Before the

DEPARTMENT OF TRANSPORTATION

Washington, DC 20590

In the Matter of	)	
	)	
V2X Communications	)	Docket No. DOT-OST-2018-0210
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COMMENTS OF THE 5G AUTOMOTIVE ASSOCIATION

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EXECUTIVE SUMMARY

The 5G Automotive Association ("5GAA") – a rapidly growing global association that brings together many of the world's major automotive, technology and telecommunications companies – applauds the Department of Transportation ("DOT") for issuing this *Notice of Request for Comments* ("*Notice*") to learn more about recent developments in vehicle-to-everything ("V2X") technologies. The issuance of this *Notice* is particularly timely in light of the increasing momentum behind Cellular Vehicle-to-Everything ("C-V2X"), a modern connected-vehicle communications platform designed to improve safety on America's roads.

Built upon earlier efforts to develop V2X services and leveraging advancements in cellular technologies, first 4G and soon 5G, C-V2X enables direct, peer-to-peer mode vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-pedestrian communications as well as communications between vehicles and mobile networks. While the *Notice* refers to LTE C-V2X and 5G NR as two different V2X technologies, such a description may be misleading. C-V2X is better described as a V2X technology platform that supports LTE C-V2X, 5G NR C-V2X, and future generations of cellular advancements. Leveraging the cellular industry's success in ensuring the functional interoperability between cellular technologies, the C-V2X platform is designed to incorporate future evolutions in cellular technologies while continuing to achieve interoperability between different versions of C-V2X.

C-V2X holds numerous advantages over Dedicated Short Range Communications ("DSRC") technology. These advantages, which can improve safety on America's roads, include (1) superior radio performance that enables new and improved V2X safety and other applications, (2) the ability to leverage commercial cellular networks, (3) an evolutionary path to 5G that will unlock advanced V2X services supporting autonomous driving, (4) an accelerated timeline for deployment, and (5) an optimized security protocol.

In light of these benefits, it is not surprising that momentum for C-V2X continues to build at a rapid pace. Most notably, Ford Motor Company – America's oldest automobile manufacturer – recently announced that it will deploy C-V2X in all new vehicles models in the United States by 2022. This announcement is one of many examples of industry stakeholders, road operators, and foreign regulators investing in and committing to C-V2X.

Finally, while C-V2X and DSRC cannot achieve ubiquitous interoperability and cannot operate on the same channel as one another, DOT policies should seek to create a level playing field that encourages investment, innovation, and deployment of C-V2X in the 5.9 GHz V2X band. At this juncture, such an approach is warranted in light of the importance of V2X services for improving safety on America's roads and the momentum of C-V2X. A level playing field ultimately will allow V2X stakeholders – rather than regulators – to choose the most capable V2X platform, resulting in the use of one technology platform and achieving the ubiquitous interoperability desired by all stakeholders. Moreover, a level playing field will ensure American leadership in V2X technologies and afford American drivers, passengers, and other vulnerable road users access to the same advanced V2X services available in other parts of the world. Given its many advantages over DSRC and the growing momentum behind this technology platform, 5GAA is confident that C-V2X will prevail as the preferred V2X solution if provided such a level playing field.

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Comments of the 5G Automotive Association

The 5G Automotive Association ("5GAA") submits these comments in response to the *Notice of Request for Comment* ("*Notice*") issued by the Office of the Secretary of the Department of Transportation ("DOT") seeking comment on Vehicle-to-Everything ("V2X") communications.[1]

I. Introduction

5GAA is a global cross-industry association of companies working to develop end-to-end connectivity solutions for intelligent transportation, future mobility systems, and smart cities. Created in 2016 by eight founding members, 5GAA's membership continues to expand rapidly. Today, over 100 companies – including many of the world's major automotive, technology, and telecommunications companies – count themselves as members of 5GAA.[2]

5GAA shares the DOT's view that V2X technologies hold the potential to deliver significant safety and mobility benefits on America's roads. Both individually and as a

[1] *Notice of Request for Comments: V2X Communications,* Office of the Secretary, U.S Department of Transportation, Docket No. DOT-OST-2018-0210, 83 Fed. Reg. 66,338 (Dec. 26, 2018).

[2] See Appendix A for a complete list of member companies.

complement to existing radar- and camera-based systems, V2X technologies can improve safety and mobility by providing vehicles and drivers with an earlier, more complete picture of the surrounding road environment. In addition, these technologies likely will yield additional efficiency and environmental benefits.[3]

The issuance of this *Notice* is particularly timely in light of increasing momentum behind Cellular Vehicle-to-Everything ("C-V2X"). Just last month, for example, Ford Motor Company – America's oldest automobile manufacturer – announced that it would deploy C-V2X in all of its new vehicle models in the United States by 2022. This announcement and other similar recent developments discussed in more detail in Section IV of these comments demonstrate an unequivocal commitment to deploy C-V2X communications in the 5.9 GHz V2X band both in the United States and around the world.

5GAA thus welcomes the opportunity to provide the DOT with information about the latest developments in C-V2X. As further explained herein, both the current version and future evolutions of C-V2X will play a leading role in delivering the safety, mobility, efficiency, and environmental benefits that have long been expected from V2X technologies.

II. C-V2X is a Modern V2X Technology Platform Designed to Leverage Existing and Future Advancements in Cellular Technologies While Promoting Interoperability Between Cellular Technologies

Built upon earlier efforts to develop V2X services and leveraging recent advancements in cellular technologies, C-V2X is a modern, connected-vehicle communications platform. C-V2X enables two complementary modes for vehicular communications: peer-to-peer (called PC5 in 3rd Generation Partnership Project ("3GPP") specifications) and network (called Uu in the

[3] *See Connected Vehicle Basics*, DOT, https://www.its.dot.gov/cv_basics/cv_basics_benefits.htm (discussing efficiency and environmental benefits of connected vehicles) (last visited Feb. 19. 2019).

specifications) communications.[4] Peer-to-peer mode communications, which can operate independently of cellular networks and without a network subscription,[5] include:

1) Vehicle-to-vehicle ("V2V") communications, which are used to communicate safety information between two or more nearby vehicles to prevent collisions;
2) Vehicle-to-infrastructure ("V2I") communications (e.g., traffic signals, variable message signs, etc.), which are used are used to communicate safety and traffic information to prevent accidents associated with roadway conditions and to improve traffic efficiency; and
3) Vehicle-to-pedestrian ("V2P") communications, which are used are used to communicate safety information between vehicles and other road users such as pedestrians, bicyclists, motorcyclists, etc. to prevent accidents.[6]

To augment these peer-to-peer mode communications, C-V2X's network ("V2N") mode capabilities allow vehicles to communicate with the rest of the world through commercial cellular networks. These V2N mode communications enable key supporting functions for the

[4] 3GPP is the world's preeminent standards body for cellular technologies. 3GPP develops specifications that are codified as accredited standards by the Alliance for Telecommunications Industry Solutions (ATIS) in the United States and by other "Organizational Partners" in different geographical regions. See http://www.3gpp.org/about-3gpp/partners for a complete list of the accredited Standards Defining Organizations (SDOs) around the world. In this document, 3GPP will be used by reference to indicate any relevant 3GPP specification adopted as a standard by the Organizational Partners.

[5] As excitement grows about the potential for C-V2X to improve traffic safety, productivity, mobility, and energy efficiency, there inevitably also has developed a few inaccuracies regarding the nature of this service. One such inaccuracy is that the peer-to-peer mode communications that C-V2X enables will require a subscription. The peer-to-peer mode communications enabled by C-V2X do not require cellular network connectivity and thus do not require a subscription. *See* Tom Rebbeck et al., *Socio-Economic Benefits of Cellular V2X*, at 28, Analysys Mason & SBD Automotive (Dec. 2017) ("Rebbeck Report"), http://5gaa.org/wp-content/uploads/2017/12/Final-report-for-5GAA-on-cellular-V2X-socio-economic-benefits-051217_FINAL.pdf.

[6] *See* 5G Americas White Paper, *Cellular V2X Communications Towards 5G*, at 4 (Mar. 2018) ("5G Americas White Paper"), http://www.5gamericas.org/files/9615/2096/4441/2018_5G_Americas_White_Paper_Cellular_V2X_Communications_Towards_5G__Final_for_Distribution.pdf. Because C-V2X is part of the 3GPP standard, any vulnerable road user carrying a mobile device could potentially benefit from the protections offered by C-V2X. *Id*. at 29.

peer-to-peer mode communications uses and expand the universe of applications enabled by C-V2X services.

The standards development for C-V2X began in 2015 when 3GPP specified C-V2X features based on the 4G LTE-Pro system in 3GPP Release 14.[7] The Release 14 version of 4G LTE-Pro, which was finalized in 2017, was the first cellular standard to incorporate C-V2X features, but it would not be the last.[8] 3GPP Release 15 incorporated C-V2X enhancements,[9] and, as referenced in the *Notice*, work already is underway to develop 5G New Radio (NR) C-V2X features in 3GPP Release 16, which is expected to be completed later this year.[10]

While the *Notice* refers to LTE C-V2X and 5G NR as two different V2X technologies, such a description may be misleading.[11] C-V2X is better described as a V2X technology platform that supports LTE C-V2X, 5G NR C-V2X, and future generations of cellular advancements. Indeed, the C-V2X platform was designed at the outset to enable an evolution path from LTE to future advancements in cellular technologies, with the first such advancement being 5G.

This design allows C-V2X to leverage future evolutions in cellular technologies while continuing to achieve interoperability. The cellular industry has designed interoperability into cellular technologies for decades, ensuring functional interoperability of cellular technologies.

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[7] Dino Flore, *Initial Cellular V2X standard completed*, 3GPP (Sept. 26, 2016), http://www.3gpp.org/news-events/3gpp-news/1798-v2x_r14ietf%20ipwave; NGMN Alliance, *V2X White Paper v. 1.0*, at 19 (June 17, 2018) ("NGMN White Paper"), https://www.ngmn.org/fileadmin/ngmn/content/downloads/Technical/2018/V2X_white_paper_v1_0.pdf.

[8] 3GPP, *Release 14*, http://www.3gpp.org/release-14 (last visited Nov. 19, 2018).

[9] Release 15's enhancements increase reliability of communication and enable higher data rates. *See* 5GAA White Paper, *Timeline for deployment of C-V2X – Update*, at 7 (Jan. 22, 2019) ("*Timeline for deployment of C-V2X – Update*"), http://5gaa.org/wp-content/uploads/2019/01/5GAA_White-Paper-CV2X-Roadmap.pdf.

[10] *See* 3GPP, *3GPP Features and Study Items*, http://www.3gpp.org/DynaReport/FeatureListFrameSet.htm (last visited Feb. 22, 2019) (identifying a study on NR Vehicle-to-Everything as part of the feature and study item list for Release 16).

[11] *Notice*, 83 Fed. Reg. at 66,338-66,339.

Thus, for example, subsequent versions of 4G LTE are backward compatible with earlier versions of 4G LTE.

The cellular industry is taking this same approach with C-V2X. C-V2X's evolution path will ensure that all vehicles equipped with this technology, regardless of the version employed, will be able to engage in direct communications with other vehicles, infrastructure, and devices equipped with C-V2X. Interoperability is achieved through the development of upper layer and application protocols that ensure backward compatibility between different generations of C-V2X. Thus, 3GPP Release 16, which will include 5G NR C-V2X features, will be functionally interoperable with 3GPP Release 15 and 14, which incorporate 4G LTE C-V2X features.[12] In other words, vehicles that incorporate 3GPP Release 15 or 16 will communicate seamlessly with other vehicles and infrastructure using Release 14, as is typically the case for 3GPP-based technologies. And of course, vehicles equipped with C-V2X also will continue to remain interoperable with existing cellular LTE and 5G networks. Consequently, this approach will not only promote interoperability, but it will allow C-V2X to keep pace with innovations and advancements in the cellular industry.

III. C-V2X's Advantages Will Improve Safety and Mobility on America's Roads

If given the opportunity to deploy in the 5.9 GHz band, C-V2X's many advantages will help make America's roads safer. As discussed in this section, these advantages include (1) a superior radio performance, (2) the ability to leverage commercial cellular networks, (3) an evolutionary path to 5G, (4) an accelerated timeline for deployment, and (5) optimized security systems.

[12] Although the physical radio layers of LTE releases and 5G NR are very different, the chipsets and associated communication stacks will integrate these radio technologies through higher layer specifications. This integration enables functional backward compatibility at the service level. *See Timeline for deployment of C-V2X – Update* at 8.

A. C-V2X's Radio Performance is Superior to That of Other Technologies – Enabling New and Improved Safety Applications

The radio performance advantages of C-V2X peer-to-peer mode can help unlock improvements in a variety of ITS applications and in a variety of different scenarios (e.g., varying road/traffic conditions and vehicle speeds). With C-V2X, drivers and vehicles will have access to a more complete and accurate picture of the surrounding road environment. For example:

- ***C-V2X's improved non-line-of-sight performance*** allows vehicles and drivers to "see" more clearly through obstructions and further around corners, providing an earlier, more expanded view of the surroundings;[13]

- ***C-V2X's enhanced reliability*** provides more certainty that critical safety messages reach their intended destination at a much greater communications range;[14]

- ***C-V2X's superior resiliency*** to out of band emissions provides a more dependable performance for vehicles and drivers;

- ***C-V2X's higher capacity*** to transmit data, a feature expected in future versions of C-V2X, will allow more and higher quality information to reach the driver and vehicle; and

- ***C-V2X's communications congestion control*** in traffic jams and other scenarios in which there is a high volume of vehicles in the same vicinity helps to ensure more consistent performance.[15]

These unique characteristics will translate into a variety of societal benefits. They are particularly important in non-line-of-sight scenarios (e.g., around corners, through large trucks, etc.). Because current and near-term in-vehicle camera and sensor-based technologies experience limitations in non-line-of-sight scenarios, C-V2X's performance advantage over

[13] *See* 5G Americas White Paper, at 21-22.

[14] *See id.*

[15] *See id.* at 22.

DSRC thus may allow vehicles to perceive and provide earlier warnings of threats hidden from view, particularly near intersections and in highway passing and braking scenarios.[16]

For example, C-V2X's increased reliability provides better support for intersection movement applications. Left Turn Assist (LTA) and Intersection Movement Assist (IMA) – both of which were identified by the National Highway Traffic Safety Administration as particularly important for improving traffic safety – benefit from C-V2X's ability to reliably deliver safety messages in intersection scenarios where line-of-sight is limited or obstructed.[17] Similarly, C-V2X's ability to reliably deliver communications over extended range enables this platform to provide unrivaled support for highway passing applications. In particular, Do Not Pass Warning (DNPW) – which provides warnings when it is not safe to pass a slower moving vehicle – requires communications over an extended range to ensure warnings are delivered in a manner that provides drivers with sufficient reaction time. C-V2X offers an unrivaled ability to reliably deliver messages over such an extended communications range in both line-of-sight and non-line-of-sight scenarios.[18]

B. C-V2X Leverages Existing and Future Commercial Cellular Networks

The performance advantages of C-V2X peer-to-peer mode are further augmented by C-V2X's V2N mode communications. V2N mode communications play an important

[16] Moreover, the C-V2X peer-to-peer radio is designed with a consistently achieved, highly reliable latency regardless of channel congestion. *See* 5G Americas White Paper at 22.

[17] *See*, Federal Motor Vehicle Safety Standards; V2V Communications, 82 Fed. Reg. 3854, 3859 (Jan. 12, 2017).

[18] In October 2018, 5GAA published a report summarizing benchmark-testing results comparing the radio performance of C-V2X peer-to-peer radios against DSRC radios.[18] *See* 5G Automotive Association, *V2X Functional and Performance Test Report; Test Procedures and Results*, (Oct. 2018) http://5gaa.org/wp-content/uploads/2018/11/P-180106-V2X-Functional-and-Performance-Test-Report_Final_051118.pdf. While the report indicated that the DSRC devices used in testing had employed receive antenna diversity, 5GAA members recently discovered that this was not the case. As a result, 5GAA is expanding its testing to collect DSRC data that reflects the use of receive antenna diversity, and 5GAA plans to file such expanded data in this docket in near term. Notably, this does not change the C-V2X test results from that report. And most importantly, 5GAA is confident this does not change the report's ultimate conclusion that C-V2X technology substantially outperforms DSRC technology.

complementary role to peer-to-peer mode communications by, among other things, providing the ability to offload less time-sensitive V2V, V2I, and V2P communications to the cellular network during times of peak congestion.[19] This offloading feature increases the reliability of C-V2X's peer-to-peer mode communications, enhancing the effectiveness of critical time-sensitive services enabled by C-V2X. In addition, vehicles will be able to unlock a host of new applications by utilizing C-V2X's V2N mode to communicate with almost anyone at any time. This V2N mode functionality would allow, for example, integration with smart-city and other connected transportation initiatives that also use cellular technology.[20]

C. C-V2X's Evolutionary Path to 5G and Subsequent Wireless Generations Will Enable Advanced V2X Services That Can Provide Support for Autonomous Driving

Fifth-generation wireless technologies will enable transformative societal benefits in a wide range of areas. With data speeds of 100Mbit/s or more, ultra-low latency of a few milliseconds or less, extremely high reliability, and massive capacity, 5G will spur the development of myriad innovative applications that will revolutionize a broad range of industries, transforming the way we work, learn, and get around. The transportation industry – and specifically the automotive industry – is widely viewed as one of the key sectors that will benefit from 5G capabilities and services. For this reason, and as discussed previously, C-V2X is designed with a clear path to 5G, subsequent 5G advances, and subsequent wireless generations. C-V2X is the only V2X platform that can make this claim.

This evolutionary path will allow C-V2X to unlock the power of 5G technologies, driving further improvements in performance, introducing new capabilities to connected vehicles and infrastructure, and extending the number of use cases for C-V2X. 5G C-V2X peer-to-peer mode

[19] *See* Rebbeck Report at 1-2.

[20] *Id.*

communications, for example, will use advanced radio technologies to achieve ultra-low latency and ultra-high capacity capabilities.[21] With respect to 5G-enabled V2N and V2I, the combination of high-bandwidth operations and edge computing capabilities will allow for the movement of larger amounts of data, over shorter distances, in smaller amounts of time, maximizing the safety benefits of C-V2X.[22]

While the advanced V2X applications enabled by 5G C-V2X likely will expand in ways that are difficult to predict, 5GAA is aggressively exploring 5G C-V2X's role in advanced driving applications that support autonomous driving. For example, 5G C-V2X can complement and augment advanced driving applications that enhance semi-automated or fully-automated driving features (likely with the assistance of vehicle-mounted radar and other sensors) by coordinating the behaviors of vehicles. These applications allow a vehicle to share the trajectory data obtained from its local sensors with vehicles in its proximity.

In addition, 5G C-V2X will enable vehicles to use extended sensor applications to share their future intentions (i.e., lane changes, etc.) and engage in persistent information exchanges with vehicles in their proximity. These extended sensor applications allow vehicles to obtain information about objects around them located beyond the view of their own onboard sensors by sharing sensor data (for example, data obtained from cameras, radar, and LIDAR) with nearby vehicles, providing a more complete picture of road and traffic conditions. Successful implementation of these extended sensor applications will require the type of ultra-low latency and ultra-high data rate communications supported by 5G capabilities.[23]

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[21] *See* 5G Americas White Paper at 14.

[22] *See* 5GAA White Paper, *Toward fully connected vehicles: Edge computing for advanced automotive communications*, at 6 (Dec. 2017), http://5gaa.org/wp-content/uploads/2017/12/5GAA_T-170219-whitepaper-EdgeComputing_-5GAA.pdf.

[23] *See* 5G Americas White Paper at 24-25.

D. C-V2X's Accelerated Timeline for Deployment Will Expedite the Realization of the Benefits of V2X Services

V2X technologies must be deployed at scale to maximize the safety and other societal benefits provided by these services. Because C-V2X offers an accelerated timeline for deployment, C-V2X is likely to be deployed at scale earlier than DSRC. This timeline is based on a number of factors.

First, C-V2X technology can be efficiently integrated into vehicles. In response to the overwhelming consumer demand for cellular-connected vehicles, virtually all new vehicles are or soon will be equipped with cellular modem chipsets.[24] C-V2X can be added as an additional feature in these chipset products, streamlining bill of materials, simplifying the supply chain and logistics, and reducing vehicle maintenance complexity.[25]

Second, C-V2X can leverage existing commercial cellular networks to realize significant network coverage in the near term. The ability of C-V2X to re-use existing commercial mobile infrastructure will not only stimulate the development of new V2N services, but it also presents road operators with the option of leveraging this infrastructure through public-private partnerships. These opportunities to leverage commercial networks will further increase with the

[24] *See e.g.*, Press Release, Ford, *Ford Readies North America's Freshest Lineup By 2020 With Onslaught Of Connected New Trucks, SUVs And Hybrids* (Mar. 15, 2018), https://media.ford.com/content/fordmedia/fna/us/en-/news/2018/03/15/ford-readies-north-americas-freshest-lineup-by-2020.html (Ford announcing that all new Ford vehicles will have 4G LTE connectivity by the end of 2019); AT&T, *Internet of Things: Connected Car News*, http://about.att.com-/sites/internet-of-things/connected_car (last visited Feb. 22, 2019) (noting that AT&T has 24 million connected cars and 3.2 connected fleet vehicles on its network); Daimler, *Daimler's Perspective on Car-to-X Technologies (5GAA member)*, at 2 (June 2018), http://5gaa.org/wp-content/uploads/2018/06/5.-Daimler-view-on-V2X-5GAA-Policy-Debate.pdf (noting 90% of new Mercedes-Benz cars are already connected worldwide); Kristen Hall-Geisler, *More cars than phones were connected to cell service in Q1*, TechCrunch (June 20, 2016), https://techcrunch.com/2016/-06/20/more-cars-than-phones-were-connected-to-cell-service-in-q1 (in the first quarter of 2016, connected cars accounted for a third of all new cellular devices).

[25] *See* NGMN *White Paper* at 42-43.

deployment of 5G networks, which is expected to see an additional $275 billion of investment in the coming years.[26]

Third, C-V2X's evolutionary path to 5G is helping to accelerate demand for and adoption of C-V2X. As previously addressed, this path to 5G and beyond ensures that future versions of C-V2X modules remain functionally backwards compatible with the current versions of this technology.[27] In effect, this evolutionary path provides consumers, automakers, roadway operators, infrastructure providers, and network operators with the assurance that C-V2X products purchased today will retain their full functionality in the future.[28]

E. C-V2X Incorporates Established and Developing Security Protocols Defined by Automotive and Cellular Standards Bodies

5GAA and its members are focused on ensuring the security of C-V2X. C-V2X peer-to-peer communications benefit from established and developing security and transport layers and application protocols defined by the automotive standards communities, including the Society of Automotive Engineers, International Organization for Standardization, European Telecommunications Standards Institute, and Institute of Electrical and Electronics Engineers. Specifically, C-V2X peer-to-peer communications employ the security credential management system ("SCMS") originally developed for DSRC. The SCMS provides security objectives including privacy, unlinkability, authenticity, integrity and confidentiality regardless of the communication technology. Moreover, 5GAA members, led by Ford and Volkswagen, are collaborating to optimize the SCMS architecture even further for C-V2X operations. This work,

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[26] *See* Accenture Strategy, *How 5G Can Help Municipalities Become Vibrant Smart Cities*, at 1 (Jan. 2017), https://newsroom.accenture.com/content/1101/files/Accenture_5G-Municipalities-Become-Smart-Cities.pdf.

[27] *See* Rebbeck Report at 2 (citing the certainty of C-V2X's future evolution to 5G as facilitating earlier deployment and after-market deployment).

[28] Moreover, this evolutionary path provides stakeholders with the ability in the decades ahead to utilize technology well beyond the current 5G iteration of C-V2X being designed today.

which will be published in a white paper by 5GAA later this year, will detail methods for streamlining and improving the SCMS for C-V2X peer-to-peer communications.

In addition, C-V2X network communications will reuse various security components already implemented in cellular networks by the commercial mobile network industry. These security components, which are used by the millions of connected vehicles on the road today, were developed through billions of dollars of private sector investment by the commercial wireless industry. And as wireless networks transition to 5G, C-V2X network communications will continue to benefit from advancements in 5G network security driven by continued private sector investment.

IV. The Momentum of C-V2X Continues to Grow at a Rapid Pace

In light of C-V2X's numerous advantages, the momentum for this technology platform – both in America and abroad – continues to grow at a rapid pace. As noted above, Ford Motor Company announced last month that it would deploy C-V2X in all new vehicle models in the United States by 2022.[29] As America's second largest automotive manufacturer, Ford's announcement represents a watershed moment in the deployment of V2X services.

American road operators also are actively exploring C-V2X. Most recently, the city of Las Vegas and the Regional Transportation Commission of Southern Nevada announced trials in Las Vegas to demonstrate a range of C-V2X technology uses cases.[30] This came on the heels of

[29] Don Butler, *How 'Talking' and 'Listening' Vehicles Could Make Roads Safer, Cities Better*, Medium (Jan. 7, 2019), https://medium.com/@ford/how-talking-and-listening-vehicles-could-make-roads-safer-cities-better-f215c68f376f.

[30] Monica Alleven, *Qualcomm hooks up with city of Las Vegas on C-V2X deployment*, FierceWireless (Jan. 7, 2019), https://www.fiercewireless.com/wireless/qualcomm-hooks-up-city-las-vegas-c-v2x-deployment.

a similar announcement by the Colorado Department of Transportation that it will deploy C-V2X along a traffic-intensive corridor used by travelers to get to popular mountain destinations.[31]

The investment, innovation, and collaboration in C-V2X by the automotive, wireless, and technologies industries was also on full display at last month's Consumer Electronics Show in Las Vegas, where C-V2X was selected as an Innovation Award Honoree in the "Vehicle Intelligence and Self-Driving Technology" category.[32] 5GAA members led the charge with C-V2X technology demonstrations by Ericsson, HARMAN International, Savari, Inc., Bosch and Veniam, Wistron NeWeb Corporation, and Continental.[33] Ford partnered with Audi, Ducati, and Qualcomm to conduct a live demonstration of C-V2X communications between a Ford pickup, an Audi crossover, and a Ducati motorcycle using Qualcomm's C-V2X chipset.[34] Other companies that partook in C-V2X demonstrations included transportation solution providers, Derq and McCain,[35] and bike manufacturer, Trek Bicycle, showing that industry interest in C-V2X is cross-sectoral and not limited to traditional automobile and wireless industry stakeholders.[36]

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[31] Sue Marek, *Colorado Will Be First With C-V2X Vehicle Deployment*, SDxCentral (June 5, 2018), https://www.sdxcentral.com/articles/news/colorado-will-be-first-with-c-v2x-vehicle-deployment/2018/06.

[32] Carlos Gonzalez, *Could 5G Be the Missing Puzzle Piece for Self-Driving Cars* (Jan. 24, 2019), https://www.machinedesign.com/motion-control/could-5g-be-missing-puzzle-piece-self-driving-cars

[33] Press Release, 5GAA, *5G Automotive Association at CES 2019: Highlighting connected mobility through 5G* (Jan. 7, 2019), http://5gaa.org/news/5g-automotive-association-at-ces-2019-highlighting-connected-mobility-through-5g; Tracy Cozzens, *Harman to demonstrate Autotalks' C-V2X capabilities at CES 2019*, GPS World (Jan. 7, 2019), https://www.gpsworld.com/harman-to-demonstrate-autotalks-c-v2x-capabilities-at-ces-2019.

[34] Drew Winter, *To C-V2X, or not to C-V2X, that is the Question at CES*, WardsAuto (Jan. 10, 2019), https://www.wardsauto.com/ces/c-v2x-or-not-c-v2x-question-ces.

[35] Press Release, Derq, *Derq Demonstrates AI-Based Road Safety Applications With Qualcomm Technologies Using C-V2X Technology at CES* (Jan. 8, 2019), http://en.derq.com/press-coverage/2019/1/8/derq-demonstrates-ai-based-road-safety-applications-using-c-v2x-technology-at-ces; Press Release, McCain, *McCain to Participate in Qualcomm Cellular-V2X Connected Vehicle Demonstrations at CES* (Jan. 9, 2019), https://www.mccain-inc.com/334-mccain-to-participate-in-qualcomm-cellular-v2x-connected-vehicle-demonstrations-at-ces.

[36] Zach Overholt, *Trek, Tome, and Ford – are B2V and C-V2X the future of safer cycling?*, BikeRumor! (Jan. 9, 2018), https://bikerumor.com/2018/01/09/trek-tome-and-ford-are-b2v-and-c-v2x-the-future-of-safer-cycling.

The rest of the world also continues to push forward with commitments to deploy, invest, and innovate in C-V2X. Most notably, the Chinese Ministry of Industry and Information Technology already has allocated spectrum for C-V2X, and regulators in other parts of the world are contemplating similar action.[37] On the industry front, South Korean telecommunications carrier KT recently announced that it has developed a reader for C-V2X technology, allowing vehicles to detect passersby and traffic signals.[38] Last November, industry-led project consortiums from Europe and China started a multi-year collaborative effort for joint 5G research and implementation of 5G trials that include C-V2X testing,[39] and around the same time, Vodafone and Jaguar Land Rover demonstrated C-V2X capabilities in London, United Kingdom.[40] And last December, Qualcomm held a C-V2X technology and field trial in Tokyo, Japan, that demonstrated the complementary benefits of utilizing network-based communications in vehicle-to-everything communications.[41] This momentum will grow as automobile manufacturers, technology companies, mobile network operators, and governments continue to demonstrate the superior performance capabilities of C-V2X in tests and trials around the globe.[42]

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[37] *See* Ministry of Industry and Information Technology of the People's Republic of China, MIIT (2018) No. 203 regulation (Nov. 2018). *See also* Stephen Lawson, *C-V2X's Momentum in China May Drive Connected-Car Development*, TU Automotive (Nov. 7, 2018), https://www.tu-auto.com/c-v2xs-momentum-in-china-may-drive-connected-car-development/.

[38] Cho Mu-Hyun, *KT develops C-V2X reader for self-driving cars*, ZDNet (Dec. 16, 2018), https://www.zdnet.com/article/kt-develops-c-v2x-reader-for-self-driving-cars.

[39] Press Release, 5G-Drive, *EU-China cooperation on large-scale 5G trials kicked off* (Nov. 26, 2018), http://5g-drive.eu/wp-content/uploads/2018/11/5G-DRIVE-Press-Release-Joint-EU-China-meeting-2018.11.29.pdf.

[40] Guy Daniels, *Vodafone and Jaguar Land Rover demonstrate C-V2X in London*, TelecomTV (Nov. 26, 2018), https://www.telecomtv.com/content/mobile/cellular-connected-cars-ready-to-help-improve-road-safety-in-europe-33309.

[41] Qualcomm, *C-V2X Trial in Japan* (Dec. 13, 2018), https://www.qualcomm.com/media/documents/files/c-v2x-trial-in-japan.pdf.

[42] *See* Appendix B for a list of recent C-V2X tests and trials.

V. While DSRC and C-V2X Cannot Achieve Ubiquitous Interoperability, Allowing Both C-V2X and DSRC to Operate in the 5.9 GHz Band Will Ensure American Leadership in V2X Innovation and Deployment

Although different versions of C-V2X can achieve ubiquitous interoperability with each other, the same cannot be said for interoperability between C-V2X and DSRC. Indeed, C-V2X and DSRC cannot achieve ubiquitous interoperability, and cannot operate on the same channel. Thus, while C-V2X and DSRC can coexist in the 5.9 GHz band by operating on adjacent channels and without a guard band, direct communications between these technologies will remain elusive.[43]

This inability to achieve ubiquitous interoperability should not lead the DOT to adopt regulations aimed at imposing such interoperability, however. The end goal of ubiquitous V2X interoperability can also be achieved by creating conditions for technologies with strong market momentum to prosper and displace those technologies that do not have market support. As momentum for C-V2X continues to build both in the United States and abroad for C-V2X, regulations aimed at interoperability at this critical juncture would threaten America's ability to lead the world in innovation and deployment of V2X technology. Such regulations ultimately would hamper the ability of V2X technologies to improve safety and mobility on America's roads, as they would problematically freeze technology solutions to a past point in time – in this case a technology designed in the 2G, pre-mobile broadband era. This *de facto* technology mandate would limit American consumers' ability to realize the aforementioned benefits inherent in C-V2X. For example, a backwards compatibility mandate would artificially constrain the performance capabilities of and innovation in future versions of C-V2X. Similarly, imposing a DSRC mandate would reduce incentives for investment and innovation in C-V2X.

[43] 5GAA members are in the process of completing testing demonstrating the ability of C-V2X and DSRC to co-exist in adjacent channels in the 5.9 GHz band. 5GAA plans to publish this data in a report that will be made public in the near future, and 5GAA intends to file that report in this docket.

Attempts such as these to engineer interoperability through regulation would ultimately delay and degrade the long-awaited safety and mobility benefits of V2X technologies.

Rather, at this juncture, given the importance of robust and ubiquitously deployed V2X technologies and the momentum of C-V2X, DOT policies should seek to establish an even playing field by encouraging stakeholders to "continue developing technologies that leverage the 5.9 GHz spectrum for transportation safety benefits."[44] Such a regulatory environment will facilitate investment and innovation in both C-V2X and DSRC and ultimately will take into account market actions by V2X stakeholders. Moreover, as other regions of the world similarly assess V2X technologies, a level playing field will ensure that America maintains optionality and the ability to benefit from economies of scale as global V2X stakeholders select a preferred technology platform in the internationally harmonized 5.9 GHz V2X band. Ultimately, such a level playing field will allow V2X stakeholders – rather than regulators – to choose the V2X platform most capable of delivering safety benefits on America's roads.

As these market dynamics play out in the short term, DSRC-equipped vehicles and C-V2X-equipped vehicles can realize some level of interoperability. Specifically, roadside infrastructure equipped with both DSRC and C-V2X radios can serve as a bridge between technologies, allowing C-V2X- and DSRC-equipped vehicles to communicate both directly to such infrastructure and, using such infrastructure as a bridge, with one another by transmitting data through the infrastructure and on to vehicles-equipped with the other technology.[45] While not a panacea for ubiquitous interoperability, utilizing connected infrastructure as a bridge

[44] *See, e.g.*, DOT, *Preparing for the Future of Transportation: Automated Vehicles 3.0 (AV 3.0)*, at 16 (Oct. 4, 2018) ("DOT Automated Vehicles Report"), https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/-automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf.

[45] To facilitate this type of interoperability, DOT policies should encourage V2X message formats used by DSRC or C-V2X to utilize the same application-level standards.

solution can be particularly effective at troublesome intersections to address red light violations and other intersection movement use cases. This approach could easily dovetail into ongoing efforts by road operators to deploy roadside infrastructure at select portions of our transportation system.[46]

To begin to level the playing field between C-V2X and DSRC, and to ensure that American drivers, passengers, pedestrians, and other road users can benefit from C-V2X technology, 5GAA recently filed a petition for waiver ("C-V2X Waiver Petition") at the Federal Communications Commission ("Commission") requesting permission for the deployment of C-V2X technology in the 5.905-5.925 GHz range of the 5.9 GHz band.[47] The C-V2X Waiver Petition has received overwhelming support from V2X stakeholders.[48] And as indicated in the C-V2X Waiver Petition, 5GAA plans to file a petition for rulemaking requesting the Commission initiate a proceeding to modify its rules for the 5.9 GHz band to allow for C-V2X operations in a broader portion of the band to accommodate advanced V2X services powered by 5G C-V2X.

Ultimately, policies promoting a level playing field will allow V2X stakeholders to select the platform most capable of improving safety on America's roads. Indeed, mobile wireless

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[46] *See, e.g.*, *SPaT Challenge Overview*, National Operations Center of Excellence, https://transportationops.org/spatchallenge (last visited Feb. 22, 2019).

[47] *See* 5GAA Petition for Waiver to Allow Deployment of Intelligent Transportation System Cellular Vehicle to Everything (C-V2X) Technology, GN Docket No. 18-357 (filed Nov. 21, 2018).

[48] *See* Comments of American Honda Motor Co., Inc., GN Docket No. 18-357 (Jan. 25, 2019); Comments of BMW of North America, LLC, GN Docket No. 18-357 (Jan. 18, 2019); Comments of Daimler North America Corporation, GN Docket No. 18-357 (Jan. 18, 2019); Comments of General Motors, GN Docket No. 18-357 (Jan. 18, 2019); Comments of Jaguar Land Rover, GN Docket No. 18-357 (Jan. 22, 2019); Comments of Volkswagen Group of America, Inc., GN Docket No. 18-357 (Jan. 30, 2019); Comments of Ericsson, GN Docket No. 18-357 (Jan. 18, 2019); Comments of Nokia, Inc., GN Docket No. 18-357 (Feb. 8, 2019); Comments of Panasonic Corporation of North America, GN Docket No. 18-357 (Jan. 29, 2019); Comments of Samsung Electronics America, Inc. and HARMAN International, GN Docket No. 18-357 (Feb. 6, 2019); Comments of Intel Corp., GN Docket No. 18-357 (Jan. 24, 2019); Comments of Qualcomm Incorporated, GN Docket No. 18-357 (Feb. 8, 2019); Comments of T-Mobile, USA, Inc., GN Docket No. 18-357 (Jan. 29, 2019); Comments of HAAS Alert, GN Docket No. 18-357 (Jan. 28, 2019); Comments of InterDigital, Inc., GN Docket No. 18-357 (Jan. 17, 2019); Comments of Savari, Inc., GN Docket No. 18-357 (Jan. 22, 2019).

industry stakeholders – and not regulators – selected LTE as the preferred 4G technology, resulting in a robust wireless broadband system that is interoperable and deployed across most of the United States. The DOT should expect the same result for V2X technologies. And given C-V2X's many advantages over DSRC, 5GAA is confident that C-V2X will prevail as the preferred technology platform and position the United States to lead the world in 21st century automotive innovation and transportation infrastructure.

VI. Conclusion

5GAA thanks the DOT for encouraging stakeholders to develop new V2X technologies that leverage the 5.9 GHz band and for issuing this *Notice* to learn more about recent developments in V2X technologies.[49] C-V2X technology offers capabilities that can enable new and improved V2X services, leverages existing and future commercial cellular networks, presents a path to 5G that will greatly expand and enhance C-V2X services in the future, features an accelerated timeline for deployment, and offers an optimized security management system. Given these benefits and the momentum for adoption of C-V2X, 5GAA strongly believes that C-V2X will emerge as the preferred V2X platform in the United States if given an opportunity to be deployed on a level playing field. 5GAA therefore looks forward to continuing to work with the DOT to ensure that V2X stakeholders, and not regulators, can choose the best technology

[49] *See, e.g.*, DOT Automated Vehicles Report at 16.

platform to deliver the safety, mobility, efficiency, and environmental benefits that have long been expected of V2X technologies.

Respectfully submitted,

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February 25, 2019

Appendix A - 5GAA Membership

- Airbus
- Airgain, Inc.
- Alpine Electronics Inc.
- American Tower Corp
- Analog Devices Inc.
- Anritsu A/S
- Applied Information
- AT&T Foundry
- Audi AG
- BAIC Group (Beijing Automotive Group Co., Ltd.)
- Baidu
- Baoneng
- Beijing University of Technology
- Bell Mobility
- BlackBerry UK Limited
- BMW Group (Bayerische Motoren Werke AG)
- Bosch (Robert Bosch GmbH)
- CATT (China Academy of Telecommunication Technology)
- CETECOM GmbH
- China Mobile
- China Transinfo
- China Unicom (China United Network Communications Group Co., Ltd)
- China Mobile Research Institute
- Clarion Co. Ltd
- Cohda Wireless
- Commsignia Inc.
- Continental Teves AG & Co. oHG
- Daimler AG
- Danlaw Inc.
- Dekra
- DENSO AUTOMOTIVE Deutschland GmbH
- Deutsche Telekom AG
- Dt&C
- Equinix
- Ericsson AB
- Faraday Future
- FarEasTone
- FEV Group GmbH
- Ford
- Fraunhofer Institute
- Geely Auto
- Gemalto SA

- General Motors
- Hirschmann Car Communication GmbH
- Hitachi
- Honda
- Huawei
- Hyundai America Technical Center
- Hyundai Mobis
- iDirect
- Infineon Technologies AG
- Intel
- InterDigital Communications, Inc.
- Jaguar Land Rover Ltd.
- Juniper Networks
- KDDI
- Keysight Technologies UK Limited
- KT R&D Center
- Laird Bochum GmbH
- Latvijas Mobilais Telefons
- Lear
- LG Electronics Inc.
- Magneti Marelli
- Mitsubishi Electronics
- Murata Manufacturing
- NavInfo
- Neusoft
- NIO China
- Nissan
- Nokia
- Noris Network AG
- NTT-DoCoMo
- OKI
- Orange SA
- P3 Group
- Panasonic
- Proximus B.V.
- PSA Groupe
- Qorvo
- Qualcomm Incorporated
- Quectel
- Renault
- Rohde & Schwarz GmbH & Co. KG
- Rohm Semiconductor
- SAIC Motor Corporation Limited
- Samsung Electronics Co., Ltd

- Savari Inc.
- SGS
- Shanghai Gotell Communication Technology Holdings Co., Ltd.
- SIAC (Shanghai Int. Automobile City)
- SK Telecom
- Skyworks
- Smart Mobile Labs
- Softbank Corp.
- Sumitomo Electric
- Swift Navigation
- Telefónica Digital España S.L.
- Telekom Austria Aktiengesellschaft
- Telstra
- TELUS
- Tencent
- Terranet, SE
- TÜV Rheinland AG
- Valeo (peiker acustic GmbH & Co.KG)
- Veniam Inc.
- Verizon
- Viavi
- Vodafone Group Services Ltd
- Volkswagen AG
- Volvo Cars
- VT Direct
- Wistron NeWeb Corp.
- ZF
- ZTE Corporation

Appendix B - C-V2X Test and Trials

A growing number of companies across the globe are demonstrating C-V2X applications. Below is an overview some of the tests and trials in which 5GAA members are participating.

Fowlerville, Michigan	Qualcomm, Ford
Denver, Colorado	Panasonic, Ford, Qualcomm, CO DoT
Paris, France	5GAA, BMW Group, Ford and Groupe PSA, Qualcomm, Savari
Ingolstadt, Germany	Audi, Ducati, Qualcomm
Shanghai, China	Ford and Datang
Japan	Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm
Shanghai, China	Continental and Huawei
San Diego, California	AT&T, McCain, Ford, Nokia, Qualcomm
Columbia, Maryland	Rohde & Schwarz, Qualcomm
Towards 5G, France	Ericsson, Orange, Qualcomm, PSA Group
Mobilifunk (A9), Germany	Vodafone, Bosch and Huawei
RACC track, MWC 2017	Audi, Vodafone, Huawei @ MWC
ConVeX (A9), Germany	Audi, Ericsson, Qualcomm, Swarco, Kaiserslautern Univ.
Car2X in Wuzhen, China	CMCC, Continental, Nokia, Fraunhofer
DT (A9), Germany	Audi, Deutsche Telekom, Huawei, Toyota
UK	Jaguar Land Rover, Vodafone, et al
MEC pilot project, Germany	Bosch, DT/T-Systems, Nokia
Car2X at A9, Germany	Continental, DT/T-Systems, Nokia, Fraunhofer

Ford, Qualcomm (Fowlerville, Michigan): Qualcomm and Ford have partnered up to test C-V2X radio capabilities such as the line-of-sight range/reliability and non-line-of-sight range/reliability.[50]

Panasonic, Ford, Qualcomm, and the Colorado Department of Transportation (August 2018, Denver, Colorado): Panasonic, Ford, Qualcomm, and the Colorado Department of Transportation demonstrated the "first real-world application of C-V2X technology connecting the vehicle, the roadways and a regional traffic management center" and showcased the technology's ability to detect oncoming traffic, data from Road Side Units, and aggregate traffic

[50] Jovan Zagajac, *The C-V2X Proposition*, 5GAA (Apr. 26, 2018), http://5gaa.org/wp-content/uploads/2018/05/3.-The-C-V2X-Proposition-Ford.pdf.

data to allow real-time monitoring of roadways connected with C-V2X.[51] Testing on C-V2X capabilities will continue on select roadways throughout Panasonic's CityNOW headquarters in Denver and will be followed by deployment in select areas along the I-70 Mountain Corridor in the back half of 2018.[52]

5GAA, BMW Group, Ford and Groupe PSA, Qualcomm, Savari (July 2018, Paris, France): Conducted first live demonstration of C-V2X direct communication technology operating across vehicles from multiple auto manufacturers. The demonstration also featured a live showcase of C-V2X direct communication technology operating between passenger cars, motorcycles, and roadside infrastructure.[53] Six demonstrations were shown including: Emergency Electronic Brake Light, Intersection Collision Warning, Across Traffic Turn Collision Risk Warning, Slow Vehicle Warning and Stationary Vehicle Warning, Signal Phase and Timing / Signal Violation Warning and Vulnerable Road User (pedestrian) Warning. The vehicles involved included two-wheel e-scooters provided by BMW Group, and automotive passenger vehicles provided by Ford, Groupe PSA, and BMW Group, all of which were equipped with C-V2X direct communication technology using the Qualcomm® 9150 C-V2X chipset solution. V2X software stack and application software, along with roadside infrastructure, were provided by industry leader, Savari.[54]

Audi, Ducati, Qualcomm (July, 2018, Ingolstadt, Germany): ConVex (Connected Vehicle to Everything of Tomorrow) trial in Ingolstadt, Germany, featured Audi Q7 and A4 cars and a Ducati Multistrada 1200 Enduro motorbike fitted with the Qualcomm 9150 C-V2X chipset solution, and showed how C-V2X can aid road safety in common scenarios involving motorcycles and cars.[55]

Ford and Datang (March, 2018, Shanghai, China): Ford and Datang have partnered to trial C-V2X "at the National Intelligent Vehicle Pilot Zone in Shanghai, the first intelligent connected car demonstration area in China. The tests built on Datang's extensive work in creating LTE-V2X technology, which is the first phase of C-V2X technology and Ford's key role in the area of

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[51] Press Release, Panasonic, *Panasonic, Qualcomm and Ford Demo the First Real-World Application of C-V2X in Colorado* (Aug. 15, 2018), https://www.prnewswire.com/news-releases/panasonic-qualcomm-and-ford-demo-the-first-real-world-application-of-c-v2x-in-colorado-300697513.html.

[52] Press Release, Qualcomm, *Panasonic, Qualcomm and Ford Join Forces on First U.S. Deployment for C-V2X Vehicle Communications in Colorado* (June 1, 2018), https://www.qualcomm.com/news/releases/2018/06/01/-panasonic-qualcomm-and-ford-join-forces-first-us-deployment-c-v2x-vehicle.

[53] Press Release, Ford, *5GAA, BMW Group, Ford And Groupe PSA Exhibit First European C-V2x Direct Communication Interoperability Between Multiple Automakers* (July 11, 2018), https://media.ford.com/-content/fordmedia/feu/en/news/2018/07/11/-5gaa--bmw-group--ford-and-groupe-psa--exhibit-first-european-c-.html.

[54] *Id.*

[55] Farah Alkhalisi, *C-V2X demos incorporate motorcycles, vehicles and infrastructure, communications between carmakers*, automotiveIT International (July 11, 2018), http://www.automotiveit.com/news/c-v2x-demos-incorporate-motorcycles-vehicles-and-infrastructure-communications-between-carmakers.

intelligent connected vehicles (ICV) in China. The evaluations were carried out according to industry harmonized test procedures from 5G Automobile Association."[56]

Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm (January, 2018, Japan): Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm have partnered to trial C-V2X capabilities where "Continental will utilize the Qualcomm C-V2X Reference Design, which features the Qualcomm 9150 C-V2X chipset with integrated Global Navigation Satellite System (GNSS) capability to build connected car systems and integrate the systems into Nissan vehicles. Nissan will perform V2X use case selection and develop test scenarios with key performance indicators (KPIs) for C-V2X technology validation. OKI, one of the leading companies in ITS, will bring their expertise in roadside unit (RSU) infrastructure and applications to demonstrate V2I as a viable technology for advanced traffic applications by integrating the Qualcomm® 9150 C-V2X chipset into their RSU. Ericsson, as one of the leading companies in the technology and service for telecommunications, will join to the V2N use case discussion, considering a combination of direct communication and LTE-A network technologies. NTT DOCOMO will provide an LTE-A network and V2N applications to demonstrate the benefits of complementary use of network-based communications for a variety of advanced automotive informational safety use cases."[57]

Continental and Huawei (December 2017, Shanghai, China): Continental and Huawei have conducted field trials on C-V2X performance, including reliability and latency. "To test in realistic conditions, Continental conducted its driving tests in China's National Intelligent Connected Vehicle Pilot Zone in Shanghai named 'A Nice City'. The joint tests leveraged Huawei's prototype C-V2X module and infrastructure for use cases such as Emergency Brake Light and Stationary Vehicle Warning. While the average latency was 11 ms, single event message latencies as low as 8 ms were achieved, and throughout the tests the packet reception rate was nearly 100 percent."[58]

AT&T, McCain, Ford, Nokia, and Qualcomm (October, 2017, San Diego, California): AT&T, McCain, Ford, Nokia, and Qualcomm, are cooperating with local government bodies to conduct C-V2X trials at the San Diego Regional Proving Ground. Ford vehicles will be using C-V2X technology and the Qualcomm 9150 C-V2X solution to facilitate direct communications, and will be complemented by AT&T's 4G LTE network communications and ITS platform that takes advantage of wireless base stations and multi-access edge computing technology from Nokia. McCain will help facilitate the effective integration with existing and emerging traffic signal control infrastructure. Testing will support direct C-V2X communications operating in the 5.9 GHz ITS spectrum to explore the safety enhancements of V2V use cases, including do

[56] Press Release, Ford, *Ford And Datang Trial C-V2X Connected Car Technology In Shanghai To Support Global Connectivity Initiative* (Mar. 29, 2018), https://media.ford.com/content/fordmedia/fap/cn/en/news/2018/03/29-/Ford_and_Datang_Trial_C-V2X_Connected_Car_Technology_in_Shanghai_to_Support_Global_Connectivity_-Initiative.html.

[57] Press Release, Qualcomm, *Leading Automotive, Telecom and ITS Companies Unveil First Announced Cellular V2X Trials in Japan* (Jan. 11, 2018), https://www.qualcomm.com/news/releases/2018/01/11/leading-automotive-telecom-and-its-companies-unveil-first-announced.

[58] Press Release, Continental, *Cellular V2X: Continental Successfully Conducts Field Trials in China* (Dec. 18, 2017), https://www.continental-corporation.com/en/press/press-releases/2017-12-18-cellular-v2x-116994.

not pass warning, intersection movement assist, and left turn assist, among others. The trials will also support advanced vehicle communication capabilities for improved traffic efficiencies, such as real-time mapping updates and event notifications relayed using AT&T's cellular network and Nokia Cloud Infrastructure.[59]

Rohde & Schwarz and Qualcomm (October 2017, Columbia, Maryland): The R&S CMW500 Wideband Radio Communication Tester Was Used to Successfully Test a Pre-Commercial Qualcomm® 9150 C-V2X Chipset.[60]

Ericsson, Orange, Qualcomm, PSA Group (February, 2017, Towards 5G, France): The initial phase of testing demonstrated Cellular V2X capabilities on the evolution towards 5G in a real environment over two use cases dedicated to connected vehicles: "see through" between two connected vehicles on a road, and "emergency vehicle approaching," aimed at notifying drivers when an emergency vehicle is nearby in real-time. These two use cases have taken advantage of improved latency, and high throughput performance, using the network-based capabilities of Cellular V2X to deliver a high-resolution video stream between two vehicles, and demonstrating reactivity to show real time event notification.

Vodafone, Bosch and Huawei (February, 2017, Mobilifunk (A9), Germany): Trial underway in the stretch of the A9 between Nuremberg and Munich in Germany. During the trial, the consortium demonstrated the viability of direct V2V communications and the ability to exhibit very low latency. In addition, the tests were intended to investigate how Cellular V2X differs from the IEEE 802.11p technology.

Audi, Vodafone and Huawei (February 2017, Barcelona): On the Circuit de Barcelona-Catalunya race track at the Mobile World Congress 2017, Audi, Huawei and Vodafone demonstrated the use of 4G cellular to enhance safety by enabling rapid exchange of information between vehicles (V2V), other road users and infrastructure (V2I). They demonstrated "see through" (connected cars can see a video feed from a vehicle in front of them in situations where it will help them to have visibility of other traffic, upcoming entry roads or other issues to negotiate); a traffic light warning (traffic light is about to change alerting the driver to slow down), pedestrian in the roadway warning; and emergency braking warning (other connected vehicles suddenly braking or changing lanes).

Audi, Ericsson, Qualcomm, Swarco, Kaiserslautern Univ (January, 2017, ConVeX (A9), Germany): The goal of the trial was to demonstrate the benefits of a Cellular V2X connectivity platform, as defined by 3GPP Release 14, to showcase range, reliability and latency advantage for real-time V2V communications. Additionally, the trial aimed to highlight new use cases that help support traffic flow optimization and improve safety. The goals of ConVeX were to use the

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[59] Press Release, Qualcomm, *AT&T, Ford, Nokia and Qualcomm Launch Cellular-V2X Connected Car Technology Trials Planned for the San Diego Regional Proving Ground with Support From McCain* (Oct. 31, 2017), https://-www.qualcomm.com/news/releases/2017/10/31/att-ford-nokia-and-qualcomm-launch-cellular-v2x-connected-car-technology.

[60] Press Release, Rohde & Schwarz, *Rohde & Schwarz Supports 3GPP Cellular V2X Device Testing for Vehicle-to-Vehicle Connectivity*, ACCESSWIRE (Oct. 19, 2017), https://www.accesswire.com/478295/Rohde--Schwarz-Supports-3GPP-Cellular-V2X-Device-Testing-for-Vehicle-to-Vehicle-Connectivity.

results of the trial to inform regulators, provide important inputs to ongoing global standardization work and shape a path for further development and future evolution of Cellular V2X technology.

CMCC, Continental, Nokia, Fraunhofer (November 2016, Car2X in Wuzhen, China): At the 2016 World Internet Conference in Wuzhen, China, the partners demonstrated Cellular V2V applications such as Emergency Brake Light that lets you know when traffic in front of you slows down and Cooperative Passing Assistant, that determines whether it is safe to change lanes, advising oncoming traffic to slow down and warning vehicles in front not to change lanes.

Audi, Deutsche Telekom, Huawei, Toyota (July, 2016, DT (A9), Germany): The companies conducted trials of Cellular V2V technology on a section of the "digital A9 motorway test bed" near Ingolstadt, Germany. Audi AG and Toyota Motor Europe research cars, and Deutsche Telekom infrastructure were specially equipped with V2V hardware from Huawei to support the trial scenarios.

Jaguar Land Rover, Vodafone et al (June, 2016, UK): Connected Intelligent Transport Environment (UKCITE) is a project to create the most advanced environment for testing connected and autonomous vehicles. It involved equipping over 40 miles of urban roads, dual-carriageways and motorways with various V2V technologies including Cellular V2X. The project established how this technology can improve journeys; reduce traffic congestion; and provide entertainment and safety services through better connectivity.

Bosch, DT/T-Systems, Nokia (June 2016, MEC pilot project, Germany): The development partnership demonstrated the application of Cellular V2X utilizing local clouds for fast vehicle-to-vehicle communication for hazard warnings and for cooperative and coordinated driving maneuvers. The work included implementing driver assistance functions such as intersection assistance and electronic brake lights.

Continental, DT/T-Systems, Nokia, Fraunhofer (November 2015, Car2X at A9, Germany): The trial demonstrated how vehicles on the motorway can share hazard information using the LTE network of Deutsche Telekom. As extremely short transmission times are vital for this purpose, a section of the Deutsche Telekom network was equipped with innovative Mobile Edge Computing technology from Nokia Networks, and upgraded with position-locating technology developed by Fraunhofer ESK. This combination permitted signal transport times between two vehicles of less than 20 milliseconds.