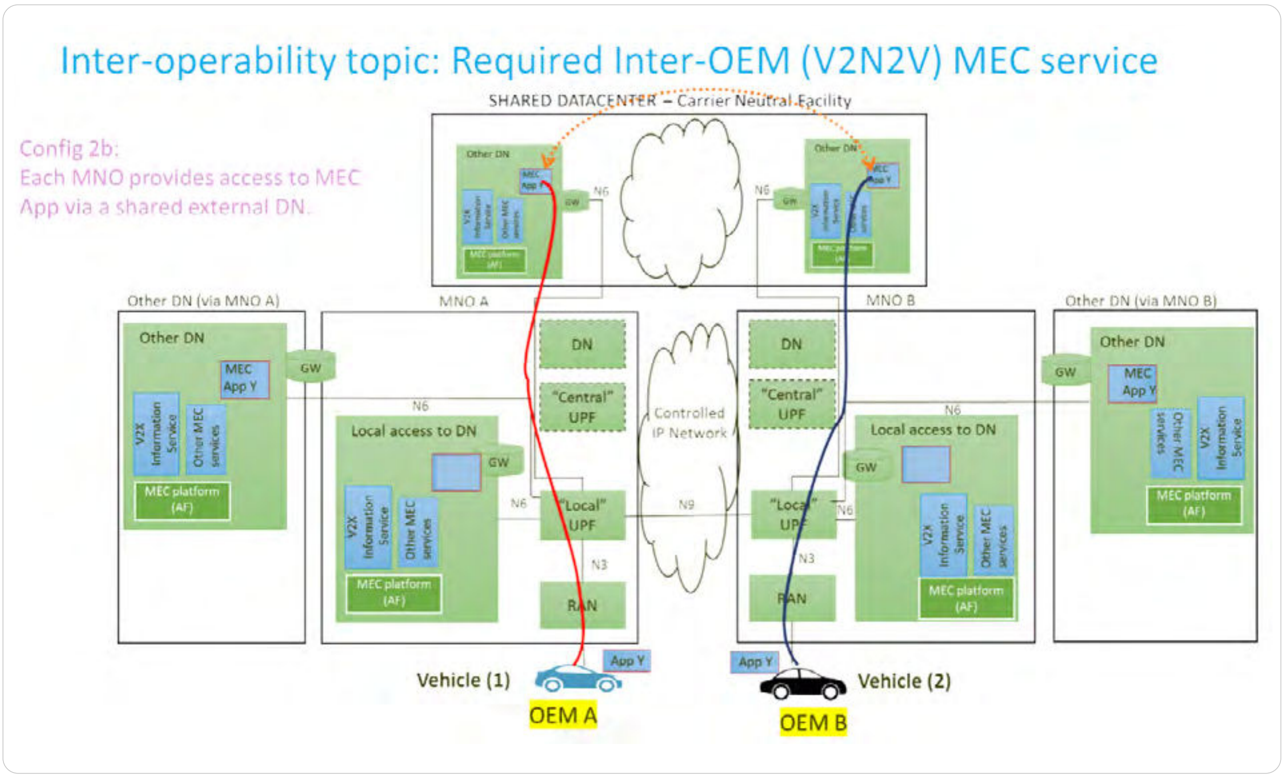

Figure B1.1-6: Required inter-OEM MEC service (shared datacentre)

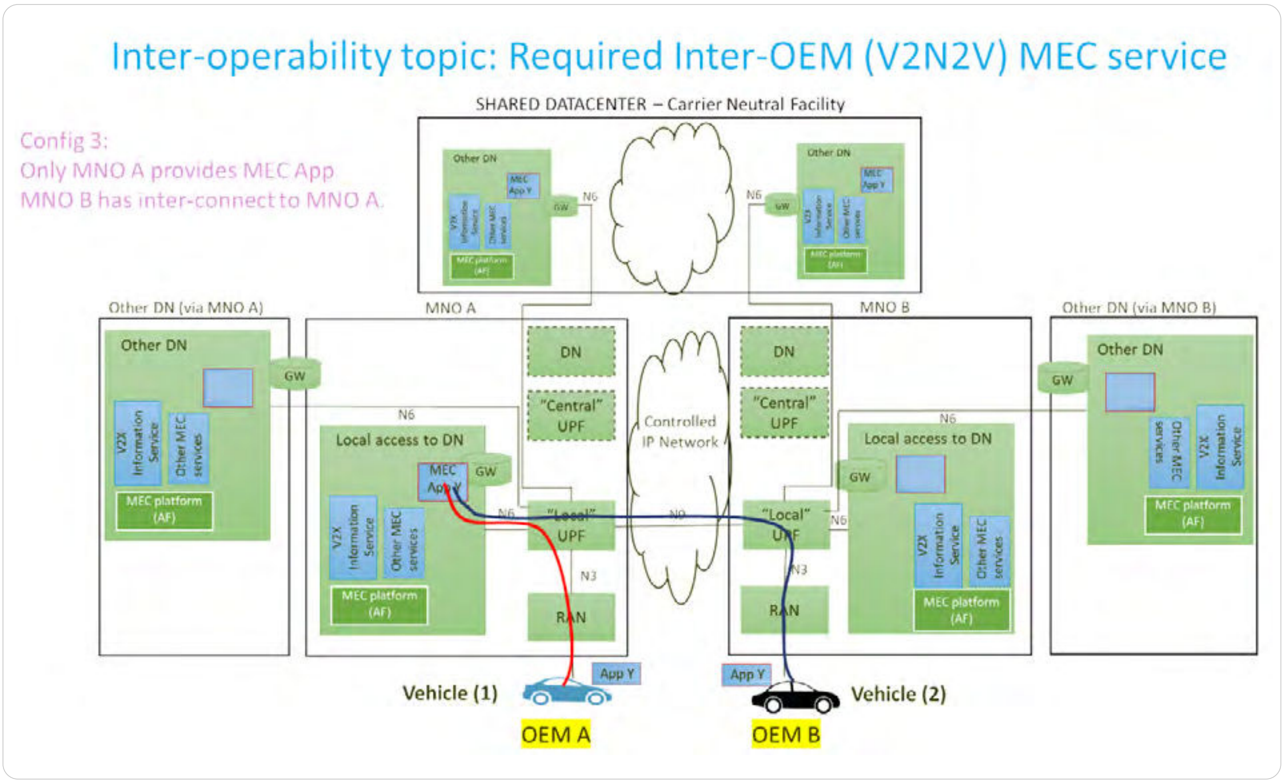

Figure B1.1-7: Required inter-OEM MEC service (single MNO MEC)

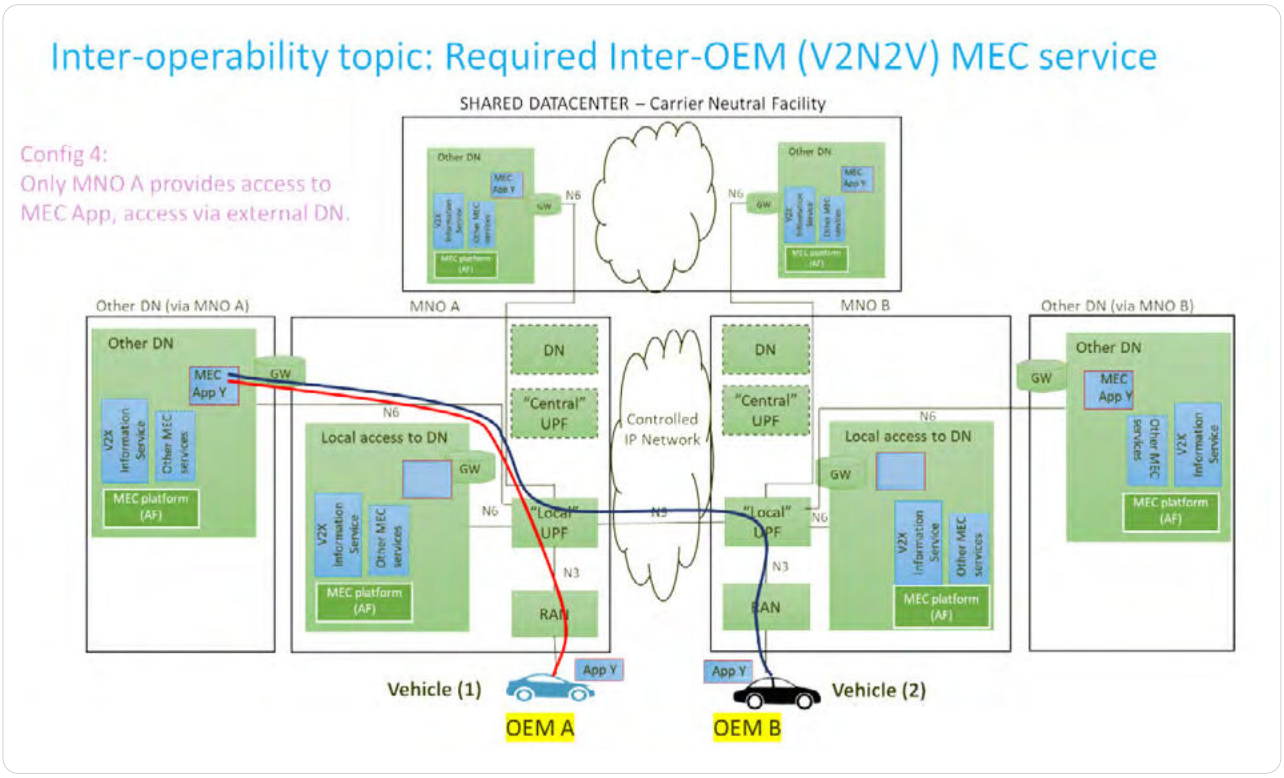

Figure B1.1-8: Required inter-OEM MEC service (single external DN MEC)

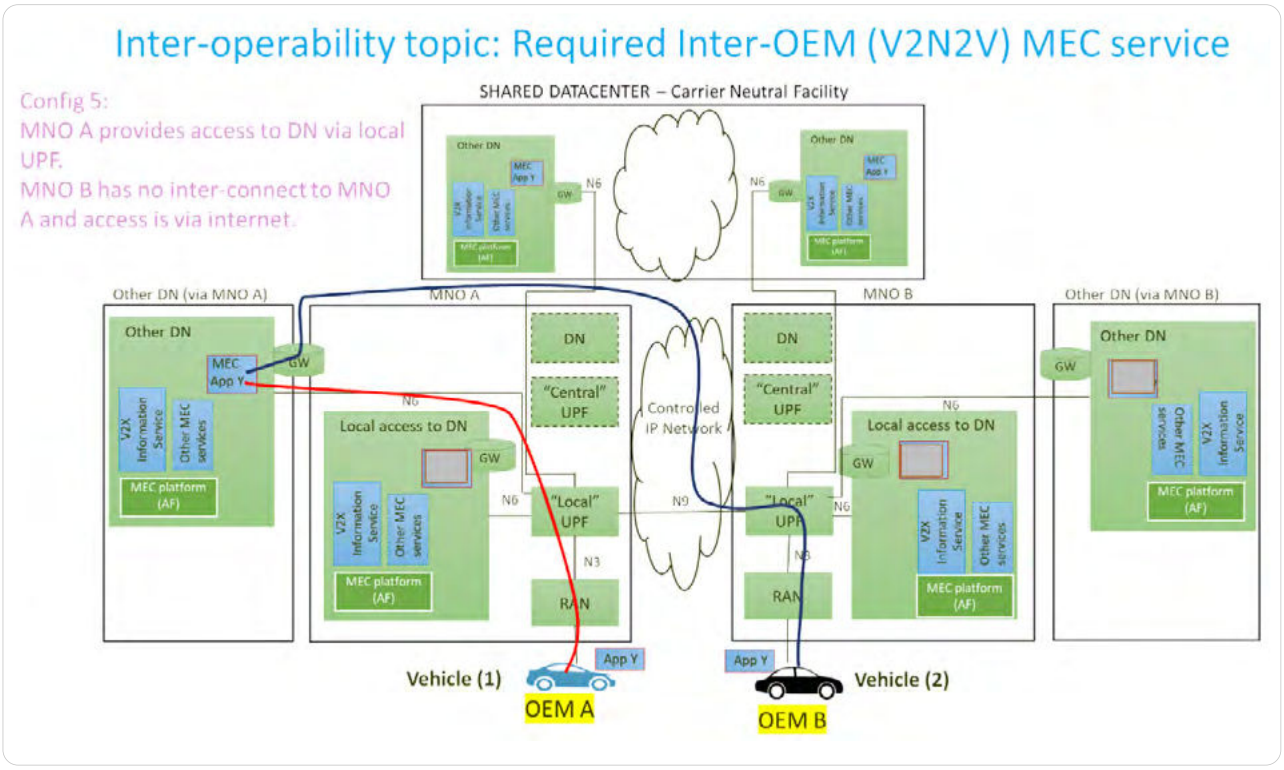

Figure B1.1-9: Required inter-OEM MEC service (external DN MEC without MNO connection)

B.1.2 MEC from UE perspective

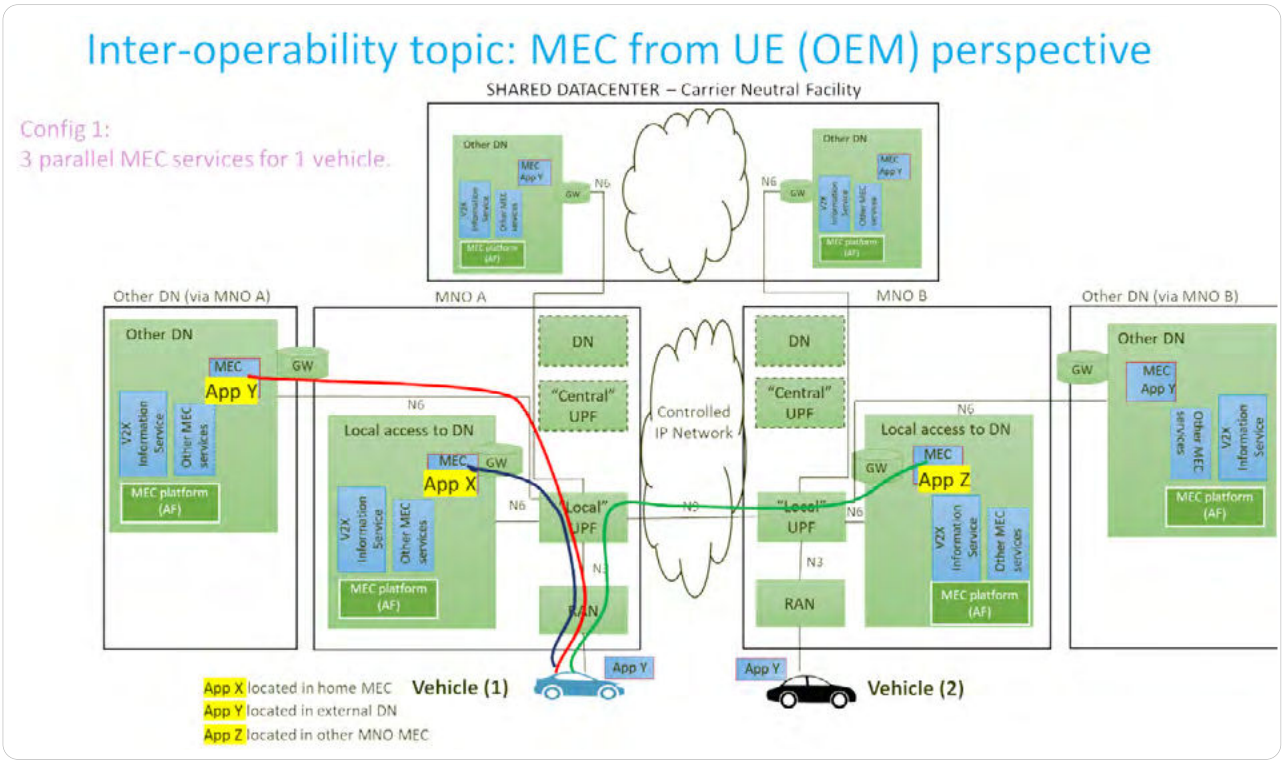

Figure B1.2-1: MEC from UE (OEM) perspective

B.1.3 Inter-MNO

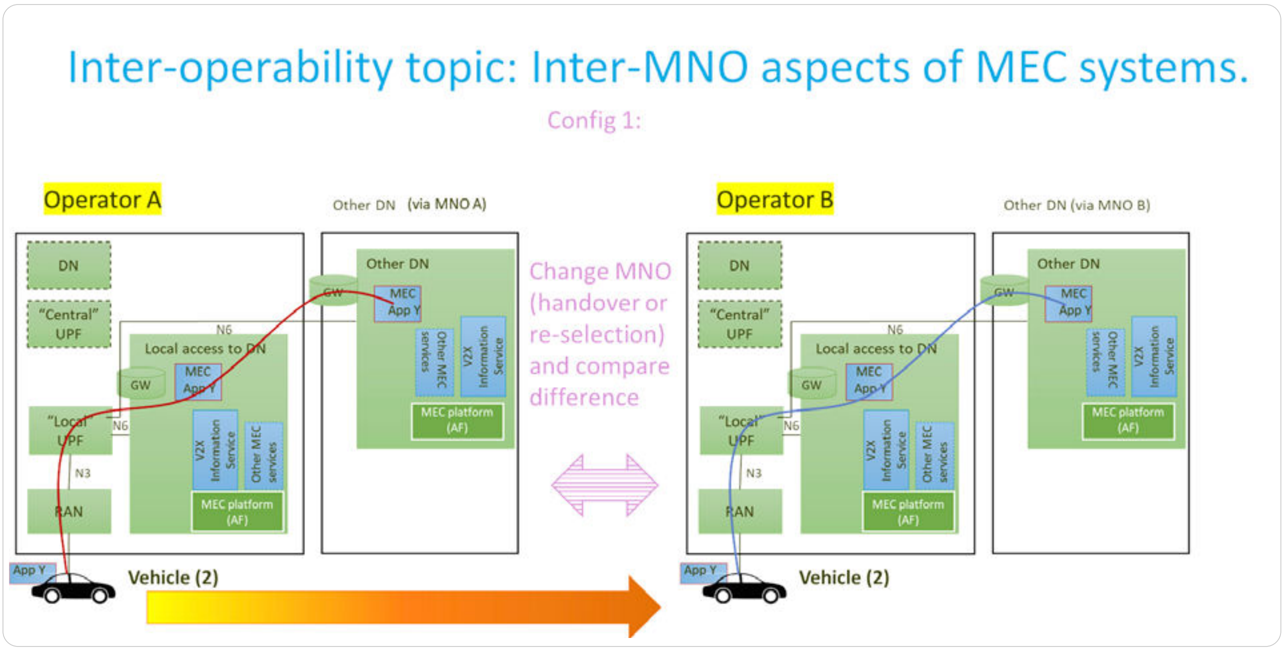

Figure B1.3-1: Inter-MNO aspects of MEC

5GAA is a multi-industry association to develop, test and promote communications solutions, initiate their standardisation and accelerate their commercial availability and global market penetration to address societal need. For more information such as a complete mission statement and a list of members please see https:/5gaa.org

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