5GAA
Automotive Association

A visionary roadmap for advanced driving use cases, connectivity technologies, and radio spectrum needs

5G Automotive Association

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Executive Summary

With this white paper, the 5G Automotive Association (5GAA) presents the results of its studies relating to the evolution of automotive connectivity for the purposes of enhanced road safety, improved traffic efficiency, greener environmental impact, and more comfortable driving.

Recognising the roadmap publications of other organisations, such as ACEA[1] and ERTRAC[2] in Europe, AASHTO TSMO guidance[3] and US DOT Strategic Plan[4], and the National Vision on Intelligent Connected Vehicles in China[5], this 5GAA white paper sets out a consolidated view of the automotive and telecommunications industries on the evolution of communication technologies, their application to automotive connectivity, and the deployment of advanced driving use cases up to 2030, which include advanced safety and automated driving (AD).

[1] https://www.acea.be/publications/article/roadmap-for-the-deployment-of-automated-driving-in-the-european-union
[2] https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf
[3] http://www.aashtotsmoguidance.org/
[4] https://www.its.dot.gov/stratplan2020/ITSJPO_StrategicPlan_2020-2025.pdf
[5] Innovation and Development Strategy for Intelligent and Connected Vehicle (Final Release Feb. 2020) http://www.tzxm.gov.cn/flfg/regulations/202002/t20200226_13154.html

Many so-called day-1 basic safety use cases have been widely analysed in the past, and several of these have already been deployed. This white paper focuses on advanced driving use cases which pave the way to automated driving, and thereby contribute to global safety and traffic efficiency goals, as well as environmental benefits for citizens and consumers.

5GAA has identified the most promising advanced driving use cases such as Cooperative Manoeuvres and Sensor Sharing, in conjunction with the adoption of Cellular Vehicle-To-Everything (C-V2X) standards as well as availability of required technologies and devices, i.e. on-board units (OBUs), road-side units (RSUs), and smartphones, integrating the latest chipsets and modules. The market trajectory of the identified use cases is described along with the expected timeline for their mass market deployment.

5GAA notes that many advanced driving use cases will require 5G-V2X radios. 5G-V2X is considered for advanced driving and LTE-V2X is considered for basic safety use cases, each encompassing both network and direct communications. Mobile network operators around the world have started to deploy 5G, building on current 4G networks. In the meantime, the planned releases of the 3GPP standards include new features for direct communications, such as low power consumption in handheld devices, enabling additional use cases. The roadmap also accounts for the work currently undertaken on the upper application layers (e.g. message types and protocols), as well as equipment availability, testing and interoperability. Finally, our findings show that some advanced driving use cases will require direct communication for their implementation.

In the next two to three years, 5GAA expects to see mass deployment of traffic efficiency and basic safety V2X use cases around the world. From 2024 onwards, we further anticipate the large-scale introduction of advanced safety and automated driving use cases supported by C-V2X. Additional connected automated driving functionalities are expected to be introduced starting in 2026.

Considering the current 3GPP releases roadmap and supply chain readiness, the 5GAA technology roadmap is summarised in Figure 1.

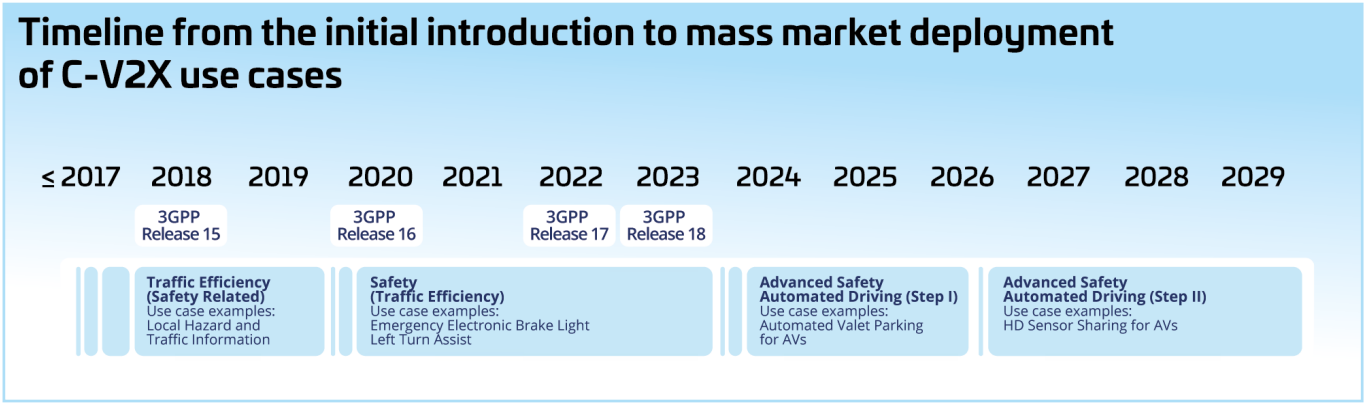


Figure 1: Timeline from the initial introduction to the mass market deployment of C-V2X Use cases

The white paper finally highlights the spectrum needs for basic and advanced driving use cases. For direct communication, this corresponds to between 10 and 20 MHz at 5.9 GHz for basic safety, and an additional 40 MHz or more at 5.9 GHz for advanced driving. For mobile network based communications this corresponds to additional availability of spectrum in low-bands (< 1 GHz) and in mid-bands (1-7 GHz) for use by mobile operators in delivering advanced driving capabilities in rural and urban environments, respectively.

To deliver end-to-end V2X services and unlock the true value of vehicle connectivity, 5GAA considers that the realisation of its roadmap would require (1) sufficient spectrum for short-range direct communications at 5.9 GHz, (2) high levels of mobile network coverage along the roads, and (3) sufficient service-agnostic mobile network spectrum for mobile network-based communications, in addition to the bands that are currently identified for International Mobile Telecommunications (IMT)[6] use.

5GAA emphasises that the introduction of the identified use cases also depends on the availability of appropriate regulatory frameworks as described, for example, by ERTRAC[7]. Investment in digital twins for road infrastructure and traffic management, including operational data interfaces, will need to complement the evolution of communication technologies and use cases, but this is outside the scope of this white paper.

5GAA, representing both the automotive and telecommunications industries involved in the deployment of V2X, underlines the need for strong cooperation with policymakers to realise this roadmap. Only an enabling and future-proof regulatory environment, conducive to C-V2X rapid deployment by OEMs and road authorities, will deliver upon our shared goals to improve road safety and reach climate-neutrality for the benefits of society overall.

[6] https://www.itu.int/en/ITU-R/Documents/ITU-R-FAQ-IMT.pdf

[7] https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

1. Introduction

The 5G Automotive Association (5GAA) brings together the automotive and telecommunications industries to address society's connected mobility, advanced vulnerable road user (VRU) protection, and road safety needs with applications such as automated driving and the integration of road users into intelligent transportation and traffic management systems. 5GAA considers Cellular Vehicle-To-Everything (C-V2X) technologies[8] – as specified by 3GPP – to be an essential step towards fully integrated intelligent transport systems (ITS) via 5G. Figure 2 illustrates the different communication modes of C-V2X.

This white paper builds on 5GAA's activities which aim to define basic safety and advanced use cases, and to provide a detailed assessment of the relevant standards, technologies, spectrum availability, and timelines for market readiness. It also includes industry recommendations to regulators in order to ensure that the corresponding spectrum is made available in time for the market introduction of these new use cases, leveraging technology evolution, on the road to automotive automation[9]. Even though this white paper discusses advanced driving use cases, one important aspect that should not be overlooked is the need for connectivity to support, for example, remote working and telematics services during travel. This becomes even more important with the advent of autonomous vehicles and efforts to encourage greener transportation through shared use of vehicles.

Work on the various use cases also builds on numerous ongoing efforts by standardisation bodies on the next-generation radio interfaces that will increase the capacity of direct and mobile network-based communications, thus enabling advanced use cases. Automotive and telecommunication companies are very much engaged in these standardisation efforts, and this white paper aims to give an overview of the roadmap for introducing these new cases, together with the necessary regulatory and spectrum policy requirements. In this context, basic safety V2X services defined the requirements for 3GPP Rel-14, and enhancements have continued in Rel-15. 3GPP Rel-16 and beyond will enable advanced driving through sensor sharing, intention sharing and cooperative perception, delivered with unprecedented key performance indicators such as latency and reliability.

[8] Cellular-V2X (C-V2X) is an umbrella term which encapsulates all 3GPP V2X technologies, including both direct (PC5) and mobile network communications (Uu), unless otherwise stated. If only direct or only mobile network communications are addressed, then the terms "direct" and "mobile network" are used, respectively. LTE-V2X relates to all 3GPP releases supporting LTE-V2X mobile network communications and LTE-V2X direct communications. LTE-V2X mobile network communications relate to 3GPP specifications, starting with Rel. 8 for LTE. LTE-V2X direct communications relate to 3GPP specifications, starting with Rel. 14. 5G-V2X relates to the combination of LTE-V2X and 5G radio access technology (NR). 5G-V2X mobile network communications is a combination of LTE-V2X mobile network communications and 5G radio access technology for mobile network communications (NR), which relate to 3GPP specifications, starting with Rel. 15. 5G-V2X direct communications is a combination of LTE-V2X direct communications and 5G radio access technology for direct communications, which relate to 3GPP specifications, starting with Rel. 16.

[9] Innovation and Development Strategy for Intelligent and Connected Vehicle (Final Release Feb. 2020) https://www.its.dot.gov/stratplan2020/ITSJPO_StrategicPlan_2020-2025.pdf

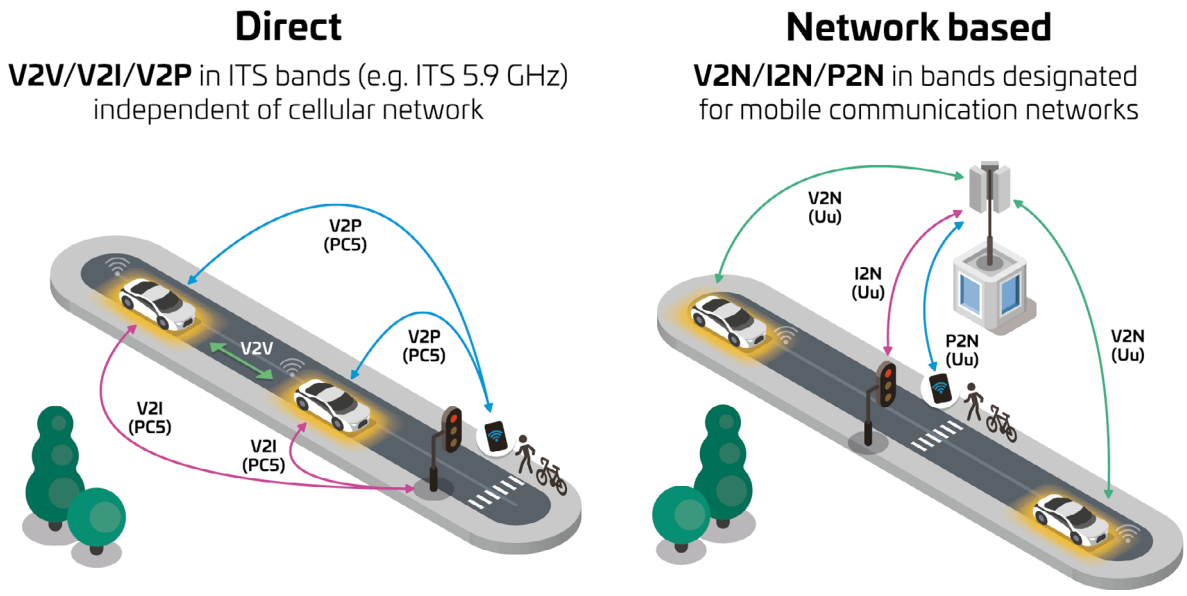


Figure 2: Direct and mobile network based communications modes supported by C-V2X

The different life cycles of vehicles and communication technologies imply that interoperability and backward compatibility are of critical importance. Given that technology evolution is a gradual process, 5GAA advocates a flexible and holistic system approach, combining network-based and direct communication possibilities and their interoperable evolution. This roadmap aims at clarifying these different aspects, from technology to standards to spectrum availability and market introduction.

Lastly, joint industry efforts must be supported by effective policy goals and objectives, promoting greener and more inclusive policies, including in the automotive sector, while accounting for the fact that citizens today require ubiquitous connectivity and innovative automotive-related services. In this context, it is essential to provide the necessary clarity around the market introduction of various new functionalities towards advanced driving.

It is important to recognise that the automotive industry has already gained comprehensive experience on which to build: more than 180 million connected vehicles are on the roads in 2020[10] and a rapidly growing number of vehicles have the capability to exchange traffic and road condition warnings with one another over cellular networks.

[10] 4G, 5G, C-V2X, and 802.11p Connected Vehicles: Global Market Analysis and Forecasts, https://tractica.omdia.com/research/cellular-v2x/

2. 5GAA visionary roadmap for the introduction of advanced use cases for connected and automated driving

5GAA members have studied and established timelines for the introduction of a number of promising advanced use cases accounting for major global developments, including those in China, Europe and the US. These regions are today the largest automotive markets and generate a great deal of momentum around connected vehicles and advanced driving. Noteworthy developments are also observed in countries such as South Korea, Australia and Japan, and 5GAA is thus actively engaging with these countries as well. These use cases, together with their service level requirements (SLRs) are detailed in the complementary 5GAA C-V2X Use Cases White Paper[11]. As indicated in Figure 3 below, the use case timelines can be segmented into four phases which reflect increasing complexity and technical requirements.

In 2020, we expect that use cases such as Traffic Information and Local Hazard will be complemented with C-V2X direct communication and will lay the foundations for road safety and traffic efficiency. From 2022 onwards, advanced use cases such as Hazard Information Sharing for Automated Vehicles (AVs) and HD Map Sharing for AVs will gradually contribute to the building blocks required for automated driving.

Initial versions of certain advanced V2N use cases, such as Tele-Operated Driving and Automated Valet Parking, can already be implemented today by individual OEMs with LTE-V2X network-based communications and on-board sensors in controlled environments, such as on private campuses. By 2025/26, we expect that these use cases will be extended to operate in more complex environments and scenarios, such as on public roads and in parking garages, leveraging 5G-V2X.

Cooperative Manoeuvres (via direct communication) and Sensor Sharing to support cooperative perception – both basic functionalities for automated driving, e.g. Highway Pilot – are supported by 5G-V2X. We predict that all new AD vehicles will be equipped with 5G-V2X from 2026, in line with their mass production and entry to the market. Complex interactions between vehicles and VRUs via mobile phones – through both direct (PC5) and network-based (Uu) C-V2X communications – are foreseen to start by 2027.

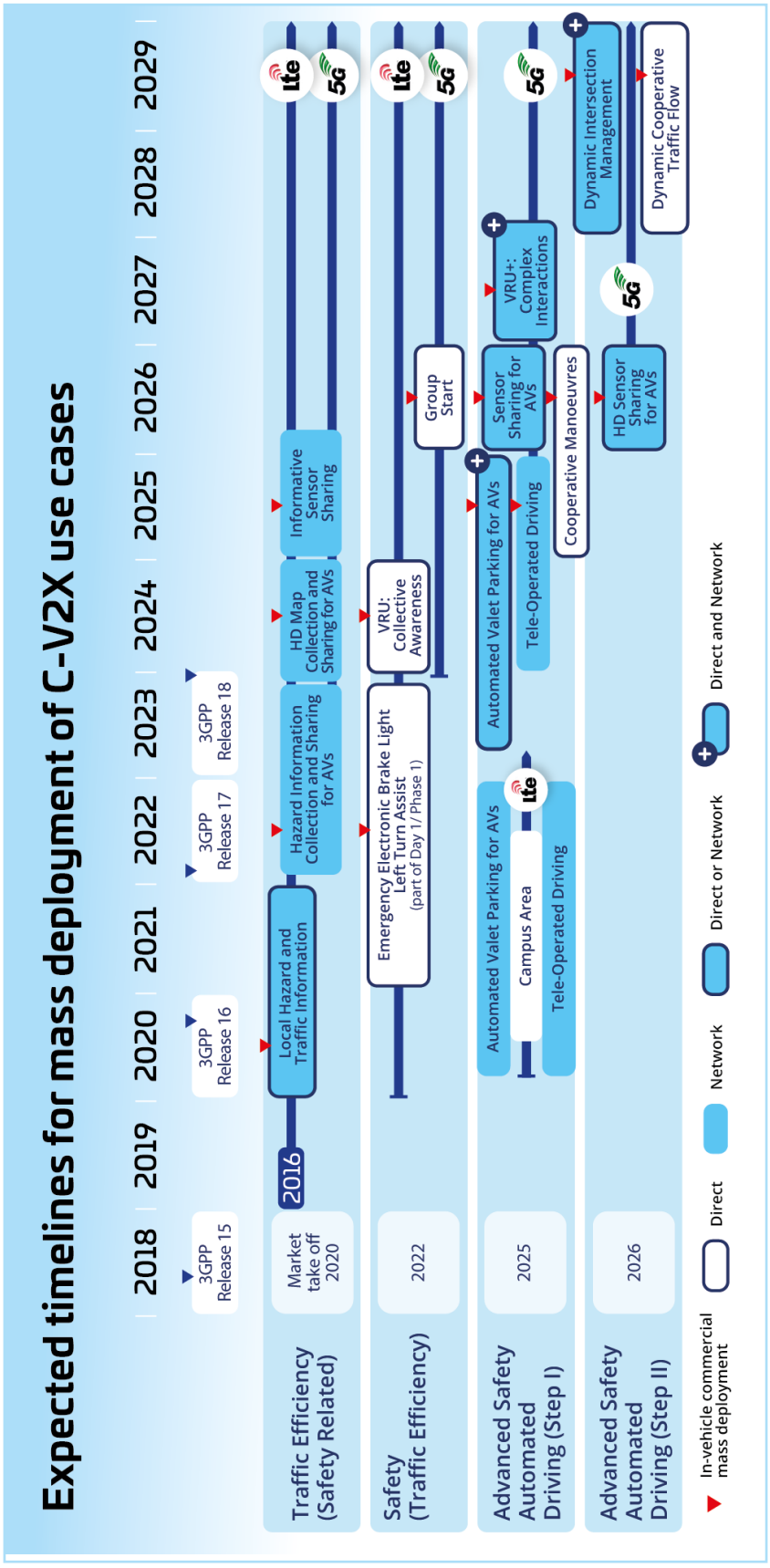
[11] 5GAA white paper: C-V2X use cases volume II: Examples and service level requirements with the use case correspondence listed in the annex https://5gaa.org/news/5gaa-releases-white-paper-on-c-v2x-use-cases-methodology-examples-and-service-level-requirements/

It is to be noted that, in the foreseeable future, we will have a combination of connected and automated vehicles co-existing with normal vehicles that are not enabled by automated driving functions. Connectivity will support automation levels, but also bring benefits to mixed traffic situations, already enabling some use cases on the road to automation.

High-Definition Sensor Sharing, based on 5G-V2X will support the development of further automated driving levels in the future, with first pilots expected after 2026. Enhanced urban and highway pilots are expected to start in 2029 in dedicated areas allowing Dynamic Cooperative Traffic Flow and Dynamic Intersection Management.

According to our studies, additional spectrum for direct communications (including the entire 5850-5925 MHz band globally harmonised for ITS) and for mobile network-based communications (particularly below 1 GHz low-band frequencies and 1-7 GHz mid-band frequencies) will have to be made available for the implementation of many of the use cases identified in the roadmap. This is particularly the case for HD Map Sharing (Uu), Tele-Operated Driving (Uu), Cooperative Manoeuvres (PC5), Sensor Sharing (Uu/PC5), Dynamic Intersection Management (Uu+PC5), Dynamic Cooperative Traffic Flow (PC5), and Complex Interactions with VRUs (Uu+PC5).

Figure 3: Expected timelines for mass deployment of C-V2X use cases



3. Standards

C-V2X builds on cellular mobile network communications (Uu interface) as well as direct communications (PC5/sidelink interface) as defined by 3GPP. The specifications for LTE-V2X Rel-14/15 are finalised. The work on Rel-16 – incorporating specifications for 5G-V2X – and subsequent releases is ongoing in 3GPP.

Generally speaking, the communication layers specified in 3GPP describe the radio communication capabilities and functionalities of C-V2X. Industry continues to develop the upper layers for the support of various use cases by standardisation bodies such as ETSI, SAE, C-SAE, and ISO. These profiles and protocols are then being implemented in end-to-end systems to enable ITS use cases. However, work on the upper layers is often region-specific, taking into account applicable considerations and regulations.

4. 5GAA radio spectrum roadmap

Based on the results of our studies[12], it is the view of the 5GAA that the provision of envisaged advanced driving use cases by LTE-V2X and 5G-V2X for direct communications will require availability of the entire 5.9 GHz band (5850-5925 MHz) which is globally harmonised for ITS by the ITU-R[13]. As the ITS industry develops further, and we begin to better understand the demands of advanced safety and automated driving, we will assess the extent to which the 5.9 GHz is sufficient to meet road users' spectrum needs, and whether additional spectrum designated for ITS will be required.

In light of this, it is the view of 5GAA that national administrations should make as much as possible of the 5.9 GHz band available for use by ITS. Specifically, our positions in relation to China, Europe, and the US are as follows:

China

In China, 5905-5925 MHz (20 MHz) is currently allocated for use by LTE-V2X direct communications for the delivery of ITS services, with the lower 10 MHz block for Vehicle to Vehicle (V2V) communications, and the upper 10 MHz block for Vehicle to Infrastructure (V2I) communications. We expect that this allocation will be sufficient to support initial use cases, but that advanced use cases will require additional spectrum. 5GAA thereby recommends that spectrum availability for C-V2X direct communications in China be extended in accordance with the globally harmonised 5850-5925 MHz band for ITS applications as defined by the ITU-R.

[12] 5GAA 'Study of spectrum needs for safety related intelligent transportation systems – day-1 and advanced use cases', https://5gaa.org/news/study-of-spectrum-needs-for-safety-related intelligent-transportation-systems-day-1-and-advanced-use-cases/

[13] ITU Recommendation 2121, https://www.itu.int/rec/R-REC-M.2121-0-201901-I/en

Europe

The availability of spectrum for ITS in Europe is broadly aligned with the globally harmonised 5850-5925 MHz band as defined by the ITU-R. In Europe, 5855-5875 MHz is designated for non-safety road ITS, whereas 5875-5935 MHz is designated for safety-related ITS. This availability is on a technology neutral basis.

United States

The US is currently consulting on the allocation of 5905-5925 MHz (20 MHz) to C-V2X direct communications, along with the option of allocating 5895-5905 MHz to C-V2X direct communications or DSRC. As outlined above, and in light of the demand for spectrum by advanced use cases, 5GAA recommends that the spectrum availability for C-V2X direct communications in the US be extended in accordance with the globally harmonised 5850-5925 MHz band for ITS applications as defined by the ITU-R.

Furthermore, our studies indicate that the current spectrum allocations available to mobile operators are not sufficient to support the advanced mobile network-based communications anticipated by the automotive industry. It is the view of the 5GAA that national and regional administrations address this with the following complementary actions:

- At least 50 MHz of additional service-agnostic low-band (< 1 GHz) spectrum be made available for mobile network operators to provide advanced automotive V2N services in rural environments with affordable deployment costs.

- At least 500 MHz of additional service-agnostic mid-band (1 to 7 GHz) spectrum be made available for mobile network operators to provide high capacity city-wide advanced automotive V2N services.

In the above, the term “additional” means availability of spectrum in addition to the bands that are currently identified for IMT use by mobile communication networks.

5. Conclusions and recommendations

Based on our vision, we believe that success in the field of advanced safety, automated driving and connected mobility will involve the engagement of all stakeholders, including the telecommunications and automotive industries, in order to foster new business models and investment paradigms. The integration of road and telecommunication infrastructures will deliver better coverage of vulnerable road users, along with enhanced capabilities in vehicles as sensors are further enabled through connectivity. We recognise that there are certain challenges, for example in future protocols, implementation descriptions and conformity/testing needed for advanced driving use cases, which ought to be addressed by 5GAA together with the relevant standards developing organisations (SDOs) and wider industry ecosystem.

We currently face a convergence of multiple trends in the automotive industry that have the potential to dramatically change mobility. Connected vehicles and road/telecommunication infrastructures form a new single digital ecosystem where wireless networks will play a major role in interconnecting elements of the distributed system. The 5GAA roadmap will serve to guide the parties involved in the ecosystem by identifying the required use cases and services which are expected to be enabled by 5G-V2X in the coming decade. This white paper highlights selected end-to-end solutions, and considers their spectrum needs as well as the required technology evolution and readiness.

The Traffic Efficiency track in the roadmap (see Figure 3) lists the entry use cases to be discussed with road operators in order to enable a true Digital Roads vision. As an initial step, digital infrastructure will bring dynamic traffic information, hazard warnings, and HD maps to the driver (up to 2024). In a second step, cooperate manoeuvres and HD sensor sharing provided by road operators will support automated driving above Level 2 through “cooperative perception” (2026). Finally dynamic cooperative driving enabled with the support of road operators at selected hotspots (e.g. intersections) will follow (2029).

The Safety Track of the roadmap is a guide for upcoming NCAP discussions in Europe, Asia and the US, with the aim of reducing collisions, injuries and fatalities associated with vehicles employing C-V2X by 2022. The challenge of zero fatalities for VRUs is addressed in two steps. First by leveraging sensors to detect the VRUs, and roadside units to alert the driver (Collective Awareness, 2024). Second by fully integrating VRUs’ mobile handsets into the ecosystem to enable complex interactions between vehicles and pedestrians, (e-)bikes, and scooters (Complex Interactions, 2027).

The cellular approach offers a unique combination of direct and network-based communications to cover the requirements and needs of all concerned stakeholders for Advanced Safety and Automated Driving. For mobile network operators, all the tracks in the roadmap present examples of future uses of the upcoming 5G-V2X

networks. Building on the unique 5G-V2X features, traffic management as well as automated driving requirements can be fulfilled. Low hanging fruit applications addressing OEM fleets, such as Automated Valet Parking and Tele-Operated Driving will open the door to more secure, safe, and interoperable network-based automotive applications across borders.

The 5GAA roadmap provides a joint stakeholder view for the automotive world. As automated vehicles need a specifically adapted end-to-end architecture, an entire new value chain of chip-makers, device manufactures, mobile network operators and OEMs has to be established. Tracks 3 and 4 of the roadmap link for the first time the readiness of C-V2X technology to automated driving levels. The initial step of connected automated driving starts in campus areas in Track 3, while the final step in Track 4 provides a glimpse, confirmed by OEMs, of the future of connected automated driving. The 5GAA roadmap can be used as a guide to establish the required partnerships among all stakeholders.

On the matter of spectrum, the 5GAA strongly recommends that national administrations make the entire globally harmonised 5855-5925 MHz band available for use by ITS communications between road users and between road users and roadside ITS infrastructure, as supported by the PC5 interface of C-V2X. The 5GAA also places a high value on the importance of communications between road users and mobile network infrastructures in enabling future advanced driving use cases, as supported by the Uu interface of C-V2X. Accordingly, the 5GAA recommends that national and regional administrations ensure the availability of sufficient spectrum for mobile communication networks in the so-called low-bands and mid-bands for the support of services, including ITS, in the coming decade.

From a business perspective, our roadmap is a call for all players to engage and collaborate in order to enable the rapid take-up of these use cases and to deliver societal benefits.

And finally, from a policy perspective, we look forward to working with regulators and policymakers to design a future-proof regulatory framework, conducive to new partnerships and providing clarity on the obligations of various parties.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