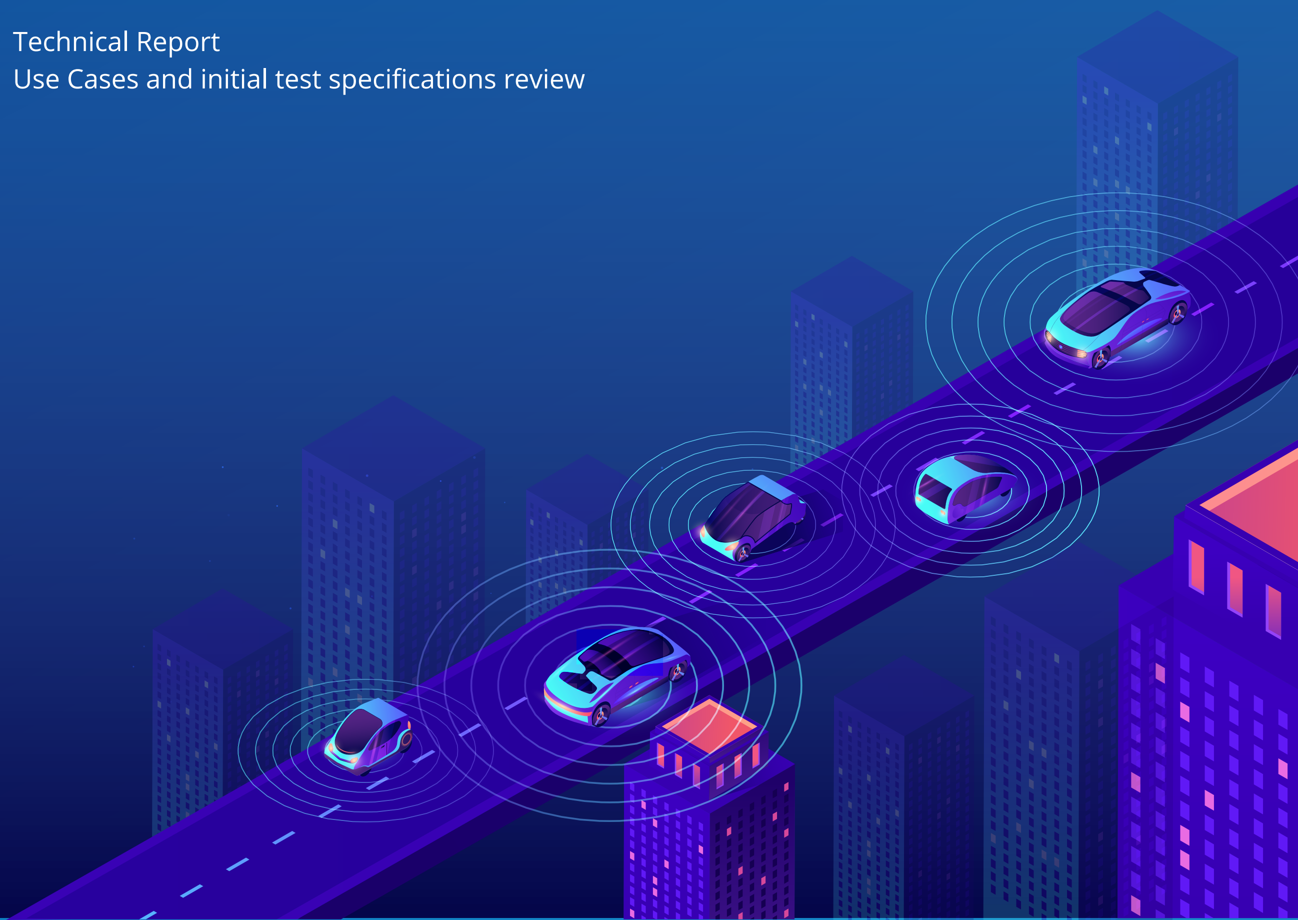
Working Item MEC4AUTO

5GAA Automotive Association

Technical Report
Use Cases and initial test specifications review



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Contents

Foreword

This Technical Report (TR) has been produced by 5GAA.
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) (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)
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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

This TR provides a review of potential Mobile Edge Computing Use Cases (UC) and requirements developed in 5GAA WG1 and other organisations, such as the European Telecommunications Standards Institute (ETSI) MEC [2] and China's IMT 2020 PG, by exploiting, for example, the collaboration agreements between 5GAA those organisations, potentially also liaising with other standards developing organisations (e.g. 3GPP and SAE), and industry groups (e.g. AECC, 5G-Americas, NGMN, etc.). Down-selection and ranking of UCs is performed according to different objectives and criteria including the feasibility of demonstration, good examples of the technology capabilities for performance evaluation, ability to demonstrate the highest business potential, etc. For this, a vehicle original equipment manufacturer's perspective on Use Cases is of primary importance, since the end application is consumed on the vehicle side. Further additional requirements, such as end-to-end security schemes, should be also considered.

1. Scope

Mobile Edge Computing is a key enabler of several Cellular Vehicle-to-Everything (C-V2X) applications that require ultra-low latency and high reliability. This document analyses the C-V2X Use Cases, in particular those defined by 5GAA WG1, that require the processing of large amounts of data and could benefit from the use of MEC instead of uploading the data to the cloud, which could cause additional round trip delays. The selection of Use Cases is based on inputs from auto OEMs and their key requirements about interoperability between different Mobile Network Providers (MNPs), different vehicle OEMs and different C-V2X application providers. In addition, other criteria for down selection includes feasibility of demonstration, technology capabilities for performance evaluation and demonstration of the highest business potential. The down selected MEC Use Cases will be used as inputs to related WG MEC4AUTO Task 2, Task 3 and Task 4 activities.

2. References

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

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3. Abbreviations

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

3GPP	3rd Generation Partnership Project
AECC	Automotive Edge Computing Consortium
AI	Artificial Intelligence
API	Application Programming Interface
ATS	Abstract Test Suite
C-ITS	Cooperative Intelligent Transport System
C-V2X	Cellular Vehicle-to-Everything
ETSI	European Telecommunications Standards Institute
GCF	Global Certification Forum
HMI	Human-Machine Interface
HV	Host Vehicle
ICS	Implementation Conformance Statement
IMA	Intersection Movement Assist
IMT-2020	International Mobile Telecommunications-2020
I/O	Interoperability
ISV	Independent Software Vendor
IVE	In-Vehicle Entertainment
JWT	JSON Web Token
KPI	Key Performance Indicators
LV	Lead Vehicle
MEC	Mobile Edge Computing (or Multi-access Edge Computing)
NFV	Network Function Virtualisation
MNO	Mobile Network Operator
MV	Member Vehicle
NGMN	Next Generation Mobile Networks
OBD	Onboard diagnostics
OBU	Onboard Unit
OEM	Original Equipment Manufacturer
QoS	Quality of Service
RNI	Regional Network Interface
RSU	Roadside Unit
RV	Remote Vehicle
RTT	Round Trip Time
TLS	Transport Layer Security
TP	Test Purpose
SDO	Standards Developing Organisation
SLR	Service Level Requirement
uCPE	Universal Customer-Premises Equipment
VIS	Vehicle Information Service
VNF	Virtual Network Functions
VR	Virtual Reality
VRU	Vulnerable Road User

4. Sources of V2X Use Cases enabled by MEC

MEC4AUTO Task 1 stakeholders reviewed the work produced in different organisations on V2X Use Cases that are enabled by MEC. For example, Task 1 reviewed 5GAA internal work, IMT-2020 3GPP, ETSI MEC, SAE, 5G-Americas, NGMN as well as AECC V2X Use Cases enabled by MEC.

4.1 AECC

The Automotive Edge Computing Consortium, or AECC, is a global consortium for driving the network and computing infrastructure needs of automotive 'big data'. The AECC has published two documents – a white paper [22] on Driving Data to the Edge: The Challenge of Traffic Distribution and an AECC Use Case and Requirement Document, which has considered the following service scenarios for edge computing in the automotive domain [21]:

- Intelligent driving focused on data collection
- High-definition map for data collection, processing and delivery
- V2Cloud cruise assist advanced Use Case in high-volume data environment
- Multi-tenant systems
- Security and system security
- Mobility service

Most AECC Use Cases have a broader scope rather than being associated with a specific application. The Use Cases considered for MEC4AUTO cover most of the Use Cases defined in AECC.

4.2 IMT-2020

International Mobile Telecommunications-2020 (IMT-2020) has published a white paper on MEC for C-V2X services. It classifies MEC scenarios according to the degree of vehicle-roadside infrastructure cooperation and in-vehicle cooperation. Vehicle-roadside cooperation involves the support of intelligent roadside devices and in-vehicle cooperation requires the support of other vehicle-shared information.

The four broad categories of Use Cases considered are:

1. Single vehicle + MEC scenario
    - Local info broadcast
    - Dynamic HD maps
    - Onboard info enhancement
    - Online onboard diagnostics (OBD)
2. Single vehicle + roadside unit (RSU) + MEC scenario
    - Dangerous driving warning
    - Illegal driving warning
3. Multi-vehicle + MEC scenario
    - V2V info bridging
    - Sensor sharing
4. Multi-vehicle + RSU + MEC scenario
    - Ramp merging assistant
    - Intelligent cross-road
    - Large-scale traffic scheduling

4.3 ETSI-MEC

ETSI-MEC has published a document that focuses on a MEC V2X information service in order to facilitate V2X interoperability in a multi-vendor, multi-network and multi-access environment [15]. It describes V2X-related information flows, required information and operations. The document also specifies the necessary application programming interface (API) with data model and data format. A Specialist Task Force (STF) at ETSI is responsible for the specifications defining the cooperative ITS vulnerable road user (VRU) service. The ETSI document defines the VRU-related requirements, as well as the functional architecture of the VRU system that will prevent collisions with other road users. In addition, it analyses the impact of Use Cases, requirements and functional architecture on existing standards, identifying which messages are needed to support the Use Cases.

5. Criteria for selection of Use Cases

5.1 Main criteria for MEC relevance

In the following sub-sections, a set of criteria for the analysis of Use Cases is described. The main motivation is to clarify the technical relevance to MEC, i.e. why each Use Case (which has already been studied by 5GAA in WG1 [1][2]) is relevant for MEC. In other words, it should be clarified why MEC is needed for a specific Use Case, or how it provides further benefits, e.g. with respect to situations without MEC (i.e. hosted in a remote cloud). The reader should also note that criteria can be both quantitative and qualitative. While quantitative evaluation can be clear for certain key performance indicators (KPIs), qualitative evaluation on the MEC relevance should be performed by a simple ranking (e.g. high/mid/low) to give an overall assessment.

5.1.1 Interoperability in multi-stakeholder environments

One of the key requirements from auto OEMs for MEC4AUTO is to address the interoperability (I/O) scenarios between two different OEMs, each with its own MNO contract as well interoperability between two MNOs where only one MNO has the MEC, or a variant where two different MNOs have different MECs. The MEC4AUTO architecture (Task 2) for interoperability scenarios should ensure that MEC services should be available even in roaming conditions by not losing the benefits of low latency and other KPIs required by these MEC services.

5.1.2 MEC performance and related KPIs

In the following, we provide a list of the main KPIs and metrics to evaluate relevance to MEC.

Metric/KPI	Description	Beneficiary
End-to-end latency	The latency definition in the scope of MEC4AUTO is referring to round trip time or RTT, measured on the application level (see also [3]). Depending on the service type, the RTT might include very 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 [4]. 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 potentially a complex assessment, even hard to be performed in an exhaustive manner. The same considerations can be made for privacy. A qualitative assessment of a Use Case for this metric can be performed.	All stakeholders

Energy efficiency	According to [3], energy efficiency can be defined on the user equipment side (terminals) and on 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 cell) and end-user (e.g. smartphones)
Bitrate guarantee	Besides latency, MEC can also impact the ability to provide bitrate guarantees. This is not intended for quantitative evaluation as it is a qualitative metric. Examples of such evaluations could be attributes like: 'best effort/elastic', 'guarantee required – fixed bitrate', 'guarantee required – minimal bitrate', 'maximum bitrate (no benefit for application if a higher one is provided)', 'event-triggered messages without fixed bitrate requirement', etc.	End-user

The reader should note that, for each metric/KPI described in the above, the actual performance gains provided by MEC should be compared against the service level requirements (SLR) of that specific Use Case. The SLRs are provided by the studies of the WG1 [1].

NOTE: the 'beneficiary' column can also be customised depending on the specific Use Case.

5.1.3 Consumed MEC services

One of the most important benefits of edge computing is the availability and exploitation of local and context information, providing the opportunity to produce (and thus consume) edge services in close proximity to the application endpoint. This approach offers multiple advantages, ranging from improved latency end-to-end, to better management of computing capabilities (by conveniently splitting server processing among MEC and the remote cloud), to improved privacy (through local filtering and anonymisation of sensitive data).

Many APIs[1] can be considered as consumers of edge services. As an example, a good reference is provided by edge service APIs standardised by ETSI MEC[2] [5] and 3GPP[3] 4G [28] and 5G [29] 'exposure functions'. These are currently the only international standards available in this space for edge computing. Other examples of APIs can also be seen thanks to the TSC Developer API sub-committee [32] in Akraino Edge Stack, which defines community APIs across various network edge stack blueprints. However, the ETSI MEC standard enables the creation of proprietary APIs which can be 'exposed' by the MEC platform [6]. As a consequence, anyone can build its own API - without

1. When it comes to consuming service APIs, 3GPP performed a study, called CAPIF [27], on 'Common API Framework for 3GPP Northbound APIs'. This is a general framework allowing an API invoker to access service APIs from the PLMN domain and third-party trusted domain. Nevertheless, the framework is not specifying APIs and it is not necessarily related to the edge.

2. The following list contains the APIs currently defined (or under definition) by ETSI ISG MEC: GS MEC 012: Radio Network Information API [8], GS MEC 028: WLAN Information API [9], GS MEC 029: Fixed Access Information API [10], GS MEC 013: Location API [11], GS MEC 014: UE Identity API [12], GS MEC 015: Bandwidth Management API [13], GS MEC 016: UE Application Interface API [14], GS MEC 030: MEC V2X API [15], GS MEC 033: MEC IoT API [15].

3. The following list contains the Exposure Function APIs currently defined (or under definition) by 3GPP: 5G Core Network Exposure Function (NEF) Northbound APIs [29], [30] include Monitoring (UE location, UE loss of connectivity, UE reachability, UE roaming status, number of UEs in area), Reporting (network congestion level in area, background data transfer), QoS and charging, and Traffic Influence supporting routing to/from edge hosts. Except for the last, all are also available with 4G Evolved Packet Core (EPC) with sometimes reduced functionality. The study on eV2X related network enhancements [31] showed the evolution of the NEF Northbound interface to support QoS prediction.

the need to standardize it - and 'expose' to higher layer MEC applications through the service registry in the MEC platform [6]. These APIs simply need to be designed by following the MEC service API guidelines in MEC-009 [7].

Regarding the MEC4AUTO Use Cases, each of them can be assessed in terms of impact on edge service consumption, i.e. by describing the possible need to produce (and consume) local services at the edge of the network. For example, a specific Use Case may benefit from the usage of a regional network interface (RNI) API and a location API for quality of service (QoS) predictions – refer to NESQO work item [33] – or a V2X API using vehicular information services (VIS) for addressing interoperability between multiple MNOs (see also MEC vision paper [34]). In addition, customised APIs can be envisaged, e.g. through data collection from cars, sensors, terminals, and suitable local elaboration and exposure through other edge service APIs to the server application.

5.2 Template for Use Cases evaluation

The tabular template proposed in this section includes aspects described in 5.1. The first four columns are related to the most commonly recognised (and frequently used) KPIs relevant for MEC, and the fifth column contains a list of other possible KPIs that can be considered case-by-case (i.e. the content of a Use Case assessment can be customised based on the other KPIs considered relevant for that specific Use Case). The last column provides a preliminary analysis on business criteria and relevance.

For each considered criteria, SLRs should refer to 5GAA WG1's work on Use Case and respective SLRs definitions. References for that work are [1][2].

Use Case	**Technical criteria and relevance**					**Preliminary analysis on business criteria and relevance**
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency...)	Business role: Who buys MEC service and receives business value from MEC?
Use Case name (ref. and short description)	NOTE: how MEC can be relevant in a certain scenario, e.g. between 2 MNOs, 2 OEMs, etc ..	NOTE: MEC can provide better E2E latency, if this helps to better meet SLR			NOTE: the content of this cell can be customised based on the KPIs relevant for this specific Use Case	NOTE: could be the OEM, the road operator, the customer/ driver, etc. It needs to be understood, why a MEC-based deployment brings value compared to a cloud-based deployment (if a cloud deployment is possible also)

In the present TR, each Use Case may optionally describe profitability and go-to-market aspects. However, these topics will be covered in detail in the TR of Task 4.

5.3 Viability of demonstration

The MEC4AUTO Task 3 will cover the experimental/demo/testing activities. It will include the alignment and coordination between the different regional demos. The applications or Use Cases considered for demonstration should work in the same way in the various regions (Europe, Asia and North America). Demos might reuse platforms or solutions already employed in other companies' engagements. End-to-end security should be considered when defining/describing the demo architecture. The Use Cases are also selected according to the viability of demonstrating them following those criteria.

5.4 Analysis of potential value chain and business potential

The MEC4AUTO Task 4 will evaluate and seek to understand the value creation by using MEC for the Use Cases selected in Task 1. It is important to establish a schedule guiding the market launch, including the multi-vendor, multi-network and multi-access environments, and global availability of MEC-application operations, and to adhere to the plan over the course of the action.

6 Analysis of selected Use Cases

6.1. Use Case 1 – 'See through'

According to the user story defined in WG1 [1] describing see-through characteristics, a driver of the host vehicle (HV) that signals an intention to pass a remote vehicle (RV) using the oncoming traffic lane is given access to a video stream showing the view in front of the RV. In this Use Case, the usage of MEC is beneficial especially due the need for interoperability between the vehicles that participate in the see-through service (this is also emphasised by SLRs in 5GAA WG1 [1]). In fact, MEC solutions and the use of standardised APIs (or more generally APIs 'exposed' in a standard MEC platform) improve interoperability in terms of data exchange. A see-through application can be designed by an independent company, so that the MEC app can run on different MEC servers/systems and the multiple client app instances can run on different cars (belonging to different OEMs), possibly also attached to different network subscriptions. The exposure of edge services through 'RESTful' messages enables interoperability in multi-dimensional scenarios.

MEC-based solutions can also be beneficial for managing video-streaming communication through a MEC server, exchange of communication capabilities (including codecs, and related software updates), but also video elaboration and object recognition on the MEC side (e.g. to help the driver during an overtaking manoeuvre).

Moreover, the presence of MEC could improve the information transferred to the HV (i.e. situation awareness and knowledge gathered about cars in the surrounding area). In fact, this could be extremely critical in situations with multiple cars in the lane, when overtaking an RV could be risky. The MEC server could provide additional information about all cars in the same lane, and transfer the video stream of the first car in the lane, together with the total distance between the first car and the last one.

> NOTE: from a performance point of view, multiple metrics are relevant to the quality of the video stream (data rate, latency). Nevertheless, the value of MEC-based solutions rests on the possibility to exploit more context information from the MEC server, e.g. using location API and other information related to the different vehicles in the zone. This means that MEC solutions should simply respect the SLR for video-streaming KPIs.

From a security point of view, MEC is providing a series of features able to improve security on the application layer (these features can be also valid for other Use Cases).

- The MEC-009 specification on 'Generic principles for designing APIs' [7] (applicable to all MEC reference points, including Mp1 and Mx2) defines the use of 'The OAuth 2.0 Authorization Framework' [35] to secure a RESTful MEC service API. It is used for the RESTful APIs defined by ETSI ISG MEC. Service-producing applications defined by third parties may use other mechanisms to secure their APIs, such as stand-alone use of JSON web tokens (JWT) [17].
- MEC uses also RESTful Transport Security (HTTPs / TLS), by including relevant fields in the security Info structure (Token, KeyID). In particular, TLS uses KeyID to establish secure transport, and HTTP uses Token to establish access authorization.
- At lower level, Security Info structure is integrated into the VNF (as typically MEC is deployed in NFV environment) and Virtual Machine (VM)/container protects NFV code. Moreover, the MEC infrastructure (mainly hosted in the MNO domain) is considered as trusted environment. This is also helping to improve service level reliability.

6.1.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/ High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency…)	Business role: Who buys MEC service and receives business value from MEC?
See through [1]	All dimensions (MNO, MEC, OEM) High relevance	Only SLR compliance	High	Location API, context information on all cars	Better service discovery phase, more reliability	MNOs can exploit their network and edge cloud to offer to road operators and to Car OEMs a key point-of-presence of edge instances that can enable interoperable See Through and other high-performing services. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing accidents, getting e.g. more funds from central governments. Car OEMs can integrate this service in their in-vehicle platforms increasing the added value of the vehicle and services package. ISVs (app vendors, virtual network function or VNF vendors, MEC vendors, MANO players) and OEMs/ODMs (e.g. Dell, HPE, server vendors and RSUs Vendors like Harman, etc.) can provide the MNOs the hardware, software components of the solution stack that constitutes the service. MNOs will monetise the service through the road operators, city governments/municipalities who will host the service on their premises (traffic poles, street light poles, universal customer-premises equipment, or uCPE, etc.) as an add-on to the MNO infrastructure in their NGCOs or regional data centres. Essentially, the vehicle owners/drivers would use the service and pay for it directly/indirectly through the road operator (e.g. tolling, taxes etc.) or city authorities. Latency/response time KPIs are key as an in-car solution has better response time for this case vs. through an MNO service.

6.2 Use Case 2 – In-vehicle entertainment (IVE)

According to the user story defined in WG1 [2], in in-vehicle entertainment content is delivered to the passengers of a moving or stationary vehicle. This Use Case is applicable to both automated and non-automated vehicles, where in the latter the driver is restricted in the content (s)he is allowed to consume. The content may include video, gaming, virtual reality (VR), office work, online education, advertisement, etc. Contextual information can be embedded in the entertainment media depending on the location of host vehicle.

In this Use Case, MEC is highly critical for improving the quality of service (QoS) performance of the content transferred, e.g. in terms of E2E latency, data rate, etc. In fact, the presence of the MEC app in close proximity to the end-user provides a low latency environment able to improve E2E performance, with respect to a generic remote cloud solution.

MEC is also beneficial due the need for interoperability between the vehicles subscribed to IVE services. MEC solutions and the use of standardised APIs (or, more generally APIs 'exposed' in a standard MEC platform) help interoperability in terms of data exchange. An IVE application can be designed by an independent company, so that the MEC app can run on different MEC servers/systems and the multiple client app instances can run on different cars (belonging to different OEMs), possibly also attached to different network subscriptions. The exposure of edge services through RESTful messages enables the interoperability in multi-dimensional scenarios.

MEC-based solutions can also be beneficial in managing video-streaming communication through a MEC server, and for communication exchanges (including codecs, and related software updates), but also for inserting additional content based on local and contextual information. As an example, some proofs of concept on 'MEC infotainment for smart roads and city hot spots' [18] exploit the presence of MEC, not only to improve the E2E performance of the content transferred to the client app (about 30% delay gain in real-life cases, and huge savings in terms of reduced load on the transport network), but also to enhance it with customised information, possibly also based on the UE location, profile and preferences (of course, based on privacy consent to use these features).

MEC also provides a series of features able to improve security towards the application layer (these features are also valid for other Use Cases).

- The MEC-009 specification on 'Generic principles for designing APIs' [7] (applicable to all MEC reference points, including Mp1 and Mx2) defines the use of OAuth 2.0 [35] to secure a RESTful MEC service API. It is used for the RESTful APIs that are defined by ETSI ISG MEC. Service-producing applications defined by third parties may use other mechanisms to secure their APIs, such as stand-alone use of JWT [17].
- MEC also uses RESTful transport security (HTTPs/Transport Layer Security, TLS), by including relevant fields in the security information structure (token vs. ID). In particular, TLS uses KeyID to establish secure transport, and HTTP uses tokens to authorise access.
- At lower levels, security information structure is integrated into the VNF (as typically MEC is deployed in that environment) and the VM/container protects the NFV code. Moreover, the MEC infrastructure (mainly hosted in the MNO domain) is considered a trusted environment. This also helps to improve service level reliability.

6.2.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/ High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency...)	Business role: Who buys MEC service and receives business value from MEC?
In-vehicle entertainment (IVE) [2]	All dimensions (MNO, MEC, OEM) High relevance	High relevance	High	Location API, context information on all cars	Reduced load on the transport network	End customers may buy premium services from content providers enabled by MEC functionalities. MNOs and content/service providers can benefit from the introduction of MEC, to offer added/value services. The ISV partners the content delivery network (CDN) enablers (e.g. Qwilt, etc.) will play a role here along with the content creation and distribution companies like Netflix, Walt Disney, etc.

6.3 Use Case 3 – Intersection movement assist (IMA)

According to the user story defined in WG1 [1], in the IMA a stationary host vehicle proceeds straight from stop at an intersection. The HV is alerted if it is unsafe to proceed through the intersection, and warned of a risk of collision due to some of the following events:

- Approaching cross-traffic from the left
- Approaching cross-traffic from the right
- Oncoming traffic intending to turn left

In this Use Case, MEC is beneficial especially due the need for interoperability between the vehicles that participate in the IMA service (this is also emphasised by SLRs in 5GAA WG1 [1]). In fact, MEC solutions and the use of standardised APIs (or APIs 'exposed' in a standard MEC platform) boost interoperability in terms of data exchange, which can be done via Uu or PC5 interfaces. An IMA application can be designed by an independent company, so that the MEC app can run on different MEC servers/systems and the multiple client app instances can run on different cars (belonging to different OEMs), possibly also attached to different network subscriptions. The 'exposure' of edge services through RESTful messages enables interoperability in multi-dimensional scenarios.

MEC-based solutions can also be useful from a scalability point of view, i.e. for the management of multiple messages coming from several vehicles. In fact, according to the SLRs, this Use Case should support high vehicle density in urban situations.

Moreover, MEC can be very useful as the IMA Use Case requires the gathering of a wide set of heterogeneous information (that can be processed in the MEC server):

- Vehicle location
- Lane designations and geometry
- Intersection geometry
- Posted speed limits
- Road conditions (if available)
- Traffic stop signs
- Traffic light signal phase and timing.
- Etc.

As a consequence, the MEC app can be the perfect processing entity, able to build a model of the intersection and of the current situation. This model is common to all vehicles, and the MEC app can conveniently dispatch suitable messages to different vehicles. The resulting saving in terms of signalling (and network capacity) can be huge, especially when considering a dense network of vehicles (according to the SLRs).

In addition, the MEC server can be a solid repository for local and contextual information, which can be read/written in an interoperable way through RESTful messages (for example: information based on local traffic laws and rules controlling right of way through three-way and four-way and unsigned intersections).

MEC also provides a series of features able to improve security up to application layer (these features are also valid for other Use Cases).

- The MEC-009 specification on 'Generic principles for designing APIs' [7] (applicable to all MEC reference points, including Mp1 and Mx2) defines the use of OAuth 2.0 [35] to secure a RESTful MEC service API. It is used for the RESTful APIs that are defined by ETSI ISG MEC. Service-producing applications defined by third parties may use other mechanisms to secure their APIs, such as standalone use of JWT [17].
- MEC uses also RESTful Transport Security (HTTPs / TLS), by including relevant fields in the security Info structure (Token, KeyID). In particular, TLS uses KeyID to establish secure transport, and HTTP uses Token to establish access authorization.
- At lower level, Security Info structure is integrated into the VNF (as typically MEC is deployed in NFV environment) and VM/container protects NFV code. Moreover, the MEC infrastructure (mainly hosted in the MNO domain) is considered as trusted environment. This is also helping to improve service level reliability.

6.3.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency…)	Business role: Who buys MEC service and receives business value from MEC?
Intersection movement assist (IMA) [1]	All dimensions (MNO, MEC, OEM) High relevance	Only SLR compliance	High	Location API, context information on all cars	Scalability. Saving in terms of signalling (and network capacity)	MNOs can exploit their network and edge cloud to offer to road operators and to OEMs a key point-of-presence of edge instances that can enable interoperable IMA and other high-performing services. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing accidents, obtaining more funds from central governments, etc. Car OEMs can integrate this service in their in-vehicle platforms increasing the added value of the vehicle and services package. Same as Use Case 1.

6.4 Use Case 4 – Vulnerable road user (VRU)

According to a US Department of Transport report [19], the case 'Vehicle Going Straight' while a pedestrian is on the road is the highest frequency vehicle to pedestrian crash scenario. Further, according to the Federal Statistical Office of Germany,[1] accidents involving pedestrians and cyclists account for around 30% of road traffic deaths in the country.

6.4.1 In-vehicle sensor-based approach

As mentioned in the WG1 Use Case description [1], there are many possible user stories that can be defined for the interaction between vehicle, VRU, and other external entities (e.g. RSU, cloud). In this contribution, the focus is on the particular case where the VRU is not equipped with a device (see also [20]), i.e. the VRU is not V2P-enabled and cannot directly communicate with a vehicle.

In the VRU Use Case descriptions [1], either the presence of infrastructure-based surveillance cameras or V2P-capable VRUs are assumed. The following VRU Use Case describes a complementary approach, which is slightly different to descriptions in [1].

In this VRU scenario, a HV uses its forward-facing, in-vehicle camera to send sensor data (e.g. HD video) concerning the road situation ahead to its machine-learning, enabled application counterpart in the edge cloud. This cloud-hosted application processes the received data and alerts the in-vehicle application frontend of imminent incidents, e.g. the likelihood of a pedestrian walking beside the road stepping into traffic. The vehicle may then decide on appropriate actions and/or notify the driver, e.g. via human-machine interface (HMI).

In this Use Case, MEC is essential for enabling the machine-learning-based application, as it is able to provide dedicated processing capabilities. Such MEC-hosted applications need 'service availability' as well as interoperability across the MEC platforms of different providers/operators/vendors and connected vehicles (belonging to different OEMs).

Moreover, scalability must be ensured and may only be supported with corresponding edge cloud deployments, for example, to cope with a varying number of service users in densely populated areas.

Further, the 'local' nature of interaction between edge cloud and vehicle relieves mobile networks of having to provide additional backhaul user data transmissions to centralised cloud entities. Here, video data is locally processed by the edge cloud and does not need to be transferred to a central cloud or data centre for AI processing.

1. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/_inhalt.html#sprg249316 [accessed: Sept. 6, 2019]

Thus, significant savings in terms of network backhaul traffic and capacity could be achieved.

The vehicle's video data is solely used for analysing the VRU movements and is relevant during service usage (e.g. vehicle usage time). However, as requirements for tracing the decision-making of automated vehicles may appear, there could be a legal/regulatory requirement imposed on the service provider for storing video data feeds for a certain amount of time (e.g. 24 hours).

For enhanced privacy, data may only be locally hosted and deleted after the (legally/regulatorily required) minimum storage time expires. If the legal framework permits, data may be pseudonymised, aggregated, and analysed by central entities for enabling additional services.

The Use Case scope appears to be limited to a one-to-one relationship between the vehicle and 'local' edge cloud, which also informs business analyses comparing the return on investment in on- versus off-board processing. However, the Use Case can easily be extended in the direction of 'collective perception' and 'situational awareness', creating added value for other traffic participants.

6.4.1.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency...)	Business role: Who buys MEC service and receives business value from MEC?
Vulnerable road user (VRU) [1]	All dimensions (MNO, MEC, OEM) High	High	High	Compute power (AI-based detection)	Scalability Service availability and reliability Savings in terms of network backhaul traffic and capacity	MEC HW/SW vendors can provide the relevant components. MNO can receive value from application hosting as well as service and communication provisioning, savings in terms of network backhaul traffic and capacity, centralized resources are used more efficiently. OEMs can integrate this AI-based service in their in-vehicle platforms increasing the added value of the vehicle and services package. Road operators and municipalities can improve the quality of life of citizens and the safety of the population, e.g., reducing the number of accidents.

6.4.2. Infrastructure sensor-based approach

As stated in the WG1 Use Case description [1], there are many possible user stories that can be defined for the interaction between vehicle, VRU, and other external entities (e.g. RSU, MEC). Here, the presence of infrastructure-based sensors (e.g. surveillance cameras) is assumed. Regarding the interaction and communication between the VRU and the external (vehicle, roadside, or network) systems, there are different possibilities (according to [20]):

- VRU is not equipped with a device
- VRU has a device that can only transmit/broadcast data, e.g. a cooperative intelligent transport system (C-ITS) transmitter attached to a backpack or the safety vest of a road worker
- VRU has a device that only receives (broadcasted) data
- VRU has a device that possesses both transmitting and receiving functionalities

The mobile VRU device can be either stand-alone (e.g. a smartphone), a device integrated in the VRU vehicle (bicycle, motorcycle), or a tethered/connected device (sensors in the vehicle, communication using smartphone, attached via cable or connected via Bluetooth/Wi-Fi).

In this VRU Use Case, an application hosted in the local MEC platform uses the attached infrastructure-based sensors (e.g. surveillance cameras, wireless detection mechanisms) for monitoring and analysing VRU movements (e.g. at crossings). In the event a VRU is predicted to step out onto the road or cross an intersection, the MEC application alerts approaching vehicles that are likely to coincide with the VRU's trajectory.

Awareness notifications are either directly shared with drivers (e.g. notification via HMI) or the vehicles' C-ITS Onboard Unit (OBU) actively monitors VRUs equipped with a corresponding device.

Here, MEC is essential for analysing possible trajectories, predicting potential collisions using infrastructure-based sensor inputs, and alerting approaching vehicles. Sophisticated, AI-based object detection algorithms may require dedicated hardware capabilities for real-time analysis of video streams. Such MEC-hosted applications have clear 'service availability' needs as well as interoperability across connected vehicles (belonging to different OEMs) and MEC platforms of different providers/operators/vendors, as well as potentially connected VRU devices.

Moreover, scalability must be ensured and may only be supported by corresponding edge cloud deployments, for example, to cope with a varying number of service users in densely populated areas.

Further, the 'local' nature of interaction between edge cloud and local traffic participants relieves mobile networks of the burden of having to provide additional backhaul user data transmissions to centralised cloud entities. Here, video data is locally processed by the edge cloud and does not need to be transferred to a central cloud or data centre for AI processing. Thus, significant savings in terms of network backhaul traffic and capacity could be achieved.

The MEC application solely uses the obtained sensor data for analysing the VRU movements and is only relevant for the local service provisioning as well as during service activity (e.g., when VRUs are present). However, as requirements for tracing the decision making of automated vehicles may appear, there could be a legal/regulatory requirement imposed on the service provider for storing video data feeds for a certain amount of time (e.g., 24 hours).

For enhanced privacy, data may only be locally hosted and deleted after the (legally/regulatorily required) minimum storage time expires. If the legal framework permits, data may be pseudonymised, aggregated, and analysed by central entities for enabling additional services.

The presence of a 'local' MEC with access to infrastructure-based sensors (e.g. surveillance cameras, wireless detection mechanisms) as well as communication capabilities extends the Use Case towards 'collective perception' and 'situational awareness', creating added value for other traffic participants.

6.4.2.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/ High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency...)	Business role: Who buys MEC service and receives business value from MEC?
Vulnerable road user (VRU) [1]	All dimensions (MNO, MEC, OEM) High	High	High	Location API, network API (vehicle/user mobility), compute power (AI-based detection)	Scalability Service availability and reliability Savings in terms of network backhaul traffic and capacity.	MEC HW/SW vendors can provide the relevant components. MNO can receive value from hosting applications as well as providing services and communications, savings in terms of network backhaul traffic and capacity, centralised resources are used more efficiently. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing the number of accidents. Vehicle owners without in-built VRU protection can improve the vehicle's feature set (based on V2X messages) and receive discounts on their vehicle insurance. Car owners could pay for the service via a corresponding service platform. Municipalities could enforce via regulation that only VRU protection-capable vehicles can enter certain areas. Municipalities could offer 'data as a service' to insurance companies (according to local privacy laws).

6.5 Use Case 5 – Vehicle platooning

Vehicles platooning allows vehicles to drive closer than normal in a coordinated manner as a group. Forming such close coordinated vehicular groups or 'platoons' enhances safety and efficiency by reducing the influence of unanticipated driving behaviour and speed variations, which ultimately increases traffic flow and reduces fuel consumption and CO_2 emissions.

In this Use Case, the lead vehicle (LV) receives information from the member vehicles (MVs) through the following basic event flow [1]:

- The LV receives information about the road and weather conditions, if available, as well as traffic conditions according to the route that the platoon follows
- The LV receives information about the status of the MVs (e.g. speed, location)
- Based on the information collected, the LV decides the behaviour and configuration of the platoon (e.g. inter-vehicle distance guidance, speed, location, direction and intentions such as acceleration, etc)
- The MVs receive configuration information about the platoon from the LV (e.g. trajectory, speed and acceleration intention)
- The MVs receive speed, position and indications of intent, such as braking and accelerating, of the preceding MV
- Based on the information assembled and considering its own dynamics and parameters (e.g. tyre pressure), the MV determines an appropriate driving behaviour (e.g. accelerate, brake, maintain speed and distance with front vehicle)

MEC nodes are actively discussed in the literature for the high-density platooning Use Case [36], [37] and the cooperative lane-change scenario [38].

MEC can be used for timely platoon-control information, such as identification of the LV and vehicles in the adjacencies of the MVs, which is then used by them to communicate with other MVs of the same platoon. This identification may be based on global traffic information, weather conditions, etc.

MEC can also be helpful for collecting the status information of one or multiple platoons and low-latency dissemination of this information to the platoon members. The status information may be, for example, the position or speed of the platoon MVs or LV. The MEC can help the LV in its platoon-formation decisions. MEC also helps with platoon en route in advance QoS notifications, where the QoS change along the path of the platoon is calculated at the MEC node and notified to the platoon LV. The LV or the MEC decide whether and how to inform MVs when the platoon reaches an area affected by a QoS notification.

MEC can support platoon reconfiguration based on QoS estimation and/or notification. The platoon reconfiguration includes changes such as MV speed, inter-MV distance, membership (i.e. adjacency list/neighbouring vehicles) or a different LV. MEC can also support in-advance QoS notification to the platoon in order to further improve its performance en route.

The latency of the communication between the MEC node and platoon members is critical for most of the aforementioned uses of MEC in high-density platooning.

6.5.1 Evaluation

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/ High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency…)	Business role: Who buys MEC service and receives business value from MEC?
Vehicle platooning	All dimensions (MNO, MEC, OEM) High	High	High	Location API Radio network information API UE application	Scalability Service availability and reliability	MEC vendors: use case can be enabled by many platforms MNO: more business opportunities, reuse of edge cloud infrastructure, OEM: performance: use case requires low E2E latency, business: enable edge-hosted applications with low-cost in-vehicle frontend, Road operator/insurance companies/society (incentives, regulations)

7 MEC APIs and introduction of conformance test specifications for V2X interoperability

Section 5.1.3 already described consumption of MEC services as one of the most important benefits of edge computing, thanks to the availability and exploitation of local and context information, providing the opportunity to produce (and thus consume) edge services in close proximity to the application endpoint. In this perspective, the selected 5GAA Use Cases (together with the usage of MEC APIs and their relevance for each Use Case) has been described in Section 6. Based on that description, a summary of some APIs relevant for the Use Cases is provided here:

Use Case	Relevant APIs and information	Notes
Use Case 1: See through	MEC application support API [6], V2X API [15], Location API [11]	Context information on all cars in the cluster
Use Case 2: In-vehicle entertainment (IVE)	MEC application support API [6], V2X API [15], Location API [11]	Context information on all cars in the cluster
Use Case 3: Intersection movement assist (IMA)	MEC application support API [6], V2X API [15], Location API [11]	Context information on all cars in the cluster
Use Case 4: Vulnerable road user (VRU)	MEC application support API [6], V2X API [15], Location API [11], network API (vehicle/user mobility), compute power (AI-based detection)	Location and network API are suitable for the VRU variant on: 'Infrastructure sensor-based approach'
Use Case 5: Vehicle platooning in 'steady state'	MEC application support API [6], V2X API [15], Location API [11], RNI API [8], UE app [14]	information to the platoon vehicles, possibly also to multiple platoons

As an important clarification, not only ETSI specified APIs should be considered for providing V2X services, but also proprietary implementations are possible (while guaranteeing interoperability). In fact, the MEC009 specification [7] defined a guideline for generic API design, following the RESTful paradigm and messages (see also OpenAPI standard representation[1]). For this purpose, in case of a proprietary implementation of a new MEC API (i.e. not standardized in ETSI), a proper definition of new MEC API resources and error message handling is sufficient (i.e. according to MEC009 guidelines), in order to provide interoperable language for all MEC applications. For further background, the reader can have a look at the ETSI Forge Repository (https://forge.etsi.org), where many API representations are implemented. It is also a suitable tool for SW developers, to test the REST messages and error codes in the consumption of MEC services (the figure below shows an excerpt of the Forge site, for the RNI API).

1. Note: The OpenAPI Specification (originally known as the Swagger Specification) is for machine-readable interface files describing, producing, consuming, and visualising RESTful web services.

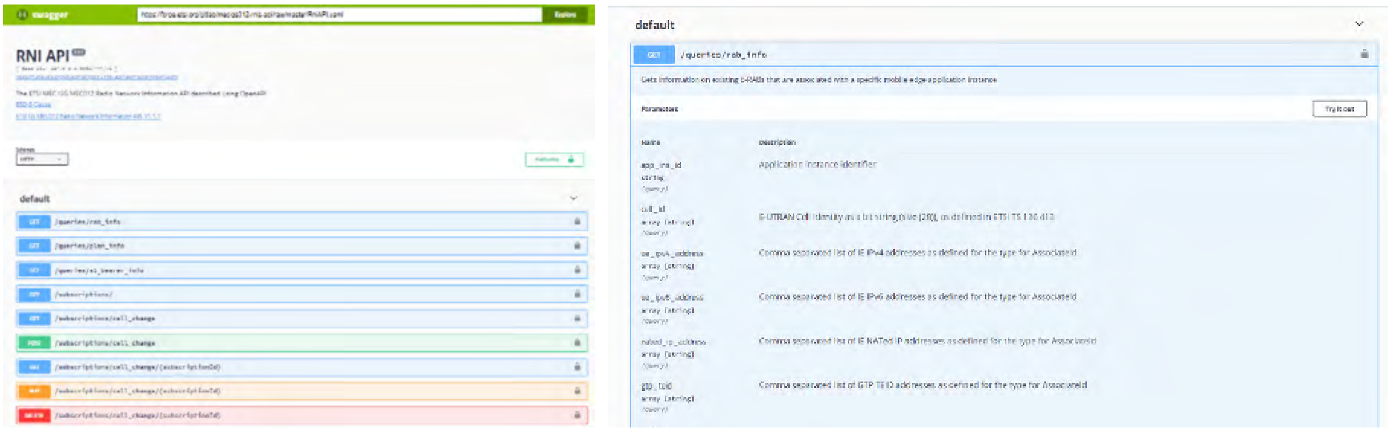

Figure 7.1 – Example of OpenAPI representation of radio network information (RNI) API,
Source: https://forge.etsi.org/

When it comes to interoperability in multi-stakeholder environments, compliancy with the standards is essential. For this purpose, recently ETSI published a deliverable [23] listing all functionalities and capabilities required by a MEC compliant implementation. This document also specifies a testing framework defining a methodology for interoperability and/or conformance test strategies, test systems and the resulting test specifications for MEC standards. In addition, the testable requirements are listed and prioritised. More recently, the group also released a stable draft of the MEC API conformance test specification, in three parts [24][25][26]:

- Part 1: Test requirements and implementation conformance statement (ICS)
- Part 2: Test purposes (TP)
- Part 3: Abstract test suite (ATS)

Test specifications are key for all stakeholders (MNOs, but also technology providers and application developers), to verify and test the correct implementation of APIs, in order to ensure proper communication with MEC applications. For this purpose, ETSI is also organising Plugtests events with the aim of offering network function virtualisation (NFV) and MEC solution providers and open source projects an opportunity to meet and assess the level of interoperability of their NFV and edge solutions, while they validate their implementation of NFV and MEC specifications and APIs.

The certification process is outside the scope of ETSI, but starting from this work, the Global Certification Forum (GCF) established at the end of 2018 a task force on MEC (as an initiative triggered by operators), called 'Multi-access Edge Computing Task Force' (GCF TF MEC), with the goal of working on MEC certification, and planning to leverage the above work in ETSI on conformance tests.

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2. The NFV and MEC Plugtests 2020 (https://www.etsi.org/about/10-events/1683-nfv-mec-plugtests#pane-5/) will include different types of test sessions covering: NFV Interoperability and API Conformance, MEC and MEC-in-NFV Interoperability and API Conformance. The test plans will be based on NFV-TST007, NFV-TST010, NFV-SOL016, MEC017, MEC-DEC025 and MEC-DEC032.

3. https://www.globalcertificationforum.org/about/task-forces-and-workstreams.html

8 Conclusions

MEC4AUTO stakeholders have analysed several Use Cases defined by WG1 and down selected five which are relevant to MEC in further analysing Task 2, Task 3 and Task 4. The table below summarises the selected Use Cases for MEC4AUTO.

Use Case	Technical criteria and relevance					Preliminary analysis on business criteria and relevance
	Interoperability (type and relevance, Low/Mid/High)	E2E Latency (against SLR)	Security and privacy (Low/Mid/ High)	MEC service consumption (list of APIs)	Other technical criteria (e.g. throughput, bandwidth saving, energy efficiency…)	Business role: Who buys MEC service and receives business value from MEC?
See through	All dimensions (MNO, MEC, OEM). High relevance	Only SLR compliance	High	Location API, context information on all cars	Better service discovery phase, more reliability	MNOs can exploit their network and edge cloud to offer to road operators and car OEMs a key point-of-presence of edge instances that can enable interoperable 'see through' functionality and other high-performing services. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing accidents and obtaining more funds from central governments. Car OEMs can integrate this service in their in-vehicle platforms, increasing the added value of the vehicle and services package. ISVs like app vendors, VNF vendors, MEC vendors, MANO players and OEMs/ODMs (Dell, HPE, server vendors and RSUs vendors like Harman, etc.) can provide the MNOs the hardware/software components of the solution stack that constitute the service. MNOs will monetise the service through the road operators, city governments/municipalities who will host the service on their premises (traffic poles, street light poles, uCPE, etc.) as an add-on to the MNO infrastructure in their NGCOs or regional data centres. Essentially, the vehicle owners/drivers would use the service and pay for it directly/indirectly through the city authorities. Latency/response time KPIs are key as an in-car solution because of the better response time for this case vs. through a MNO service.

In-vehicle entertainment (IVE)	All dimensions (MNO, MEC, OEM) High relevance	High relevance	High	Location API, context information on all cars	Reduced load on the transport network	End-customers may buy premium services from content providers enabled by MEC functionalities. MNOs and content/service providers can benefit from the introduction of MEC, to offer added-value services. The ISV partners the CDN enablers (e.g. Qwilt, etc.) will play a role here along with the content creation and distribution companies like Netflix, Walt Disney, etc.
Intersection movement assist (IMA)	All dimensions (MNO, MEC, OEM) High relevance	Only SLR compliance	High	Location API, context information on all cars	Scalability Saving in terms of signalling (and network capacity)	MNOs can exploit their network and edge cloud to offer to road operators and OEMs a key point-of-presence of edge instances that can enable interoperable IMA and other high-performing services. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing accidents and gaining more funds from central governments. Car OEMs can integrate this service in their in-vehicle platforms, increasing the added value of the vehicle and services package. Same as Use Case 1
Vulnerable Road Users (VRU)	All dimensions (MNO, MEC, OEM) High	High	High	Location API, network API (vehicle/user mobility), compute power (AI-based detection)	Scalability, service availability and reliability, savings in terms of network backhaul traffic and capacity.	MEC HW/SW vendors can provide the relevant components. MNO can receive value from application hosting as well as providing service and communication savings in terms of network backhaul traffic and capacity, centralised resources are used more efficiently. OEMs can integrate this AI-based service in their in-vehicle platforms increasing the added value of the vehicle and services package. Road operators and municipalities can improve the quality of life of citizens, and the safety of the population, e.g. reducing accidents.

Vehicle platooning	All dimensions (MNO, MEC, OEM) High	High	High	Location API Radio network information API UE application	Scalability Service availability and reliability	MEC vendors: use case can be enabled by many platforms MNO: more business opportunities, reuse of edge cloud infrastructure, OEM: performance: use case requires low E2E latency, business: enable edge-hosted applications with low-cost in-vehicle frontend, Road operator/insurance companies/society (incentives, regulations)

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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