5GAA Automotive Association

Toward fully connected vehicles: Edge computing for advanced automotive communications

White Paper

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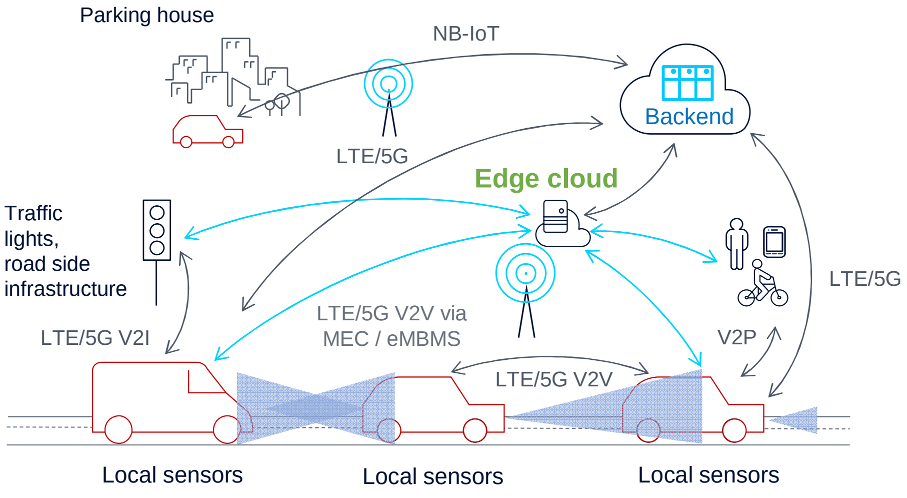
Executive Summary

Connected Vehicles and especially connected Autonomous Driving (AD) vehicles bring a whole new ecosystem with new requirements on the Cloud and the network architecture to support the new workloads and to satisfy the real-time service requirements. Such ecosystem includes the vehicles, the road infrastructure, the network infrastructure, and the Cloud.

Edge Computing based Vehicle-to-Cloud solutions enable edge cloud capabilities for different levels of autonomous driving, including Highly Autonomous Driving (HAD) and Fully Autonomous Driving (FAD)[1] through providing different services for the driving process (e.g., High Definition real-time Maps, real-time traffic monitoring and alerts, and richer passengers experience), supporting vehicles on roads to drive co-operatively and to be aware of road hazards, and providing better user experience and trust to drivers and passengers.

Figure 1: V2X Communications – the big picture



This white paper provides an overview of automotive use cases and shows how Edge Computing provides compute/storage/networking capabilities at the network edge, and how it can be considered a supporting technology for multiple services for connected AD vehicles. The paper draws the attention to the value of Multi-access Edge Computing (MEC) as a standardized solution for Edge Computing, especially important from automotive stakeholders' point of view (while also serving other vertical market segments). In particular, from a standardization perspective, some use cases targeting fully connected cars (i.e. FAD with the maximum level of automation) have challenging requirements that may be fulfilled only with the introduction of 5G networks. Finally, this paper also illustrates the opportunities that are here already today in deploying Edge Computing to support AD, using the flagship services as examples.

[1] In the context of this paper, we refer to Highly Autonomous Driving (HAD) and Fully Autonomous Driving (FAD) by referring respectively to SAE levels 4 and 5 of automation [19].

1 - Introduction

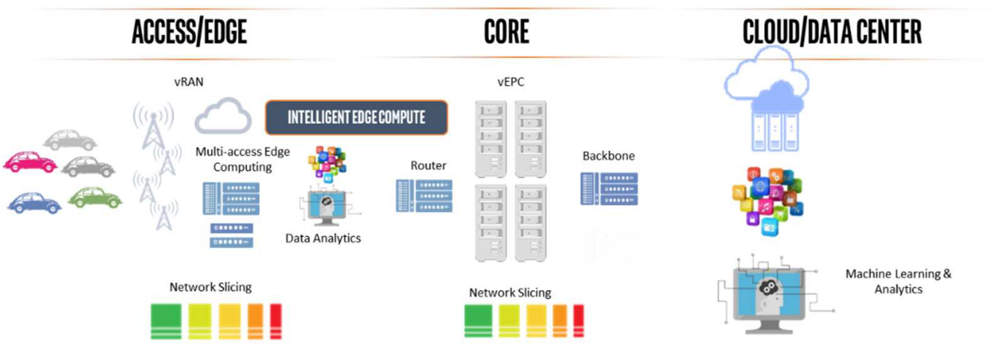
The connected Autonomous Driving (AD) vehicles market is driving the evolution of the Internet of Vehicles (IoV) (or Vehicular IoT) and is growing at a five-year compound annual growth rate of 45%, which is 10 times as fast as the overall car market. In addition, the vehicle prices that are currently out of reach for most car buyers, will drop significantly in the next few years due to the rapid advancement of embedded technologies which extends the connected AD vehicles technologies to non-luxury categories. Consequently, the business opportunity is significant for connected AD Vehicles. Revenue in the connected car market will amount to nearly $8.2 billion in 2017 and is expected to grow to over $18 billion by 2021 in the U.S. alone, according to research firm Statista 0.

That growth has potential to continue, as connected cars make up 12% of those on roads today, with 34.3% projected in 2021 [13]. All this drives several smart services opportunities for drivers, passengers as well as car makers and Telcos/service providers and many more actors in this new market, such as: (i) Automated Driver Assistant Services (ADAS) as driver assistant, parking assistant, self-parking, and automated/unmanned driving, (ii) Telematics as traffic alerts and roads weather conditions alerts, (iii) Infotainment services as music streaming, video streaming to passengers, (iv) Tourist visit to passengers with Augmented Reality (AR) and Virtual Reality (VR), and (v) Remote and automated management for smart vehicles as software/firmware updates.

Edge Computing: a key technology supporting connected AD vehicles

The expansion from Cloud to Edge Computing for connected AD services is driven by both the need to have more processing power closer to the vehicles to guarantee the required latency and the need to have reduced network churn with continuous access to the Cloud. Edge Computing is addressing this paradigm shift by aiming to offer a different services environment and cloud-computing capabilities within the roads infrastructure and the access network infrastructure in close proximity to vehicles and Road Side Units (RSUs).

Figure 2: Example of Edge Computing Support to Services for Connected and Autonomous Vehicles by offering Network Slicing and Data Analytics at the Edge



Edge Computing can benefit from new functionality to better handle the big volume of data coming from vehicles and road side units and to dynamically allocate CPU and Acceleration resources based on the services' needs (e.g., computer vision Vs. video streaming Vs. data aggregation).

The following features are found beneficial to Edge Computing:

- Network Slicing to tailor the capacity and capabilities of the network for each different service (see the above Figure 2, showing an example of Edge Computing Support to Services for Connected and Autonomous Vehicles)
- Service-specific profiles for dynamic assignment of service-specific HW-acceleration to optimize the compute and storage based on simultaneous services requirements

- Hierarchical deployment of the Edge Computing environment using a hierarchy of gateways/roadside units with the Edge Computing servers arranged to reduce the latency and distribute the processing.

New Business Opportunities for the automotive ecosystem

The network infrastructure for connected AD vehicles will provide not only Network as a Service (NaaS) but also Infrastructure as a Service (IaaS) in a multi-tenancy fashion. The edge computing infrastructure represents a pool of connected resources that can be used by the Mobile Network Operators (MNOs) and also by diverse service/application providers who commercialize services as well as micro-services (e.g., Augmented Reality to serve multiple services, Video Analytics to serve diverse services) for connected AD vehicles. Such infrastructure leads to new opportunities for business models as shown in the following table.

Table 1: Possible business opportunities offered to automotive stakeholder's car-to-cloud

Business Models	Players
Business-to-Business (B2B)	• Car makers monetize application providers for UX services to passengers • CSP monetize the use of the Cloud by car makers • MNOs monetize the use of the network by application providers & OTA
Business-to-Consumer (B2C)	• Car makers monetize personalized services to passengers • MNOs and CSPs monetize car makers for driving assistant and passengers' experience
Business-to-Business-to-Consumer (B2B2C)	• MNOs monetize the network infrastructure for compute/storage by Application providers (e.g., HD maps providers, Virtual reality applications) • Application providers monetize car makers for the provision of applications • Car makers monetize users (passengers, drivers in non-fully autonomous vehicles)
Consumer-to-Consumer (C2C)	• Passengers (and drivers in non-fully autonomous vehicles) share road hazards information with vehicles in non-line of sights in a mutual way

2 - Automotive use cases powered by Edge Computing

The information exchanged between vehicles, infrastructure, pedestrians, and network using V2X technology is enabling a multitude of new and exciting applications. Exploitation of the edge processing power and its ability to intelligently process the information can add value to it, and to provide useful low latency service experiences.

The Edge Computing solution introduced by ETSI ISG MEC (ref. section 3) provides application and content providers with cloud computing capabilities and IT service environment at the very edge of the mobile network. This environment is characterized by the proximity, often in both physical and logical sense, to the clients, enabling very low latency between the client and the server applications, high bandwidth for the application traffic, and near real-time access of the applications to context-rich information, e.g. related to device locations and local radio network conditions. These qualities of the edge computing ensure an unparalleled quality of experience with highly contextualized service experience and efficient utilization of radio and network resources.

The ETSI ISG MEC edge computing solution can be deployed within the Mobile Network Operator's infrastructure together with the management and orchestration, security, privacy and subscriber management frameworks already in place. This way the environment for edge applications is secure and well managed, making it more suitable critical applications as well as for applications with high business value.

2.1 Categorization of V2X applications

The 5G Automotive Association (5GAA) categorizes a comprehensive list of connected vehicle applications, categorized in four main groups of use cases [18]:

(i) Safety,

(ii) Convenience,

(iii) Advanced Driving Assistance and

(iv) Vulnerable Road User (VRU).

Safety use cases such as those listed in Table 2 are designed to reduce the frequency and severity of accidents. The United States' National Highway Traffic Safety Administration has compiled some extensive research and statistics regarding both vehicle-to-vehicle [16] and vehicle-to-pedestrian [17] crash scenarios.

The V2X use case group "Safety" includes several different types of use cases to support road safety using the vehicle-to-infrastructure (V2I) communication in addition to the vehicle-to-vehicle (V2V).

For some use cases, MEC systems could provide a support for Real-time data analysis, data fusion and reduced ingress bandwidth with respect to the remote cloud.

Table 2 Safety Automotive Use Cases

Use case	description	Relevance for MEC
Intersection Movement Assist	Warn driver of collision risk through an intersection.	High

Convenience use cases, such as those listed in Table 3, provide time-saving services to manage data and the health of the vehicle. This group of V2X use cases requires cost-effective communication to be enabled between the vehicles and the backend server (e.g., car OEM's server). Software Over the Air (OTA) updates and other telematics use cases are typically included in this group.

Table 3 Convenience Automotive Use Cases

Use case	description	Relevance for MEC
Software Updates	Deliver and Manage Automotive Software Updates	Mid

Advanced Driving Assistance use cases such as those listed in Table 4 are focused on improving traffic flow, traffic signal timing, routing, variable speed limits, weather alerts, etc. This group of use cases collects the most challenging requirements for V2X (from a MEC perspective). It can require distribution of a relatively large amount of data with high reliability and low latency in parallel.

Additionally, the advanced driving use cases would benefit from predictive reliability. This means that vehicles moving along should have the possibility to receive a prediction of the network availability ahead of them to allow preparations accordingly.

Table 4: Advanced Driving Assistance Automotive Use Cases

Use case	description	Relevance for MEC
Real-Time Situational Awareness & High Definition Maps	Alert driver of Host Vehicle (HV) moving forward of hazard (icy) road conditions in front.	High
See-Through	Driver of Host Vehicle that signals an intention to pass a Remote Vehicle (RV) using the oncoming traffic lane is provided a video stream showing the view in front of the RV.	High
Cooperative Lane Change (CLC) of Automated Vehicles	Driver of Host Vehicle (HV) signals an intention to change the lane with at least one Remote Vehicle (RV) in the target lane in the vicinity of the HV.	High

VRU use cases such as those listed in Table 5 support a safe interaction between vehicles and pedestrians, motorcycles, bicycles or any other non-vehicle road user.

Table 5: VRU Automotive Use Cases

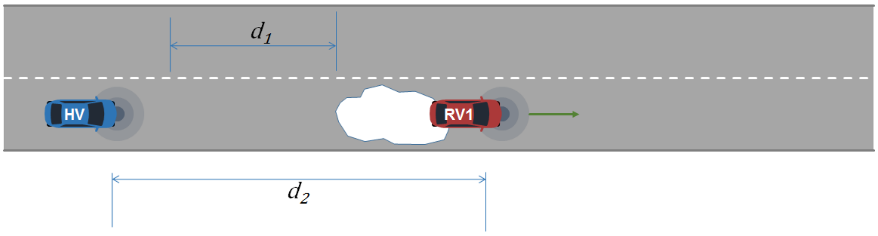
Use case	description	Relevance for MEC
Vulnerable Road User Discovery	Detects and Warns drivers of VRUs in the vicinity.	High

The following use case examples are detailed to better illustrate the edge computing that is required to process the exchanged information.

Use case example #1: Real-Time Situational Awareness & High Definition (Local) Maps

Real-time situational awareness is essential for autonomous vehicles especially at critical road segments in cases of changing road conditions (e.g. new traffic cone detected by another vehicle some time ago). In addition, the relevant high definition local maps need to be made available via download from a backend server.

Figure 3: Real-time Situational Awareness and High-Definition (Local) Maps



The use case for real-time situational awareness and High Definition (Local) Maps should not only be seen as a case to distribute information on relatively slow changing road conditions. In fact, it should be extended also to situations where there is a need to distribute and aggregate locally available information in real time to the traffic participants via RSUs.

Edge computing deployment is ideally suited for Real-Time Situational Awareness & High Definition (Local) Maps use case due to the real-time and local nature of the information needed for accurate and augmented situational awareness of the road users. An alternative to edge computing is to make the road users themselves create and maintain their real-time situational awareness from the broadcast information they receive from peer users. Edge computing solution allows offloading such tasks to the network edge, by augmenting the broadcast information with other available information via data fusion from available sources, and efficiently broadcast large amounts of data to many users locally.

Use case example #2: See-Through (For Passing)

In See-Through use cases (part of a class of applications called *High Definition Sensor Sharing*), vehicles such as trucks, minivans, cars in platoons share camera images of road conditions ahead of them to vehicles behind them.

In particular, the See-Through (For Passing) application is an example of an Advanced Driving Assistance application. It warns the driver of a host vehicle who is intending to pass a remote vehicle of potential hazards such as an oncoming remote vehicle in the passing lane or a lack of room in front of the leading remote vehicle. The goal of the use case is to prevent catastrophic head-on collisions during a passing maneuver.

Figure 4: See-Through (For Passing)

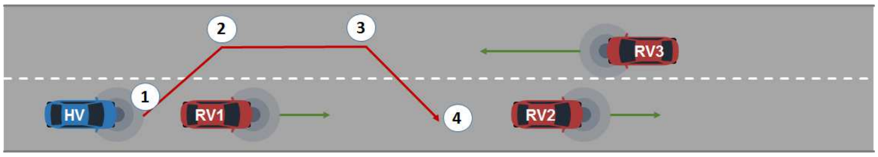


Figure 4 illustrates the scenario along with the main operational states identifying this use case:

- State 1 = HV starts receiving streaming video from RV1
- State 2 = HV has fully moved into the passing lane, continues receiving video streaming from RV1
- State 3 = HV has reached the position in the passing lane when it is ready to start the maneuver to return to the starting lane
- State 4 = HV completes the passing maneuver and can stop receiving the streaming video from RV1

In summary, here the aim is to provide HV driver a clear, reliable and real-time view of the road situation in front of the vehicle it is trying to pass and help avoid a possible collision. Based upon the visual information from the RV, the HV driver is able to make an informed decision to overtake the RV when there is no traffic coming in on the opposite direction, and complete a successful passing maneuver with the additional visual information from RV1.

Moreover, the application will need to perform a number of computations such as estimating the distance and path required to complete the passing maneuver, the trajectory of the oncoming RV3, the estimated gap between RV1 and RV2 at the end of the maneuver and the risk of a crash between HV and RV3 if their paths overlap. As a consequence, the presence of a MEC server on-board can be beneficial not only to host computational power for the data processing, but also (and especially) to transfer realtime video streaming, and potentially perform also video processing/orchestration at the edge (which is a relevant use case in MEC [3]).

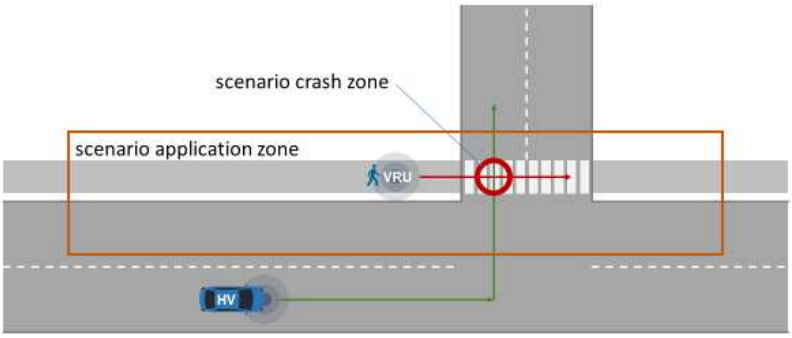
Edge Computing is an ideal solution for use cases like See-Through where very low latency communication and local context are key characteristics. The edge computing application has real-time communication channel with the participating vehicles in the area, and near limitless computing power compared to any in-vehicle embedded processor environment. Edge application can also benefit from additional information that is not directly available for the participating road users.

Use case example #3: Vulnerable Road User Discovery

The VRU use case covers pedestrians and cyclists. A critical requirement to allow efficient use of information provided by VRUs is the accuracy of the positioning information provided by these traffic participants. Additional means to use available information for better and reliable accuracy is crucial to allow a real-world usage of information shared by VRUs. The VRUs making their presence/location known through their mobile devices (e.g., smartphone, tablets), along with vehicle's use of that information, will be an important key element to improve traffic safety and to avoid accidents.

In this example, the driver of a Host Vehicle (HV) that is intending to make a left turn is alerted to the presence of a VRU (a VRU may be pedestrian, bicycle, motorcycle or other entity that is identified or represented in a safety and/or awareness message. Figure 5 below illustrates the scenario involving a vehicle and a pedestrian.

Figure 5: Left Turn VRU Warning



For the application to issue a valid warning, it will need to calculate the trajectories of HV and VRU, know the geometry of the road and intersection and determine the risk of collision in the time frame where their trajectories meet.

Edge Computing is also here an ideal solution for use cases like VRU detection, especially in the view of exploiting local context and information available at the edge. In particular, MEC has recently released a first set of APIs (including Radio Network information, and Location APIs) that can be exploited to improve the accuracy of the positioning information of all traffic participants.

Looking toward connected AD vehicles: Real-time Passenger's Awareness

Connected AD vehicles need environment and surrounding awareness in real-time not only for reliable driving but also for better passenger's experience and trust in the vehicle. Vehicles need to have high precise view of their surroundings, road structure, topology and status in real-time. In addition, passengers need to be aware of any impending hazards for more comfortable experience.

Vehicles can detect non-line of sight hazards via V2V communications from other vehicles but also from road infrastructure units (e.g., street cameras) that visualize the hazards, analyze them (through computer vision on an Edge Cloud) and disseminate to other vehicles in the proximity. This provides reliable AD considering non-line-of sight-hazards as well as passengers' awareness of hazards ahead of them.

2.2 Impacts on Edge Computing and technical challenges

The use cases listed in the previous section identify several challenges from a technical standpoint. Edge Computing solutions can contribute to the effective realization of many V2X use cases of interest, especially when performance and system requirements are challenging, in terms of low delay, QoS management and prediction, deployment flexibility and access to local context-rich information. In addition to that, the two challenges, big data processing and storage, and multi-operator support, are particularly important to be solved for a successful implementation of automotive use cases.

Handling AD Big Data Emerging from Autonomous Vehicles

There are many unprecedented challenges for services deployments. A typical challenge in IoV is the big data processing and storage resulting from a huge and growing number of sensors in smart/connected vehicles and roads. This, in turn, requires new services platforms with powerful processing and computing resources, low cost and trusted storage, and real-time communication capabilities. MEC appears as a promising opportunity to migrate Cloud resources closer to the vehicles and the data sources and hence save network resources and reduce the latency.

AD vehicles bring a whole new ecosystem with new requirements on the Cloud and the network architecture to support the new workloads and to satisfy the real-time services requirements. By 2020, one AD vehicle will use 4,000 GB of data per day (soon creating significantly more data than people – each car will generate about as much data as about 3,000 people – and a million AD vehicles will generate 3 billion people's worth of data) – versus 1.5GB for average Internet user per day [14]. An AD vehicle will generate and consume roughly 40 terabytes of data for every eight hours of driving (as an example an HD map for a city is about 1.5TB without counting the daily uploads and downloads for the maps dynamic update).

The revolution in the automotive industry, i.e., the huge amount of data generated from connected and AD vehicles, is coming at the expense of network resources both from a bandwidth cost as well as from real-time requirements' perspective. This has a huge impact on the Cloud-only approach. At the same time, the local computing power and storage capacity equipped in a self-driving vehicle is not enough, due to space, heat dissipation, and the cost of executing the heuristics or artificial intelligence needed to provide the required levels of autonomy.

Consequently, the current trend is to distribute the workload and Cloud services from vehicle to cloud. Given the critical nature of self-driving vehicles and their reliance on mission-critical applications, they necessitate strict requirements in terms of latency, network availability, and reliability. This, in turn, requires highly redundant connectivity solutions leveraging multi-RAT access network infrastructure and distributed edge computing (i.e., moving the cloud resources closer to the data sources).

Multi-operator support

Wireless communication is a key enabling technology for co-operative intelligent transportation systems. Road users (including cars) involved in the communication (e.g. LTE-V2X) may use services provided by different operators. Cross-operator interoperability is therefore critical for V2X applications enabled in the edge cloud.

It will be extremely important for providers of MEC applications that they will be able to develop, test, deploy and maintain their applications based on standard processes and procedures applying to all MEC-enabled networks per country or geography. The multiplication of cloud instances by an order of magnitude when moving from one or few cloud instances on the Internet to numerous MEC-based instances per country per network operator must not result in an otherwise unbearable extra effort for MEC application providers compared to Internet-based cloud solutions today.

In a multi-operator scenario, the end-to-end latency between the vehicles is limited by the location of peering points for data traffic between the mobile operators' networks. These peering points are usually located centrally in the mobile operators' networks. The end-to-end latency between the vehicles will thus be the same if MEC is deployed close to the vehicles or close to the peering points. To achieve the low latency described in this document, new local peering points between the mobile operators' networks need to be deployed.

In addition, to achieve a profitable and sustainable business model, mobile operators, ecosystem partners and automakers will face tremendous pressure from end users and regulators in building a secure and integrated connected car platform. Deep partnerships will be required to address connectivity and vehicle operations to deliver safe and secure applications.

One important aspect is the ownership and responsibility of the applications on this connected car platform. There are many potential actors in the ecosystem who could take this responsibility, e.g. road traffic operators, mobile network operators, and automakers. Different types of standardization in different Standards Development Organizations will be required depending on the selected actor.

2.3 MEC in action

Recently, several trial initiatives related to automotive use cases are demonstrating V2X use cases with the support of Edge Computing [7][8][9]. These activities are often the result of the collaboration of different stakeholders (car markers, OEM suppliers, operators, network infrastructure vendors and technology providers).

The increased interest in Edge Computing and the progressive introduction of 5G systems are also demonstrating the maturity of this technology as a suitable enabler for the use cases described in the previous sections. Some examples of trials are described here below.

Road safety showcase at Digital A9 Motorway Test Bed

An Edge Computing infrastructure is currently deployed in the A9 motorway (and covering approximately 30km). Based on the first pilot installation in 2015, the project consortium Car2MEC (Continental, Deutsche Telekom, Fraunhofer ESK and Nokia) demonstrated how vehicles on the motorway can share hazard information using the live LTE network of Deutsche Telekom [7]. The use cases included were co-operative passing assistant and electronic brake lights.

The LTE network used in the demonstration was equipped with MEC technology in order to boost the performance and to permit sub 20 ms end-to-end latency between two vehicles (including the driver display). In addition to MEC solution in use, the location positioning technology was upgraded with a solution by Fraunhofer ESK.

Figure 6: Co-operative passing assistant in action

Digital A9 motorway test bed located in Bavaria between Nurnberg and Stuttgart offers a technology-neutral platform where innovative companies can trial automated and networked driving in real-life conditions on the motorway with the aim is to improve the road safety and to pave the way for Mobility 4.0 in the digitalized world.

Along with the Project ConCorDA, kicking off in October 2017 under the umbrella of the European Automotive & Telecommunication Alliance, this test bed will be extended in 2018 to support multi-operator MEC capabilities in a multi-telco vendor environment together with Vodafone and Huawei.

UK's first fully connected road test environment for vehicles

Vodafone, together with other consortium partners of automotive manufacturers, technology, and infrastructure providers and service operators, created the UK's first fully connected road infrastructure using a globally unique combination of wireless technologies which enables real-world testing of connected, semi-autonomous and eventually autonomous driving in a safe and managed way. Currently, Vodafone is in discussion with other partners to further enhance the connected road infrastructure using Edge Computing techniques.

3 - Standardizing edge computing for automotive

ETSI MEC is introducing a set of standards to enable hosting applications with ultra-low latency and high reliability in a distributed cloud and especially at the edge of the network. The optimized location in close proximity to the users and catered with the contextual information and the APIs offered within the MEC environment enable innovative and powerful services for connected AD vehicles. Especially for these use cases, the deployment of a service is involving many actors and a diverse ecosystem of stakeholders, so the value of a standardized solution is essential to avoid market fragmentation and ensure interoperability.

In the following sections, we analyze the activities in ETSI MEC, 3GPP and 5GAA and describe the possible synergies among the different bodies.

3.1 ETSI MEC

ETSI has initiated MEC standardization to promote and accelerate the advancement of edge-cloud computing in mobile networks, by launching the MEC Industry Specification Group (ISG) in December 2014. The objective of ETSI MEC ISG is to create an open environment across multi-vendor cloud platforms located at the edge of the network, accessible by application/service providers and third parties in an effort to overcome the challenges related with centralized cloud computing environments in terms of latency, and assurance of higher end to end throughput between the client and the server application.

ETSI ISG MEC already has reached most of its original objectives by publishing the first set of specifications in the summer of 2017. The published specifications create the baseline for edge computing solution where both the application enablement and applications' access to network information have been covered by stage 3 level API specifications. By relying on the published API specifications, an application developer can ensure its application's interoperability with the ETSI MEC compliant edge computing environment. With these APIs, the application is able to manage its connectivity with the external environment, discover the available services around it, and use those services to receive radio network and location information, as well as to make on-demand bandwidth reservations to better ensure predictable application experience.

The baseline MEC standard of today already covers many vertical market segments. In the context of automotive, a new study on "MEC support for V2X use cases" [15] has recently been launched in the ISG MEC. This work focuses on identifying the available support that can be provided by MEC for V2X applications. It intends to collect and analyze the relevant V2X use cases (including the findings from external organizations), to evaluate the gaps from the already defined MEC features and functions, and identify new MEC requirements, including new features and functions. This may include identifying new MEC service APIs or interfaces, as well as changes to existing APIs.

3.2 5GAA

The 5G Automotive Association is a multi-industry organization created to develop, test and promote communications solutions that rely on 3GPP Cellular-V2X technology, and to initiate their standardization and accelerate their commercial availability and global market penetration. 5GAA is in the center of the new ecosystem that is being built from the convergence of automotive, communication and cloud service/application sectors.

In the 5GAA mission statement the association addresses the following high-level activities:

- Defining and harmonizing use cases, business and go-to-market models for automotive and ITS applications
- Elaborating technology selections and roadmap evolution strategies
- Influencing standardization and regulatory bodies and certification and approval processes
- Addressing V2X connectivity and communication challenges, including wireless network and distributed cloud architectures, protocols and security for reliable and low latency communication.
- Running joint innovation and development projects for testing, piloting and trialing

Edge Computing is a clearly important area for automotive use cases and thus 5GAA is actively working in that field. Moreover, an impact in standardization (e.g. in ETSI MEC, where the standard body is represented through member companies common in both organizations) is also a possible outcome for 5GAA.

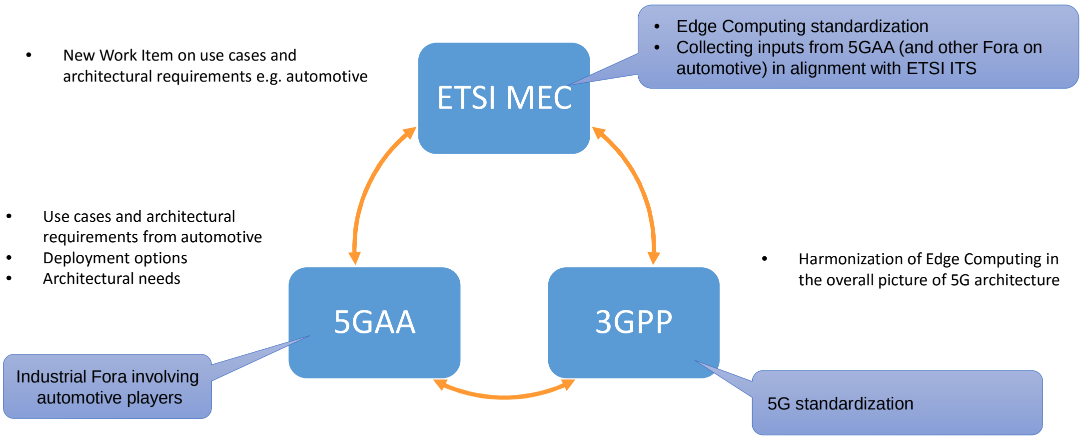
3.3 Synergies between the different organizations

A great value is associated with the standardization of edge computing technology, as open standards are the way to open the market and ensure interoperability. This is particularly true for automotive use cases with a large number of stakeholders. Now, by considering the different bodies described in the above and the related different points of view and scopes, here below are some considerations that may help to draft few key actions for a proper alignment from a standardization perspective:

- Edge computing has been recognized as an important technology for 5G in many white papers and in literature from a long time.
- 3GPP has adopted the Edge Computing concept as part of their 5G architecture that is being developed as we speak. 3GPP is also developing the API framework for the northbound APIs, taking into account corresponding ETSI ISG MEC APIs. The first 5G specification release is expected to be complete by the end of 2018.
- ETSI MEC whose reference architecture and API definitions are recognized as a technical reference in edge computing, is continuing the standardization efforts to add features and capabilities and to enlarge the application area of MEC solution. ETSI MEC has introduced the concept of Application enablement framework, covering service exposure and detailed APIs for many use cases (like automotive, as well as other industrial use cases).
- Regarding connected AD vehicles, 5GAA is already considering Edge Computing and MEC as part of 5GAA architecture, e.g. especially suitable for V2N2V and low latency use cases.

As a consequence, the figure below summarizes some possible synergies that will help a better harmonization among these bodies.

Figure 7: Synergies among 5GAA, ETSI MEC and 3GPP



Conclusions and future works

This white paper provided an overview of automotive use cases, as introduced by 5GAA, and showed how Edge Computing can be considered as a key technology supporting multiple services for connected AD vehicles.

Moreover, the paper draws attention to the value of MEC as a standardized solution for Edge Computing, especially important from automotive stakeholders' point of view while also serving other vertical market segments.

In fact, a great value is associated with the standardization of edge computing technology, as open standards are the way to open the market and to ensure interoperability. In particular, from a standardization perspective, some use cases targeting fully connected cars will require the fulfillment of challenging requirements, possible only with the introduction of 5G networks.

In this perspective, a proper synergy between standards (ETSI, 3GPP) and 5GAA is considered particularly important for the development of interoperable technology solutions and for the acceleration of their commercial availability and global market penetration.

Abbreviations

3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
AD	Autonomous Driving
ADAS	Automated Driver Assistant Services
AR	Augmented Reality
B2B	Business-to-Business
B2B2C	Business-to-Business-to-Consumer
B2C	Business-to-Consumer
BSM	Basic Safety Messages
C2C	Consumer-to-Consumer
CAM	Co-operative Awareness Message
CAD	Connected and Automated Driving
CAV	Connected and Automated Vehicles
FAD	Fully Autonomous Driving
HAD	Highly Autonomous Driving
IaaS	Infrastructure as a Service
IoV	Internet of Vehicles
MEC	Multi-access Edge Computing
NaaS	Network as a Service
OTA	Over the Air
RSU	Road Side Unit
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VR	Virtual Reality
VRU	Vulnerable Road User

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