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

5GAA Automotive Association
White Paper

CONTACT INFORMATION:
Executive Manager – Thomas Linget
Email: liaison@5gaa.org

MAILING ADDRESS:
5GAA c/o MCI Munich
Neumarkter Str. 21
81673 München, Germany
www.5gaa.org

VERSION:	3.0
DATE OF PUBLICATION:	22 November 2024
DOCUMENT TYPE:	White paper
EXTERNAL PUBLICATION:	Yes
DATE OF APPROVAL BY 5GAA BOARD:	21 November 2024

Contents

Executive Summary

This third edition of the 5G Automotive Association (5GAA) C-V2X Roadmap provides an update of 5GAA's vision for the global deployment of smarter, safer and more sustainable mobility and transportation services. It includes advanced driving use cases and offers a road operator perspective on the deployment of use cases with a particular focus on safety in the US and EU regions.

Since the publication of the first 5GAA Technology Roadmap in 2017, the number of cellular-connected vehicles on the road has now reached more than 300 million[1] globally (December 2024). Two-thirds[2] of new cars sold in the world's leading automotive markets are now connected and several automakers have already released 5G cellular network-connected cars relying on the 3GPP Release 15 specifications of 2019. Many automotive original equipment manufacturers (OEMs) and service providers have extended the list of informative hazard warnings delivered over the cellular network to a fast-growing number of cars. From 2026, Euro-NCAP[3] plans to include the sharing of hazard events via a common cloud in its assessment protocol. Today, more cities provide green lights signal pre-emption to emergency responders, and time-to-green information to vehicles and smartphones[4]. Several proof of concept (PoC) trials based on cellular network connectivity have been conducted around the world to verify and improve the effective protection of vulnerable road users (VRUs).

[1] Abi Research, Connected Car Sales, Market Data, 14.12.2022, MD-CCAR-109

[2] https://www.counterpointresearch.com/insights/global-connected-car-sales-q3-2023

[3] https://www.euroncap.com/media/80158/euro-ncap-assessment-protocol-sa-safe-driving-v104.pdf

[4] https://oca-ev.org

Some OEMs have started to deploy automated vehicle marshalling (AVM) in their production environments.

Vehicles enabled with both cellular-V2X (C-V2X) network and direct communications technologies have been available in China since 2020. Intersection safety use cases are reflected in the new China-NCAP. The US Federal Communications Commission (FCC) has granted waivers to OEMs, road operators and technology providers – more than 50 entities in total – to allow the deployment of C-V2X direct communications in the US. This is also supported by the V2X National Deployment Plan published by the US Department of Transport (USDOT) in August 2024. South Korea decided to deploy C-V2X like China and the US, with an initial focus on safety and efficiency use cases. European OEMs have explicitly expressed their support for 5G-V2X direct communications to pave the way toward automated driving. Japan's government is focusing on a plan[5] to align spectrum usage with other parts of the world to facilitate direct communications adoption. India has also initiated work on the use of V2X technology to improve road safety considering the local road traffic environment and specificities of the vehicles on their roads.

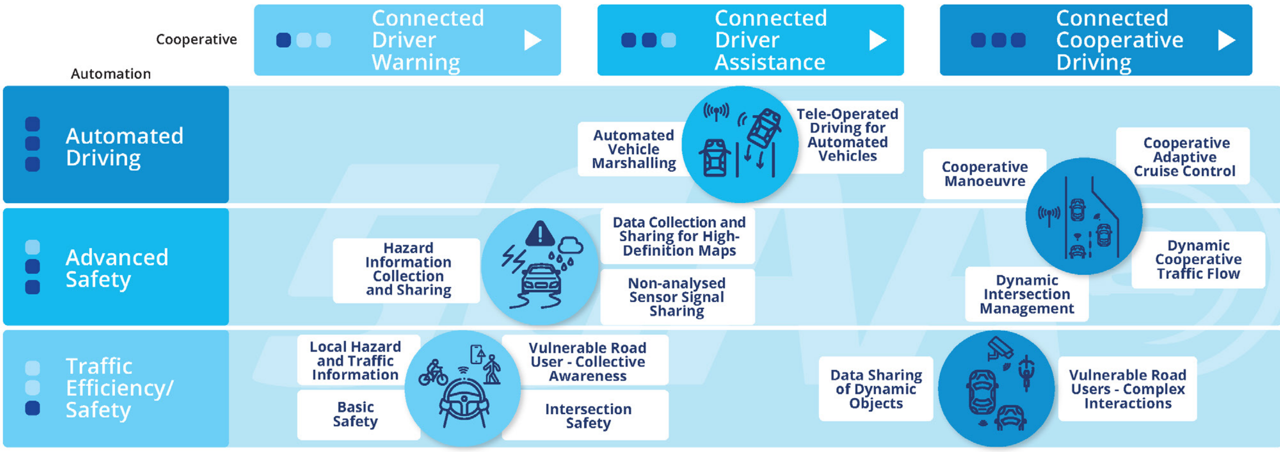

Figure 1: Evolution of C-V2X use cases towards connected cooperative driving

5GAA's high-level overview of the C-V2X market's evolution remains valid compared to our 2022 Roadmap. At the same time, we are pleased to observe positive new market developments that are reflected in the following pages.

The latest Roadmap also shows that more time is needed to bring some of the cooperative automated driving use cases to market readiness even though the first SAE Level 3 (L3) automated driving cars have already been certified in some regions of the US and Europe. The L3 functionality of those cars only indirectly benefits from greater connectivity, for example via data-collection and -sharing for high-definition maps. The direct support of V2X for advanced driver-assistance system (ADAS) functions requires further work by the ecosystem partners. Indeed, several service and message type standards need to be finalised with corresponding profiles before enabling true

[5] https://www.soumu.go.jp/menu_news/s-news/01kiban14_02000660.html

cooperative automated driving use cases. In parallel, regulatory work is progressing in many countries to authorise higher automation (L4) in the vehicles on their roads. In some jurisdictions like Germany, this requires proper connectivity coverage within any L4 operational design domains (ODDs).

With this updated Roadmap, 5GAA recognises the critical importance of an aligned approach between automotive, telecoms, and road operators.[6] Road operators are currently focusing on improving traffic safety and efficiency. This is also reflected in the approved revision of the EU ITS Directive[7] in 2023, with a strong focus on enabling relevant data exchange as well as in the USDOT's V2X Deployment Plan. Following an intensive exchange with various road operators, 5GAA provides in this White Paper distinct road operator-specific roadmaps for Europe and the US.

5GAA constantly monitors the evolution of technology enablers that could play an important role in the connected vehicle ecosystem. As a new addition, the latest Roadmap explains how multi-access edge computing (MEC)[8] and non-terrestrial networks (NTN)[9] are expected to influence the deployment of use cases from 2027 onwards. For example, it highlights that NTN will initially support narrowband data-rate use cases such as third-party emergency or breakdown call and traffic management in disaster situations from 2027 onwards, in line with OEMs' requirements.[10]

Summarising the development over the past few years, the 5GAA Roadmap recommends building upon the fast-growing number of connected vehicles to deploy more use cases and services over the cellular networks. This would improve general traffic safety, efficiency, comfort, and sustainability. It is essential for the different ecosystem players including road operators to intensify their cooperation to find the right approaches for each region or country and to identify and enter sustainable win-win cooperation and business relationships. This improved ecosystem cooperation is also needed to enable standardisation, technology and regulatory work to pave the way for the wide-scale deployment and operation of automated driving. This vision is also reflected in the latest strategy release in China, published in June 2024 (under the name Vehicle-Infrastructure-Cloud Integrated Systems – VICIS).[11] An integrated approach encompassing both direct communications and cellular networks will play an important role in the future of connected mobility, including enhancing the comprehensive protection of VRUs.

6 5GAA has published a complementary whitepaper 'Road Traffic Operation in a Digital Age' [x] with focus on scalable data sharing

7 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0040-20231220

8 https://5gaa.org/content/uploads/2023/04/5gaa-moving-toward-federated-mec-demos-trials.pdf

9 https://5gaa.org/5gaa-discusses-the-role-of-non-terrestrial-networks-in-the-connectivity-of-the-car-of-the-future/

10 Maximising the benefit of future satellite communications for automotive – 5GAA

11 https://www.miit.gov.cn/xwdt/gxdt/sjdt/art/2024/art_53796f0c2b98445783b4dc5ae99ace8f.html
https://www.miit.gov.cn/zwgk/zcwj/wjfb/tz/art/2024/art_b236a25edf9f4a8f9b60dbcda924753b.html

1. Introduction

5GAA has been developing different kinds of roadmaps to guide its strategic work since its foundation in 2016. The previous edition[12] of the C-V2X use case roadmap, released in November 2022, stated "we are on the road to deployment". Since then, both the underlying technologies and the deployment of V2X services have made substantial advances.

Deployment of V2X services is driving a growing demand for efficient information and data sharing among ecosystem stakeholders. As well as road authorities this includes road operators and infrastructure owners and operators (IOOs) which are digitalising their operations, optimising road maintenance, and providing information to all road users. To address this public need, 5GAA has published a white paper[13] that outlines the architecture, methods and real-world references on the realisation of a scalable solution for traffic information sharing. To complement the white paper, 5GAA has produced technical reports that provide further detail on how to realise a number of use cases using a network-based V2X architecture.[14] [15]

Many suppliers are producing LTE-V2X chipsets, modules, and on-board units (OBUs) supporting direct communications and numerous OEMs are deploying these in China. Road-side units (RSUs) are also being rolled out for deployment in China and undergoing large field tests in other regions. The deployment of basic safety use cases in China has followed the growth in the number of enabled vehicles. Many OEMs have also extended the deployment of local hazard information collection and sharing via the cellular network in other regions. Millions of cars connected via 5G cellular networks are on the streets in China, Europe, US and elsewhere, and the first chipsets supporting 5G-V2X direct communications are already available for testing and prototyping.[16]

The US and South Korea have also decided to deploy LTE-V2X direct communications complementing 4G or 5G network connectivity in road vehicles. In October 2023, the USDOT published a draft V2X deployment plan with ambitious targets for C-V2X[17] deployment in three phases through 2034.[18] More recently, in August 2024, USDOT published their final version of the plan following feedback from a host of stakeholders.[19] The growing deployment of C-V2X technology and services has also

[12] https://5gaa.org/5gaa-publishes-updated-2030-roadmap-for-advanced-driving-use-cases-connectivity-technologies-and-radio-spectrum-needs

[13] https://5gaa.org/road-traffic-operation-in-a-digital-age-a-holistic-cross-stakeholder-approach

[14] Vehicle to Network to Everything (V2N2X) Communications; Architecture, Solution Blueprint, and Use Case Implementation Examples

[15] Business Perspectives on Vehicle-to-Network-to-Everything (V2N2X) Deployments

[16] https://auto-talks.com/worlds-first-5g-v2x-chipset-verification

[17] 5GAA definition: 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.

[18] https://www.its.dot.gov/research_areas/emerging_tech/pdf/Accelerate_V2X_Deployment.pdf

[19] https://www.its.dot.gov/research_areas/emerging_tech/pdf/Accelerate_V2X_Deployment_final.pdf

triggered NCAP in Europe and China to include V2X in their safety roadmaps.[20]

More and more cellular network-connected vehicles benefit from cloud-based, real-time traffic information and warning sharing, relying on data from other vehicles as well as from road operators and service providers. (e.g. Vodafone[21], Haas Alerts[22], final V2X USDOT deployment plan...].

European OEMs have embraced 5G-V2X direct communications, making announcements via both the French *Plateforme Automobile* (PFA)[23] and 5GAA.[24] They have also confirmed the benefits of 3GPP technology with its complementary cellular communication (Uu) and direct communication (PC5) elements. Clearly, the increased market penetration of the technology and supported use cases justify our view that the current status can be summarised as "C-V2X deployment has become a reality, and we are on the way to achieving widespread connected mobility with 5G-V2X" (see Annex IV for V2X terminology).

Various countries have released new regulations for automated driving deployment (as compared to testing) by refining 'type' approval as well as defining ODDs. Several cities have started to allow on-demand services using SAE L4 vehicles [US[25], China[26]]. Network connectivity is becoming essential to support the on-demand services and in some countries also to enable their operation.

Some of the forecasts that 5GAA made in 2022 have materialised. On the other hand, the complexity and level of coordination and standardisation required between OEMs has delayed the deployment of several advanced safety and cooperative automated driving use cases. The following sections provide more details on the state of play and recommendations to accelerate the deployment of 5G-V2X technologies.

20 https://www.euroncap.com/media/79890/euro-ncap-rating-review-2023.pdf

21 https://de-he.step.vodafone.com

22 https://www.stellantis.com/en/news/press-releases/2023/may/safely-aware-industry-leading-v2x-activation-equips-1-8-million-stellantis-vehicles-with-emergency-vehicle-alert-system

23 https://pfa-auto.fr/wp-content/uploads/2023/07/PTF_V2X_short-range-radio-technology-choice_2023.pdf

24 https://5gaa.org/open-statement-europe-converging-towards-5g-v2x-including-direct-communications

25 https://waymo.com/waymo-one-san-francisco/

26 https://www.scmp.com/tech/tech-trends/article/3271143/wuhan-driverless-taxis-offer-peek-future-intracity-transport-china

2. C-V2X Roadmap III

The 5GAA C-V2X Roadmap III is based on the Roadmap I and II categories Traffic Efficiency-Safety Related, Safety-Traffic Efficiency, Advanced Safety, and Automated Driving (Step I & II), covering the time period 2020-2030.

In Figure 2 below, as in the previous version, an LTE and 5G pointer indicate the different radio technology 'swim lanes' where use cases are located either on one or both arrows. The green triangles symbolise current 'first in-series production' cases, whereas the red triangles stand for future 'foreseen in-vehicle in-series production'.

The newly introduced 'M' symbol represents (single or cross-) mobile network operator MEC use cases. The light grey colour stands for existing-V2X use cases with extended coverage by NTN satellite communication.

Roadmap III confirms the envisaged timeframe of in-vehicle mass deployment for the automated valet parking (AVP) use case using network communication in 2026. A 5GAA technical report on AVP released in June 2022[27] outlined the communication solution using cellular public networks for AVP Type-2 in mass deployment. In the updated version of this 5GAA AVP technical report in May 2023[28], cellular private networks and direct communication were also described as communication solutions for AVP Type-2. Towards mass deployment of AVP, 5GAA stakeholders worked on the ETSI AVM standard (TS 103 882) defining vehicle motion control (VMC) operation.[29] This will be the basis for the VMC Interface Implementation Profile (IIP) for cross-vendor interoperability tests (Plugtest). 5GAA members are also discussing with related market stakeholders the ecosystems and end-to-end AVP service flow from discovery and reservation to handing back the vehicle to the user at the very end of the AVP service. In addition to the open market deployment, e.g. in public garages, automotive OEMs have already considered AVM use cases in their factories to operationalise automated end-of-production-line solutions.[30][31]

The go-to-market approaches for the roadmap use cases up to 2024 (based on 5GAA Roadmap II) have been confirmed. OEMs have widely adopted local hazard and traffic information as well hazard information- collection and -sharing use cases; this means that traffic data is planned to flow freely to and from the vehicles between several brands as of 2026. The latter use case has been driven globally since 2023 in Europe by the European ITS Directive and Safety-Related Traffic Information (SRTI) delegated

[27] https://5gaa.org/report-on-automated-valet-parking-technology-assessment-and-use-case-implementation-description/

[28] https://5gaa.org/cross-working-group-work-items-automated-valet-parking-technology-assessment-and-use-case-implementation-description/

[29] https://portal.etsi.org/webapp/WorkProgram/Report_WorkItem.asp?WKI_ID=64360

[30] https://www.press.bmwgroup.com/deutschland/article/detail/T0402335DE/pilotprojekt:-autos-bewegen-sich-fahrerlos-innerhalb-der-produktion?language=de

[31] https://www.telekom.com/en/media/media-information/archive/automated-driving-in-port-logistics-1071752

acts[32] and the Data for Road Safety Initiative,[33] in the US by the latest studies of the US FHWA as well as in China by C-SAE and the China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV) with the Vehicle-Infrastructure-Cloud Integrated System (VICIS) pilot programme. In addition, Euro-NCAP is pushing for sharing hazard events through a common cloud for their "safe driving" assessment category.[34]

Vehicle-to-vehicle (V2V) basic safety use case deployment based on direct communication is still dominated by China's Multi-OEM LTE-V2X (compared to Europe with a single-OEM ITS-G5 rollout), as already indicated in the 5GAA Roadmap II. China-NCAP 2024 is driving the adoption of its 'intersection safety' use case category, especially with the test scenario called 'Car-to-Car Straight Crossing Path Obstructed' (C2C SCPO).[35] As a consequence, most premium OEMs in China are expected to adopt the SCPO use case using LTE-V2X direct. This technology push is shown on the updated Roadmap via a green triangle symbol meaning 'in-series production' for the direct communication-based use case.

The use of technology to further improve intersection safety will continue to evolve. A prime example of this involves the use of infrastructure-based sensors (e.g. cameras, lidars, radars) at an intersection to detect VRUs, vehicles, and potentially other objects or incidents (collision, fire, smoke...) impacting safety, and then disseminating relevant information to oncoming road users near the intersection using C-V2X.

This type of system can be used to address a wide range of intersection safety use cases. It also offers day-1 safety benefits for V2X-equipped vehicles during early market introduction when only a small fraction of vehicles is equipped with direct communication equipment.

5GAA plans to publish a technical report on infrastructure-based intersection safety use cases documenting the concept of operations, descriptions of various deployment options, and detailed system-level profile recommendations on the messages and protocols needed to enable interoperable and trustworthy implementations. The profiles for various regions of the world are being defined based on the use of existing message standards, such as the sensor data-sharing message (SDSM) in the US, collective perception message (CPM) in Europe, and sensor-sharing message (SSM) in China.

With the series production start of SAE L3 vehicles by Mercedes as well as BMW in 2023, the data-collection and -sharing for HD maps use case was brought forward from 2024 to 2023, a perfect example of the benefit of 5G cellular connectivity for automated driving (AD).

The success of the HD map-based sharing might be one reason why other sensor-sharing use cases – non-analysed sensor signal-sharing, and data-sharing of dynamic objects – kept their foreseen in-vehicle in-series production dates in 2026 and 2027, respectively. The finalisation of the sensor-sharing protocols at C-SAE, SAE, and ETSI

32 SRTI regulation https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R0886

33 https://www.dataforroadsafety.eu/

34 euro-ncap-protocol-safe-driving-vehicle-assistance-v09.pdf

35 https://www.castc.net/news/9786.cshtml (in Chinese)

come along with high go-to-market expectations, especially when considering the introduction of 5G-V2X direct in Europe.

MEC-enabled uses cases involving a single MNO, such as AVP, are expected in 2026 whereas multi-MNO MEC use cases have been pushed to 2028-2029. Despite some efforts at ITS World Congress in Hamburg in 2021 and the 5GAA showcases in Detroit (2023) and Berlin (2024), market traction on the road operator and OEM side was lower than anticipated during the 5GAA Open Workshop on Edge Computing and V2X back in 2018.

Teleoperation on the open roads is still limited to campus/restricted-area deployments leveraging indirect control through advice/suggestions to the vehicle. Although direct control of vehicles' motion-based teleoperation is technologically feasible, the current trial/temporary licences approach hinders faster go-to-market strategies in Germany, for example.

In addition to the sensor-sharing use cases driven by LTE-V2X and 5G-V2X developments, we are seeing future cases involving cooperative adaptive cruise control (ACC), group start, and other cooperative manoeuvres. In Europe, 5G-V2X may also be used to enhance support for VRU protection use cases (see VRU+ complex interactions on Figure 2). A first demonstration for VRU-to-vehicle communication with LTE-V2X direct devices has been shown for cyclists in the US (a special certification programme has started[36]).

Another update of the Roadmap III is the introduction of NTN-supported use cases. Based on 3GPP Releases 17, 18, planned Release 19, and announcements from the mobile phone industry to support NTN direct-to-device (D2D) technology as a network coverage extension for C-V2X, uses cases such as third-party emergency call and traffic management in disaster situations have been added to the present Roadmap.

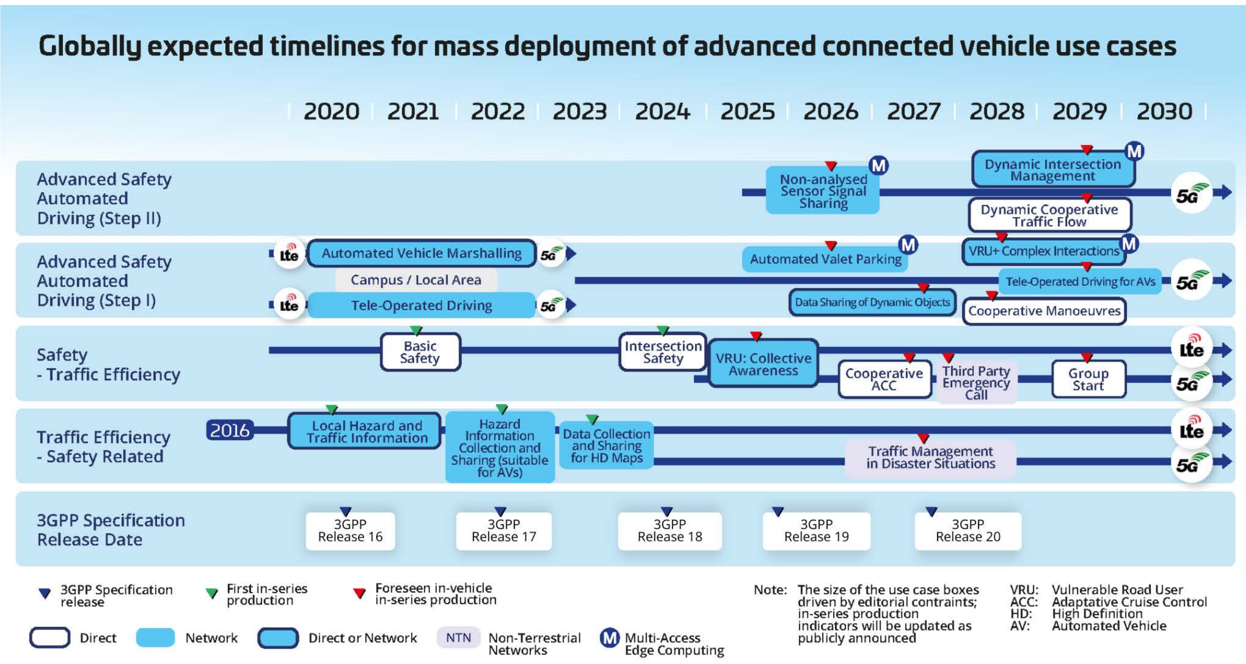

Figure 2: Globally expected timelines for mass deployment of advanced connected vehicle use cases

[36] Berlin Technology Demonstrations Highlight Life-Saving Potential of Latest Cellular Vehicle-to-Everything Tech – 5GAA

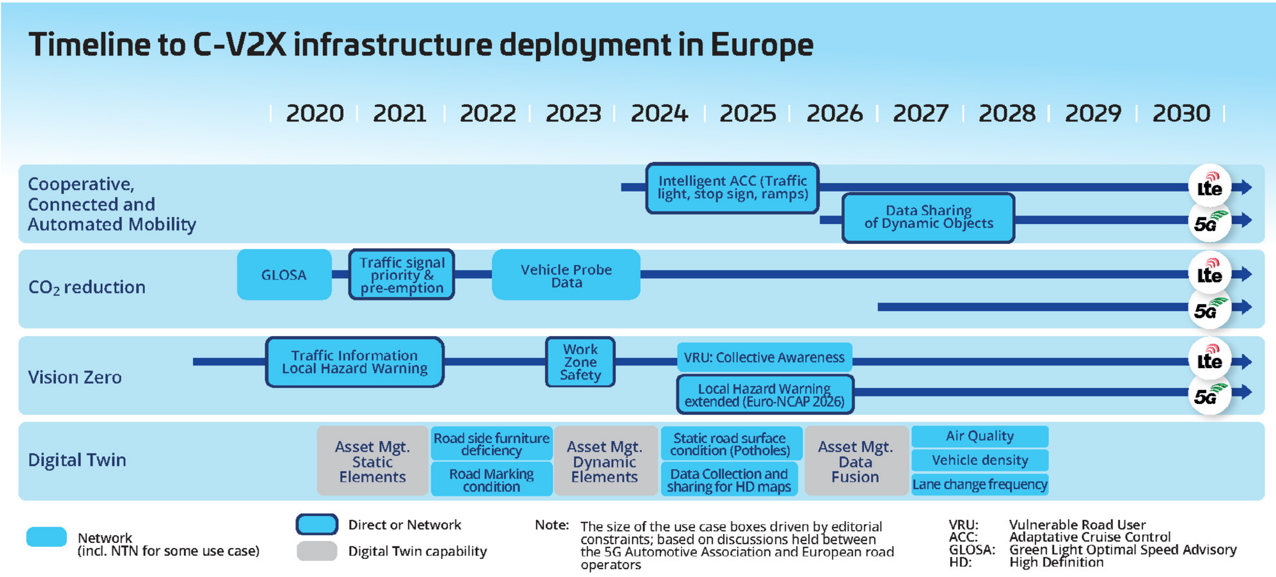

Figure 3: Timeline to C-V2X infrastructure deployment in Europe

Based on the discussions held between 5GAA and European and US operators, pathways to C-V2X infrastructure were established both regions. This is in line with governments worldwide aspiring to use V2X deployment to achieve Vision Zero, or a future in which there are no fatalities or road injuries involving vehicles on their countries' roads. With the revision of the ITS Directive in Europe (2023), C-SAE V2X Strategy 2030 announced, and US V2X deployment plans published (2024), a combination of V2N and infrastructure to vehicle (I2V) will contribute to Vision Zero. Road operators are often primarily deploying V2X direct (leveraging aftermarket devices) for their own fleet (e.g. road maintenance, winter service, public transport, emergency services…) as well as for hazard warnings like road worker alerts (e.g. by Autobahn GmbH). In addition, hazard information and alerts are being collected in centralised databases (crowd-sourcing, EU Napcore, Data for Road Safety (DfRS), Euro-NCAP 2026). In the future, NTN has potential to vastly improve proper service coverage to the complete road network, even low trafficked roads, in the future. Expanding the service from highways to rural roads will be essential to achieve Vision Zero. The benefits of the policy also extend to post-crash services (e.g. emergency vehicle traffic light prioritisation, eCall) as well as intersection safety (red light violation warnings) with V2N and/or V2I coverage.

Sustainability and reduced CO_2 from road traffic are becoming more and more important. Pre-emption and prioritisation at connected intersections (e.g. Green Wave for Trucks in Antwerp[37] [38] and Open Bridges notification in Florida[39]) are not only increasing traffic efficiency but also decreasing CO_2 emissions. Sharing vehicle traffic data at intersections and highways allows CO_2-efficient traffic planning.

Following multiple exchanges with European and US road operators a trend towards

[37] https://be-mobile.com/nl/news/1-8-million-for-cooperative-intelligent-transport-systems-in-trucks

[38] Talking Traffic - DMI ecosystem

[39] FDOT Launches New Bridge Notification System on Florida 511 - Home

increased services such as traffic light priority for public transport, blue and orange light vehicles has been observed. Use cases and the technology deployed differs between regions. Public and private road operators in Europe are also discussing additional ADAS functionality from the infrastructure via 5G-V2X direct.[40]

Cooperative, connected and automated mobility/Connected and automated vehicles (CCAM/CAV) is currently mostly related to ADS, such as AD L4 support for people movers at city intersections or AD L4 trucks on highways. Several (private) road operators are focusing their business in this direction.[41]

Road asset management is essential for road operators to reduce the cost of road maintenance. Leveraging traffic data and fusion techniques can be applied to both static and dynamic elements, e.g. roadside furniture deficiency, road markings, and road surface condition. 5G-V2X can also help road operators measure air quality, vehicle density, and lane-change frequency.

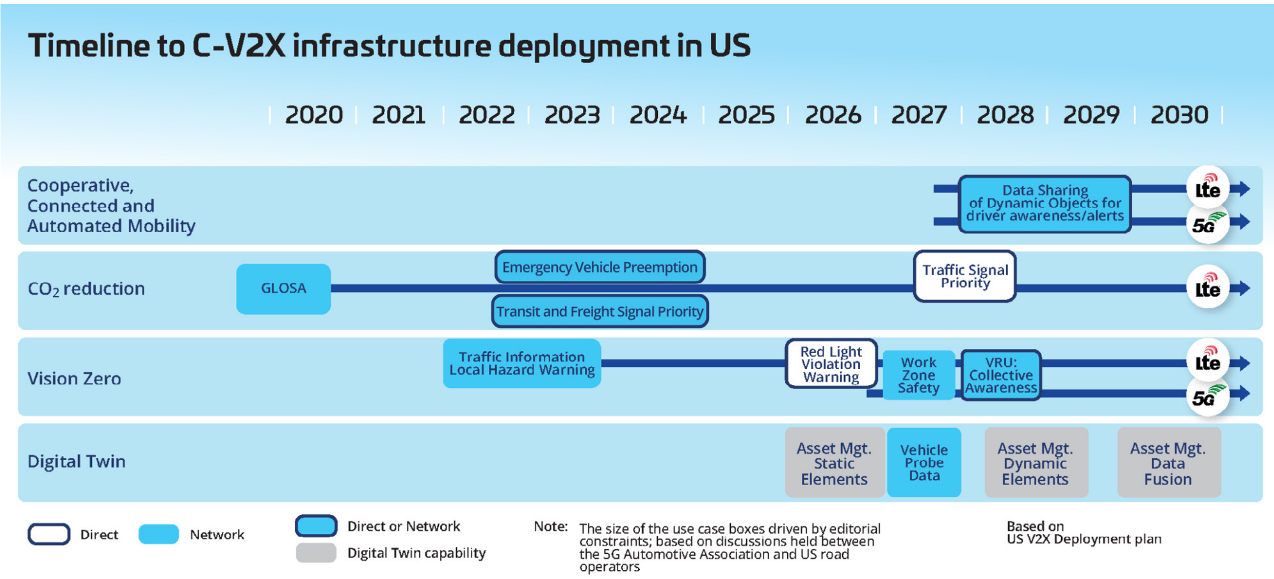

Figure 4: Timeline to C-V2X infrastructure deployment in the US

The expected deployment guidance to the USDOT-led National Deployment Plan will likely reflect the recommendations in 5GAA's *United States Vehicle-to-Infrastructure Communications Day One Deployment Guide,* released in October 2023, as it provides a set of day-1 recommended messages that can be used in the 30 MHz range without performance degradation. Applications can be mapped to what USDOT calls the short-term phase, approximately 2024 to 2027, and are primarily V2I messages aimed at basic safety – largely at signalised intersections with traffic signals. This aligns with a long-term USDOT goal to equip 85% of the signalised intersections in the top 75 metropolitan areas in the US with C-V2X, presumably direct communications (although the goal of full coverage of the National Highway System will likely require

[40] https://5gaa.org/road-operator-use-case-modelling-and-analysis/

[41] https://5gaa.org/road-operator-use-case-modelling-and-analysis/

complementary network communication). USDOT will also support the development and deployment of smart intersections, combining detection and communications. Importantly and complementary to both of the above, the USDOT plan presses for aftermarket devices that could equip public and private fleets with C-V2X. This, in turn, could enable priority and pre-emption-driven equipping of intersections to open a deployment path to RSU installations that are applicable to OEM fleets within a few years. There are also existing implementations of pre-emption and priority using network communication.[42] Based on the experience gathered by these installations, network communication can complete the USDOT deployment plan, in combination with an open, interoperable nationwide platform.[43]

To help accelerate deployments, 5GAA has outlined and described a transformative approach for automotive stakeholders, emphasising scalable digital data exchange and a federated architecture to manage road traffic information efficiently.[44] The architecture ensures bidirectional communication, delivering static, semi-static, and near real-time data for safe and efficient transportation. The paper concludes with recommendations for a US National Roadway Digital Strategy, federated information-sharing structures, and aligned investments, emphasising the integration of different technologies and data-driven decision-making.

In the mid-term (beyond 2027), 5GAA expects more VRU use cases for two-wheelers (two-wheeled equipment) and implementation of SAE J3224, which allows deployment of SDSM between equipped vehicles and the roadside infrastructure, and perhaps other advanced applications.

[42] https://appinfoinc.com/applied-information-cv2x-testing-in-metro-atlanta

[43] https://itsa.org/advocacy-material/beyond-5-9-v2x-deployment-plan

[44] https://5gaa.org/road-traffic-operation-in-a-digital-age-a-holistic-cross-stakeholder-approach/

3. Use Case Descriptions

3.1 Road Operators

In the following section, four road operator use cases have been elaborated. The objective is to provide examples for each of the listed use case categories.

3.1.1 Green Light Optimised Speed Advisory and Signal Violation Warning

In this use case, a vehicle is advised on potential manoeuvres to take when approaching a traffic signal to minimise full stops and hard accelerating and braking behaviour. This smoothens the driving experience for the user and reduces the risk of collision. Several user scenarios have been identified:

A) In the first scenario, the traffic light will turn green by the time the vehicles reach the intersection and advise the drivers to stay within a given speed range that allows them to reach the green-light phase without the need for slowing down and accelerating again.

B) Another user scenario indicates to the oncoming vehicles the traffic light ahead is about to turn red, and the vehicles advise drivers to decelerate and come to a smooth stop at the traffic light.

C) Lastly, the signal violation warning use case plays a similar role but instead of merely suggesting an ideal speed, the driver receives an alert indicating the risk of a violation of an upcoming traffic signal if the driver does not adapt to the situation. Other oncoming drivers, and VRUs, should also receive a timely warning to increase awareness of their surroundings.

3.1.2 School Bus Warning

This use case serves to warn and inform drivers of the presence of a school bus. However, it equally serves as a warning to the bus driver of approaching vehicles violating the road rules – US drivers must stop when a school bus is loading/unloading passengers, as indicated by an extended stop-arm situated on every school bus. If a vehicle is not stopping, a warning is issued that a vehicle is misbehaving, and this enables the bus driver to take appropriate action. In the approaching vehicle, the driver is simply 'informed' of the presence of a school bus stopped ahead, and in an imminent situation the driver receives a 'warning' that the bus is stopped ahead.

3.1.3 Roadworks Warning

This use case explicitly warns and informs drivers of the existence of roadworks ahead. In the first instance of this use case, the roadwork is situated a short distance ahead of the vehicle's location, therefore posing imminent risk not only to the vehicle but also informing of potential workers active in the construction zone. This takes the form of an active warning to the driver. In the second instance, the roadworks zone is further ahead on the planned route. In this case, the vehicle can avoid the roadwork altogether by taking another route.

3.1.4 V2X Enhancing ADAS

The interest in 'V2X on top of ADAS' has increased since the Roadmap II release. One use case already regulated in legislation is automated valet parking (AVP).[45] With AVP being discussed within the German Automotive Association (VDA),[46] 5GAA and ETSI working groups, the different operation design domains (ODDs), such as for factory marshalling and mixed traffic parking garages, and their effect on the V2X protocols form a new requirement. It became obvious that the ODD-dependent functional safety strategy has an impact on the V2X protocol and therefore future protocols must be extendable and adjustable with mandatory elements supporting the required functional safety strategy.

In addition, the results of the SECUR project (V2X Project by UTAC, France) led to a separate discussion in Euro-NCAP about V2V communication centring around "displaying a message to the driver vs. initiating an action of the vehicle". Different categories of messages on the vehicle display such as information/awareness and warning have been created in the SECUR project. 'Warning' was defined in an NCAP way, meaning if there is no driver reaction the vehicle must act (currently based on information collected from its own vehicle sensors). A concrete example of such a warning is forward collision warning (FCW). China-NCAP 2024 includes such a scenario (C2C SCPO) targeting intersection safety with V2X direct support.

Both activity streams led to the creation of an ETSI study item focused on functional safety [TR 103 917] for future V2X messages. The upcoming C-SAE 'Roadmap based on C-V2X' lists functional safety as a future topic to be addressed for C-ADAS and C-ADS.[47]

'V2X on top of ADAS' does not automatically require functional safety. Euro-NCAP lists intelligent ACC functions based on road elements, e.g. intersections, traffic lights, roundabouts, and stop signs for 2026. Given the ramp-up of a common hazard event database starting in 2026, crowd-sourcing might enhance the hazard event data quality to enable intelligent ACC for latent and dynamic events in 2029. (Soft interventions might be introduced based on direct and network-based communication.)

[45] Automated-Valet-Parking-Technology-Assessment-and-Use-Case-Implementation-Description-Final

[46] https://www.vda.de/en/news/publications/publication/automated-valet-parking-systems

[47] C-SAE 'C-V2X-based Research and preparation of the Intelligent Networked Integrated Development Roadmap, officially released as draft for comments at the 2023 World Intelligent Connected Vehicles Conference, Beijing, 20-14 Sept.

Conclusions and Recommendations

Since the release of the 5GAA Roadmap II, the US and South Korea decided to allow the deployment of C-V2X direct communications (LTE-V2X direct). In addition, Japan has started to investigate assigning spectrum in the ITS 5.9 GHz frequency band for direct communications. Finally, European OEMs have stressed the desire to deploy 5G-V2X direct communication in Europe in the future.

China NCAP 2024 and Europe NCAP vision 2030 are both pushing direct communication for vehicle safety.[48] China NCAP 2024 has defined non-line-of-sight scenarios (intersection, highway) in which direct communication will be required to get a 5-star+ ranking (category 'crash avoidance'). Several premium OEMs have started to implement LTE-V2X direct communication, among others Buick GL8 Avenir, GAC Motor's AION LX Plus/AION V Plus, SAIC Motor's Rising Auto R7, and NIO's ES8\ES7\EC7\ET7. Euro-NCAP will recognise direct communication as part of its 'safe driving category' starting from 2026, focusing on 'local hazard warnings'. In the latest draft EuroNCAP protocol on Vehicle Assistance (dated November 2024) awards credits for vehicles able to send and receive local hazards via cloud and/or direct communication (ITS-G5 or C-V2X).

However, complexity in standardisation and the level of coordination needed across stakeholders including OEMs, IOOs, policymakers, MNOs and other players has led to delays in the deployment of several advanced safety and cooperative automated driving use cases. Meanwhile, further standardisation work (SAE, C-SAE, ETSI) is necessary to enable communications to play a bigger role in support of cooperative automated driving.

New regulations for automated driving and certification of vehicles as well as ODDs have been released,[49] which include the requirement for seamless connectivity in the defined ODD. Examples include AD SAE L4 people mover, AVM at OEM plants as well as AVP in public garages[50].

5GAA sees the need for increased cooperation within the stakeholder ecosystem to make a significant impact on safety, efficiency, and sustainability. Therefore, the updated 5GAA Roadmap III includes road operator roadmaps for both the US and Europe. Investment in data exchange and services infrastructure complementing the digitalisation of road infrastructure is a prerequisite to ensure data availability and quality. In addition, 5GAA sees public and private actors introducing more C-V2X direct communication aftermarket devices. For these devices, integration into common public key infrastructure (PKI) data encryption systems must be ensured. 5GAA will continue to cooperate with road operators and regional organisations around the world to understand evolving needs and facilitate cooperation.

In areas with no terrestrial network coverage, NTN will play a growing role in providing seamless and ubiquitous connectivity. First, narrowband IOT NTN will support narrowband data rate services. Later, new radio (NR) NTN based on 3GPP Releases 17 and 18 will support wideband and broadband services. The mass deployment will depend on the actual implementation of new satellite constellations based on 3GPP

48 https://cdn.euroncap.com/media/74468/euro-ncap-roadmap-vision-2030.pdf

49 EU-Level - Connected Automated Driving

50 EU-Level - Connected Automated Driving

standards. In September 2024, 5GAA published a separate technical report on its vision regarding deployment scenarios of services benefiting from NTN.[51]

Since the last Roadmap's publication in 2022, the major European carmakers have signed a joint letter to give new impetus to connected cars in Europe, based on 5G-V2X technology including direct communications, moving beyond past technology disputes. In the EU work programmes under the ITS Directive for the period 2024-2028, the development of automated functions leveraging communication technology is explicitly mentioned. In China, the launch of the Vehicle Infrastructure Cloud Integrated System (VICS) emphasises scaling and nation-wide harmonised services using a hybrid solution of C-V2X direct and network-based communications technologies. The recently announced US V2X National Deployment Plan starts with a public infrastructure programme driving infrastructure-to-vehicle solutions for highways and urban areas (e.g. intersections) following a similar hybrid solution to deploy C-V2X nationwide.

This updated roadmap serves as strategic guidance to engage in technical activities with 5GAA members in the years to come. Focusing on V2X for ADAS/ADS, trust has become one of the most important topics. Going forward, 5GAA and partner organisations are increasing efforts to pave the way towards more advanced technologies including closely coupling ADAS and ADS with connectivity (direct or network) and enabling more complex cooperative manoeuvres by developing corresponding, highly secure interfaces for sending and receiving vehicles. Among the lowest hanging fruits, 5GAA is working on enhanced trust concepts for ADAS/ADS in areas such as AVP, infrastructure-based information, VRU detection, and automated braking functions.

[51] https://5gaa.org/maximising-the-benefit-of-future-satellite-communications-for-automotive

Annex I: Standards and Spectrum

Radio Access Layers

3GPP introduced the RAN LTE (4G) in Release 8 and 5G NR radio access technology (RAT) in Release 15. Successive releases have continuously expanded the specifications with additional features and incremental, backwards compatible enhancements. Mobile network operators, network vendors, device manufacturers and chipset suppliers typically implement only a subset of the optional features that belong to a certain 3GPP release, according to market request, and to the requirements of their specific product and service.

It is worth noting that some 3GPP features are intended to improve system capacity and performance, i.e. supporting a higher service penetration in the network for a given user experience. Other features instead primarily target link performance, thus directly improving the service experienced by a specific user.

In the LTE case, automotive-specific enhancements were introduced in Release 14, including some Uu interface-related aspects such as enhancing the quality of service (QoS) framework, optimising scheduling for periodic traffic and by adjusting multi/broadcast functionalities. Nevertheless, most automotive services can be supported even without such Release 14 enhancements in the Uu interface. 3GPP has also specified since Rel-14 the C-V2X radio interface for automotive direct communications (PC5 interface) based on LTE RAT, called LTE-V2X Direct. In 3GPP Release 15 this PC5 interface was enhanced to provide higher throughput.

3GPP Rel-15 introduced 5G targeting many vertical industries. Automotive use cases can benefit greatly from 5G NR features in Rel-15 and its evolution in ensuing releases. Additionally, some enhancements to the 3GPP 5G Core Network also benefit certain automotive use cases, including various network exposure features, predictive QoS, network slicing, etc. The specifications for Rel-14 and Rel-15 were finalised in 2017 and 2018.

Since Release 16, 3GPP has been specifying the C-V2X direct communications (PC5) radio interface for automotive uses based on 5G NR RAT and including many additional features, such as shorter symbols enabling even lower latency, feedback channels to increase reliability, as well as higher capacity and support of unicast and multicast in addition to broadcast transmissions. 5GAA refers to 5G-V2X, including direct communications, as the worldwide consensus for the future of automotive connectivity while different deployment options may appear in different regions, e.g. with or without LTE-V2X. In 3GPP Release 17, 5G-V2X was enhanced to increase power efficiency supporting UE devices carried by VRUs. The work on Rel-16 and 17 –

incorporating specifications for enhancements – was completed in 2020 and 2021; and work on further enhancements in Release 18 is ongoing in 3GPP.

Additionally, 3GPP has been working on the UE positioning topic since Release 9 with the enhanced cell identity (ECID) and observed time difference of arrival (OTDOA) methods. In Rel-15, 3GPP introduced mechanisms in LTE to provide efficient assistance data for GNSS applications, in particular global navigation satellite systems real-time kinematic (GNSS-RTK). Thanks to this, UEs can benefit from centimetre-level positioning accuracy enabled by the carrier phase-based RTK, which will be a key enabler for most advanced C-V2X use cases. It is worth mentioning that to further improve the scalability of the system, 3GPP also specified transmission or broadcasting of such positioning assistance data via system information blocks (SIBs). The GNSS-RTK support is also specified in Rel-16 for NR.

The evolution of 3GPP C-V2X capabilities is depicted in Figure 5 showing how new functional capabilities are gradually enabled by each new release to deliver more advanced automotive use cases such as sensor-sharing, cooperative manoeuvres, VRU complex interactions, etc.

C-V2X: Evolution and functional capabilities

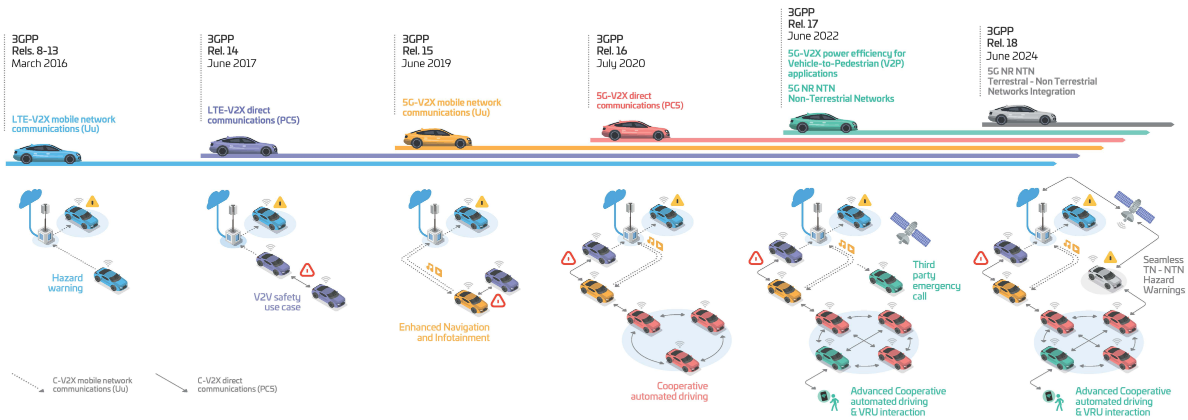

Figure 5: Evolution of 3GPP C-V2X capabilities

Upper/Application Layer Standards

For a scalable sharing of road traffic information between actors using interconnected back-end systems, standard internet technology and protocols, such as advanced messaging queuing protocol (AMQP) with publish/subscribe, methods needs to be used in combination with the use of meta data to allow filtering and transcoding, i.e. when information is 'published', actors 'subscribing' get the information pushed to them based on their filtering choice. The use of AMQP with meta data to identify the actual information (payload) exchanged provides a payload-agnostic solution, i.e. different types of information in different formats can be exchanged, such as ETSI formats, SAE formats, DATEX formats. This provides a future-proof platform for the data exchange, extendible to support additional payload formats or formats used in other regions as well. The use of meta data provides powerful methods to filter information, e.g. only get what is supported. The use of AMQP, meta data and interoperability is further described in 5GAA technical reports[52].

Implementation Profiles

Interoperability is one of the prerequisites for successful mass deployment and operation of AVP service on open markets. Interoperable service operation across various automotive OEM brands and AVP service operators (e.g. parking garage operators) requires unambiguous implementation of the vehicle motion control (VMC) interface on both the vehicle side and the AVP infrastructure side, i.e. remote vehicle operation (RVO).

In 5GAA, AVP interface implementation profile (IIP) is a technical specification described as the minimum set of testable requirements to ensure the interoperability of VMC interface implementations in AVP Type-2 service operation. An IIP contains all necessary technical requirements on both the vehicle side and the RVO side to enable interoperability over the VMC interface, including the vehicle motion control mode at the application layer, the communication protocol stack configurations covering transport, network, and access layers, as well as security and safety solutions and setup. Multiple IIPs may exist due to various technical options at each layer and existing IIP may evolve to new versions. But interoperability is guaranteed only between implementations following the same IIP and the same version.

IIPs are used by developers and testers of AVP products for vehicles and AVP infrastructure to ensure the interoperability over the VMC interface with other vendors. The nomenclatures of IIPs, once agreed by stakeholders, are also used in messages and communications for AVP service announcements and for processes like discovery, negotiation, reservation, billing, etc., to ensure interoperability throughout the service operation.

Given the fact that multiple protocols and technical solutions exist for RVO to control the vehicle, and different communication technologies can be used for the communication between vehicle and RVO, 5GAA foresees different implementations of the VMC interface on the market. To enable successful AVP service deployment on the open market, IIPs and the nomenclature of IIPs need to be harmonised across all stakeholders. To avoid fragmented markets and reduce the complexity and cost of AVP Type-2 products, the number of harmonised IIPs needs to be limited.

52 https://5gaa.org/vehicle-to-network-to-everything-v2n2x-communications-architecture-solution-blueprint-use-cases

Spectrum Considerations

5GAA foresees an important medium-term (2025-2027) objective aimed at confirming the 5.9 GHz spectrum configuration for mass adoption of C-V2X direct radios for advanced driving in different regions of the world.

In China, 5GAA anticipates that the Chinese authorities will initiate a regulatory process for allocating an additional adjacent band for 5G-V2X, preferably 40 MHz below the current 20 MHz allocation in which LTE-V2X direct is deployed.

South Korea evaluated V2X technologies and made a technology decision in December 2023. It has adopted the 3GPP technology LTE-V2X, a similar 20 MHz plus 40 MHz allocation could be used for C-V2X.

In Japan, where a V2X system based on ARIB is being operated in 760 MHz, the Ministry of Internal Affairs and Communications (MIC) is actively studying 5.9 GHz V2X system for advanced V2X services targeting the frequency allocation in Japan FY2026.

In the US, the regulatory process and litigation challenging the FCC 5.9 GHz band ruling has delayed adoption of FCC rules permitting the mass market deployment of LTE-V2X in the 5.9 GHz band and mass-market deployment. However, many 5GAA members as well as multiple departments of transportation, and other industry stakeholders have filed FCC Waiver Requests that were largely approved, which enable the start of C-V2X mass deployment. Infrastructure deployment has already started and 5GAA expects first vehicle deployments to follow soon. FCC voting on a final ruling was scheduled for end 2024.[53]

In Europe, 5.9 GHz was designated for safety-related ITS on a technology-neutral basis in 5875-5935 MHz under the CEPT/ECC Decision (08)01 and EU Decision 2020/1426. Furthermore, the frequency band 5855-5875 MHz is available for ITS (non-safety applications) under the same ECC Recommendation (08)01. 5GAA is advocating to adopt a priority-based framework for use of ITS channels that could lead to adjacent operation of the two different technologies.

Countries such as Brazil, South Africa, Australia, Mexico, and others have allocated and adopted rules permitting deployment of V2X in the harmonised 5.9 GHz spectrum. Furthermore, based on results of 5GAA studies on the spectrum needs of C-V2X network-based (V2N) communications, the following conclusions can be drawn:[54]

a) At least 50 MHz of additional service-agnostic low-band (<1 GHz) spectrum

[53] https://docs.fcc.gov/public/attachments/FCC-24-123A1.pdf

[54] https://5gaa.org/wp-content/uploads/2021/10/5GAA_Day1_and_adv_Use_Cases_Spectrum_Needs_Study_V2.0.pdf

would be required for mobile operators to provide advanced automotive V2N services in rural environment with affordable deployment costs.

b) At least 500 MHz of additional service-agnostic mid-band (1 to 7 GHz) spectrum would be required for mobile operators to provide high-capacity, citywide advanced automotive V2N services.

Annex II: Attributes and Technical Enablers

Mobile Network Positioning

Using the service from mobile networks to receive 3GPP standardised RTK-GNSS correction data is a widely known service already available for the automotive industry. The sector is also currently evaluating 5G NR precise positioning to enhance accuracy in areas of poor GNSS coverage (e.g. tunnels, underground parking, urban canyons) as a feature to support autonomous driving and V2X (basic) safety and local hazards applications. Also, autonomous driving use cases may require high position accuracy (e.g. 20 cm accuracy to locate a vehicle in the centre of a designated lane) and in many scenarios GNSS cannot provide such accuracy (e.g. 2 m accuracy), so 5G NR is under evaluation as part of the sensor-fusion capabilities to provide enhanced position accuracy supplementing GNSS and GNSS corrections.

Direct Communications – Positioning

In addition to positioning over the network, 3GPP decided to study positioning techniques over PC5, i.e. device-to-device. This positioning approach leveraging the direct communication capabilities of 5G allows users to position devices in out-of-coverage scenarios as well. In turn, PC5 may enhance the reliability, availability and robustness of the positioning framework within 5G. In its most basic realisation, positioning over PC5 makes 'ranging' between devices possible – i.e. if the distance and the angle of arrival is known, a position in a local coordinate system can be determined, giving a 'relative position'. However, it should be noted that as soon as one device is either a static anchor with a known fixed position or a device with a position in a global coordinate system, an 'absolute position' can also be obtained. PC5 positioning is also studied to be combined with positioning over the network. Again, this hybrid positioning mode can improve the reliability and robustness of the 5G-based positioning, especially in urban mixed traffic environments. Rel-18 supports PC5-based positioning for different solutions including TDoA, AoA and round-trip time. The positioning accuracy depends on the scenario and the available bandwidth.

Mobile Network Mobile Network – APIs/ Quality of Service

Specifically, mission critical services such as safety, advanced safety, and automated driving features will benefit from mobile network QoS capabilities. In this way, basic mechanisms that will be deployed by mobile network operators include a 3GPP

QoS framework and 'network slicing' to ensure network performance for prioritised automotive applications even in congested situations, and 'network exposure' API's facilitating the usage of QoS-on-demand by the end users. Based on the AVP use case, more technical details can be found in the relevant 5GAA technical report[55].

It is important to note that all described QoS mechanisms are working on an application level, and not device level. So, different applications might make use of different network slices, and some applications might use a network exposure API for QoS-on-demand while others may not. This also addresses the needs of automotive applications with different QoS requirements because they are operated in parallel (e.g. an AVP application is executed while status information is transmitted to the OEM back-end, or a map download is performed).

Network slicing is a tool for separating network resources in order to provide a more consistent service. Additional tools, such as the 3GPP QoS framework, may be applied for data traffic flows within a given network slice. User route selection policy (URSP) provides a foundation for delivering dynamic selection, enabling traffic steering and the separation of services for devices when using network slices. When devices have URSP capabilities, the UE is able to use these slices according to the policies defined for the subscription.

The network offers the information about available slice types to the device via URSPs, thus adding further details regarding which network slices the device's underlying applications should use when activated. Therefore, the device knows in advance of operating a certain use case which slice types are available and how to get access to the relevant one for that application. Questions on which applicable slice(s) to use need to be discussed with the corresponding MNOs, and this relationship or profile still needs further standardisation according to slice types and characteristics. 5GAA is making contributions to (profiling) standardisation efforts.

The 5G System supports network exposure interfaces for more dynamic interaction. It exposes different network services, which can be viewed, configured or modified by authorised application service providers.

The network exposure interfaces are following the HTTP REST Model, which is widely used within the internet community. 3GPP has standardised a set of APIs for the network exposure function (NEF), such as for setting up QoS flows. CAMARA works in close collaboration with the GSMA Operator Platform Group to align API requirements and publish APIs to simplify the use of 3GPP network features, e.g. for QoS-on-demand.

Multi-access Edge Computing

The application of MEC is being widely discussed and tested in the automotive industry for use cases requiring low latency. For example, the ITS and C-ITS use cases, collision avoidance and VRU collective awareness applications are being developed, deployed, and tested based on MEC-infrastructure.

Thanks to 5GAA efforts on multi-operator requirements for MEC operation, architectures and operational setups exist, making the low latency characteristics also

[55] 5gaa-wi-avp.pdf

available for end-customers/users subscribed to various MNOs. MEC could also be an enabler for automated driving functions, such as AVP, especially to reduce efforts and complexity in the operation of the AVP service.

Non-Terrestrial Networks

In 3GPP, NTNs aim to provide 5G connectivity to devices via a range of base-station connections made to satellites, high-altitude platforms, or uncrewed aerial vehicles (UAV). 5G UE should be capable of connecting to NTN with minimal changes, using an evolution of existing NR waveforms and protocols and not requiring a separate radio transceiver. The main changes are expected to be in the frame-and protocol timers, to support much longer 'time of flight' for signals. Subject to regulatory conditions in each market, new frequency bands for NTN may be allocated. Existing satellite bands are in the 2 GHz (S- and L-bands), 10-20 GHz, and 30-40 GHz frequency bands. Various network architectures are proposed, to provide roaming and mobility between networks. By making use of a new generation of low-cost LEO satellites and lower cost launch platforms, the deployment cost of networks is being significantly reduced. Using LEO satellites and 2 GHz (S band) will enable normal 5G devices to connect to NTNs without significant extra costs in the UE. 3GPP standardised NTNs are an essential requirement for the automotive industry to use these networks as a complementary form of connectivity for road hazard information, emergency calls/breakdown calls and fleet monitoring, to cite just a few applications.

Annex III: Use Case Descriptions

The use case descriptions below are listed in a specific order to reflect their place on Figure 2 on the globally expected timelines for mass deployment of advanced connected vehicle use cases.

Local hazard and traffic information: A host vehicle (HV) is made aware of some events on the route ahead. This can happen either by other vehicles (i.e. remote vehicles, RV) or via some back end/cloud service that collects and aggregates data of several vehicles; e.g. C-V2X TR UC Volume I, (5GAA ref. T-200111), Section 6.1.4

Hazard information collection/sharing: Vehicles collect hazard and road events based on vehicle sensor data for further use by autonomous vehicles (AVs) and V2X application servers; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.13

Basic safety: Day-1 use cases targeting hazard information and warning use cases examples; e.g. C-V2X TR UC Volume I, (5GAA ref. T-200111), Section 6.1

Intersection safety: Day-1 use cases targeting intersection safety; see C-V2X TR UC Volume I, (5GAA ref. T-200111): Cross-Traffic Left-Turn Assist, Section 6.1.1, and Intersection Movement Assist, Section 6.1.2

VRU collective awareness: Alert the host vehicle of an approaching VRU on the road or crossing an intersection and warn of any risk of collision; see C-V2X TR UC Volume I, (5GAA ref. T-200111), Section 6.1.7

Group start: Self-driving or semi-automated vehicles form a group to jointly start straight on at a traffic light. No turns are permitted; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.6.4

Cooperative ACC: CACC is an extension to the adaptive cruise control concept. CACC realises longitudinal automated vehicle control by adapting the speed and distance with the preceding vehicles through efficient communication of safety-relevant information. For the cooperative implementation, dedicated communication between road users is anticipated, see C-V2X TR UC Volume III, (5GAA ref. T-210022), Section 5.1.1

Cooperative manoeuvres: An AV identifies a difficult or dangerous situation (e.g. collision with a moving object) and undertakes to coordinate with neighbouring AVs in order to jointly decide and perform their manoeuvres; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.4

VRU complex interactions: A VRU is preparing to cross the street; after sharing its intent, nearby vehicles acknowledge to reassure the VRU that it is safe to cross; as the VRU is crossing, it continues communicating with stopped vehicles, it tells vehicles when it has cleared the zone. It double-checks with vehicles just before moving in front of them; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.1.2

Data collection and sharing for HD maps (formerly named 'HD map sharing for AVs'): Collecting and sharing information about static road objects and temporary road conditions with map providers. Build HD maps that are dynamically updated and more accurate to reflect the near real-time environment/conditions with additional precise and accurate position of the objects; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.6

Data-sharing of dynamic objects (formerly named 'Sensor-sharing for AVs'): Vehicles/ infrastructure collect information on dynamic objects in or near the road and on other traffic participants based on own sensor data. They only share the relevant information as a result of processed and analysed sensor data also including some meta data; see C-V2X TR UC Volume III, (5GAA ref. T-210022), Section 5.4.1

Non-analysed sensor signal-sharing (formerly named 'High-definition sensor-sharing'): Supports the development of further automated driving capabilities in the future. Non-analysed sensor signal data, perceived by other road users (e.g. other vehicles, VRU) in the road and/or infrastructure, is provided to the host vehicle. The relevant information is shared as an (unaltered or encoded but raw) data stream that could be used at vehicle's sensor fusion; see C-V2X TR UC Volume III, (5GAA ref. T-210022), Section 5.4.2

Dynamic intersection management: An autonomous vehicle (AV) goes through the intersection with a traffic light. The AV goes through or stops, taking signal timing into account. The traffic flow is coordinated with other traffic participants dynamically through the intersection manager; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.1

Dynamic cooperative traffic flow: Generic: 1. Main traffic participant wants to perform a certain action (e.g. lane change, get off highway, U-turn, ...). 2. Participant shares this intention with other traffic participants potentially involved in the manoeuvre. 3. The informed traffic participants indicate their support or decline the planned manoeuvre to the main traffic participant. 4. The main traffic participant informs a superset of the traffic participants informed in step 2 whether it plans to perform the manoeuvre; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.5

Automated valet parking: When a vehicle arrives at its destination parking area, the vehicle is parked by itself through automated driving with the aid of a parking data centre. Based on ISO 23374 [1] Intelligent transport systems – Automated Valet Parking Systems (AVPS); see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.3.1; C-V2X TR UC Volume III, T-210022, Section 5.4.3

Tele-operated driving: When the vehicle detects the need for remote support, it starts sharing video and/or sensor data (either raw or pre-processed) and/or situation interpretation to provide adequate 'perception' of the environment to the remote operator. Based on the perceived situation the remote operator can provide the appropriate trajectory and/or manoeuvre instructions to help the vehicle resolve the uncertain situation; see C-V2X TR UC Volume II, (5GAA ref. T-210021), Section 5.4.10

Extended emergency call: An xCall is an emergency voice call initiated manually or automatically from a vehicle to a Public Safety Answering Point and the corresponding incident related data such as the minimum set of data (MSD). With this information, emergency responders can quickly locate the area and provide assistance, see C-V2X TR UC Volume III, (5GAA ref. T-210022), Section 5.1.4

Annex IV: V2X Terminology

Full term	Shorter alternative	Technical term (only for technical reports or specs)	Other technical terms used in 3GPP
(C-V2X)* direct communications [mode]	(C-V2X)* direct	(C-V2X)* PC5	Sidelink
(C-V2X)* mobile network communications [mode]	(C-V2X)* mobile network	(C-V2X)* Uu	Uplink/Downlink

- 3GPP is a global organisation developing technical specifications that are transposed into standards on cellular communications technologies for the different generations of mobile networks: GSM (2G), UMTS (3G), LTE (4G) and 5G, targeting a wide range of consumer and industry applications. The acronym V2X (vehicle-to-everything) is added when applied in a vehicle connectivity context.
- 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 includes all 3GPP releases supporting LTE-V2X mobile network communications and LTE-V2X direct communications.
    - LTE-V2X mobile network communications relates to 3GPP specifications starting with Rel-8 for LTE.
    - LTE-V2X direct communications relates to 3GPP specifications starting with Rel-14.
- 5G-V2X includes 5G radio access technology (NR), operated with or without LTE-V2X (evolution of V2X within different regional markets will potentially lead to different deployment options).
    - 5G-V2X mobile network communications relates to 3GPP specifications including Rel-15 and later releases.
    - 5G-V2X direct communications relates to 3GPP specifications including Rel-16 and later releases.

Annex V: Glossary of Terms

3GPP:	Third-Generation Partnership Project
AD:	Automated Driving
ADAS:	Advanced Driver Assistance Systems
API:	Application Programming Interface
ARIB:	Association of Radio Industries and Businesses of Japan
AV:	Automated Vehicle
AVP:	Automated Valet Parking
C-SAE:	China Society of Automotive Engineers
C-V2X:	Cellular Vehicle-to-Everything Communication
CACC:	Cooperative Adaptive Cruise Control
CAICV:	China Industry Innovation Alliance for the Intelligent and Connected Vehicle
CEPT:	European Conference of Postal and Telecommunications Administrations
CPS:	Collective Perception Service
ECID:	Enhanced Cell Identity
ERTRAC:	European Road Transport Research Advisory Council
ETSI:	European Telecommunication Standards Institute
EU:	European Union
FCC:	Federal Communications Commission
GNSS-RTK:	Global Navigation Satellite Systems Real-Time Kinematic
IMT-2020:	International Mobile Telecommunications 2020
ISO:	International Standard Organisation
GSMA:	Global System for Mobile Communications
MEC:	Mobile Edge Computing
MCS:	Manoeuvre Coordination Service
MIC:	Ministry of Internal Affairs and Communications of Japan
MNO:	Mobile Network Operator
NCAP:	New Car Assessment Programme
NR:	5G New Radio
NTCAS:	National Technical Committee of Automotive Standardisation of China
NTN:	Non-Terrestrial Networks
ODD:	Operational Design Domain
OEM:	Original Equipment Manufacturer
OTDOA:	Observed Time Difference Of Arrival
PSM:	Pedestrian Safety Message
QoS:	Quality of Services
RAT:	Radio Access Technology
RAN:	Radio Access Network
SAE:	Society of Automotive Engineers of United States
SDO:	Standard Development Organisation
SSO:	Standard Setting Organisation
ToD:	Tele-operated Driving

TSG:	Technical Specification Groups
URSP:	User Route Selection Policy
V2I:	Vehicle-to-Infrastructure Communication
V2N:	Vehicle-to-Network Communication
V2P:	Vehicle-to-Pedestrian Communication
V2V:	Vehicle-to-Vehicle Communication
V2X:	Vehicle-to-Everything Communication
VAM:	VRU Awareness Message
VDA:	German Association of Automotive Industry
VRU:	Vulnerable Road User
xCall:	Extended Emergency Call

The 5G Automotive Association (5GAA) is a global, cross-industry organisation of over 115 members, including leading global automakers, Tier-1 suppliers, mobile operators, semiconductor companies, and test equipment vendors. 5GAA members work together to develop end-to-end solutions for future mobility and transport services. 5GAA is committed to helping define and develop the next generation of connected mobility, automated vehicles, and intelligent transport solutions based on C-V2X. For more information, please visit https://5gaa.org

5GAA

Automotive Association