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February 25, 2019

Finch Fulton
Deputy Assistant Secretary for Transportation Policy
U.S. Department of Transportation
1200 New Jersey Avenue SE.,
West Building Ground Floor, Room W12-140,
Washington, DC 20590-0001.

**RE: Federal Motor Vehicle Safety Standards; V2X Communications, Request for Comments (RFC), U.S. DOT – National Highway Traffic Safety Administration [Docket No. DOT-OST-2018-0210]**

Dear Deputy Assistant Secretary Fulton,

Ford Motor Company (Ford), a domestic manufacturer and importer of motor vehicles with offices at One American Road, Dearborn, Michigan 48126-2798, submits the following comments on the V2X Communications Request for Comments (RFC), Docket No. DOT-OST-2018-0210, dated December 26, 2018. Ford also participated in the development of the comments submitted by the 5G Automotive Association (5GAA), and incorporates them by reference.

In this RFC, the U.S. Department of Transportation (DOT) requests comment on how recent developments in communications technologies impact both V2X in general and the Department's role in encouraging the integration of V2X. They pose nine questions related to available technologies, interference, interoperability, backwards compatibility, security and more. We have provided responses to those questions in an attachment. In addition to those responses, Ford offers the following comments:

1. Ford believes vehicle-to-vehicle communications is a key enabler of our vision to design smart vehicles for a smart world.
2. Ford appreciates and supports the efforts of the DOT to maintain a technology neutral approach to vehicle-to-everything communications.
3. While the technology does not currently exist to enable interoperability of DSRC and CV2X at the radio level, similar benefits can be achieved via functional interoperability.
4. Ford interprets backward compatibility to mean that new safety services can be added in complementary fashion to the ones that have already been deployed.

Vehicle-to-everything communications enables smart vehicles for a smart world

Ford believes that vehicle-to-everything technology is a key enabler of our vision of designing smart vehicles for a smart world. Current driver-assist technologies utilize on-board sensors to essentially “see” what’s going on around them. C-V2X will enhance such capability as well as future self-driving technologies by allowing vehicles to also “listen” and “talk” to other vehicles, pedestrians and the road infrastructure around them. We believe that V2X technologies are critical enablers to make transportation potentially safer and more efficient. C-V2X is a key part of Ford’s vision of delivering smarter vehicles in a smarter world – a world where connected technologies improve traffic safety but also help businesses provide on-demand services along your route or even help cities move to new ecosystems such as streets without traffic signals as we know them.

For these reasons, at the 2019 Consumer Electronics Show, we announced our intention to deploy cellular vehicle-to-everything (CV2X) technology in all of our new vehicle models in the United States that we launch beginning in 2022 provided a conducive regulatory environment is in place to make that possible.

Technology neutral approach

Ford appreciates the efforts of the DOT to maintain a technology neutral approach to vehicle-to-everything communications. We believe that innovators and markets should have the freedom to decide which communications solution meets the needs of the traveling public without artificial constraints. Ultimately this will deliver V2X goals of improved safety and mobility sooner.

In the following section, we submit a concept of functional interoperability. As we define it, functional interoperability would not require a “single communications protocol” to enable the potential benefits of V2X technologies. Ford believes that in the end, V2X technologies will converge into a single, most optimal and effective solution, but regulations should be flexible enough to allow that to happen naturally.

Functional interoperability

While the technology does not currently exist to enable interoperability of DSRC and CV2X at the radio level, similar benefits can be achieved via functional interoperability.

It is technically impossible to achieve radio level (PHY/MAC) interoperability between V2X communications solutions that belong to distinct families of technologies (DSRC is 802.11, while C-V2X is cellular). Simply put, the distinct waveforms of the radio signals cannot be reconciled by such devices. Instead, Ford believes that functional interoperability could sustain the benefits of V2X deployments without sacrificing the advantages that new technologies can offer.

We define functional interoperability as the ability for the information that vehicles and other transportation stakeholders exchange through V2X to be semantically coherent regardless of the medium through which such information is delivered, as long as safety critical requirements (for example latency and reliability) are met. Safety applications should be able to leverage standard common application level interfaces (for example the Basic Safety Messages) to deliver safety benefits without being concerned as to which channel is utilized to deliver this information. This enables the underlying radio technology to evolve at its own natural pace independent of the rate at which safety applications are advancing. Such an approach does not impose undue hardship on evolving V2X technologies (802.11 and Cellular alike).

To achieve functional interoperability, a common translation or interworking point would be necessary to “translate” between the two or multiple technologies. One promising option is to deliver focused geo-fenced interoperation through road side units (RSUs) that implement multiple V2X technologies and performs translation between two or more distinct radio interfaces. Ostensibly this can be done in geo-fenced areas that present the highest risk to vehicle occupants – for example at busy intersections or dangerous arterials where visibility is poor and the non-line of sight benefits of V2X are useful. This approach incurs the lowest societal costs for such services, as deploying RSUs is less complex than trying to manage this in vehicles.

As an example of this approach, we can look at how the cellular industry has rapidly evolved while delivering ever-improving internet capability. In this case the “mediator” are cell towers that serve multiple evolving technologies (for example 2G, 3G and 4G devices), allowing new phones to make a connection with older ones. Note that this is feasible only within the same family of technologies (e.g. 802.11 or Cellular but not across).

Backwards compatibility

Ford interprets backward compatibility to mean that new safety services can be added in complementary fashion to the ones that have already been deployed. The most viable way to accomplish this is to deliver the new services (a) with incremental but integrated hardware (“system on a chip” or SOC), and (b) by securing additional spectrum or re-using ITS spectrum. These services can be designed to create the least amount of disruption to existing ones. We again can look at how the cellular industry has evolved: a 4G phone can operate in 2G and 3G networks by virtue of having silicon that spans all cellular technology generations. Note that this is feasible only within the same family of technologies (e.g. 802.11 or Cellular but not across).

The same principles apply to V2X. The set of services defined for the older generations of the technology (for example safety applications that utilize the Basic Safety Message) will continue to function in a way that meets the performance requirements for safety. Moreover, the new devices have the potential to present a growing number of additional safety services that leverage the enhanced capabilities of the technology in a complementary manner. For example, autonomous driving systems may be able to utilize higher bandwidth and lower latency of the 5G CV2X radios while using the Basic Safety Message applications to receive alerts about imminent non-line-of site safety threats.

Conclusion

In summary, C-V2X and DSRC have virtually the same software and protocol stack, which ensures that the same messages can be sent by both technologies using the same security and privacy. Field tests suggests that C-V2X can make communication between vehicles, pedestrians and infrastructure quicker, more reliable and more affordable. Because it’s based on cellular technology, it’s already widely available and has significant momentum with major investments to launch 5G networks and beyond. Functional interoperability has the potential to bridge the two technologies in geo-fenced areas. Federal authorities and road operators (for example State DOTs and the Independent Owner Operator community) can play a constructive role in enabling functional interoperability to advance safety while encouraging innovation on our roadways.

Ford appreciates the opportunity to provide these comments. If you or your staff have any questions regarding these comments, please contact Nick Baracos (email: nbaracos@ford.com or phone: 313-248-2003).

Sincerely,

Desi Ujkashevic

Attached
Attachment 1 DOT Request for Comment

## Ford Response to V2X Communications RFC Questions

Ford Motor Company (Ford), a domestic manufacturer and importer of motor vehicles with offices at One American Road, Dearborn, Michigan 48126-2798, submits the following comments on the V2X Communications - Request for Comments (RFC) Docket No. DOT-OST-2018-0210, dated December 26, 2018. Ford participated in the development of the comments submitted by 5GAA, and thereby, incorporates by reference those comments in our response. Further to the 5GAA's submission, we want to provide additional emphasis on the following aspects regarding Deployment of Cellular Vehicle –To-Everything (CV2X) Technology as it relates to the questions in this RFC.

1. **What existing or future technologies could be used for V2X communications, including, but not limited to, DSRC, LTE C-V2X and 5G New Radio. What are the advantages and disadvantages of each technology? What is the timeframe for deployment of technologies not yet in production? Please provide data supporting your position.**

As the U.S. DOT has pointed out in its RFC, there are two main communication technologies for V2X: DSRC and LTE C-V2X. DSRC On Board Units (OBU) are currently available while LTE C-V2X OBUs will be available by Q1 2019. The next major generation of the C-V2X referred to 3GPP Release-16, which improves bandwidth and latency, OBUs are projected to be available in the Q4 2021.

Ford and its partners have done extensive comparative testing of the currently available V2X technologies which provided the following directional insights:

- C-V2X OBUs provide additional improvement compared to DSRC OBUs in Basic Safety Message (BSM) reliability of reception in realistic road situations, which included non-line-of-sight radio conditions.
- Under the same interference conditions resulting from the operation of Wi-Fi signals in the adjacent bands C-V2X communication showed improved resiliency compared to DSRC through higher reliability of packet reception as a function of distance.

2. **Of the V2X communications technologies previously discussed, at present only DSRC is permitted to be used in the 5.9 GHz spectrum band for transportation applications. If that allocation were to be changed to allow any communication technology for transportation applications, could DSRC and other technologies (e.g., C-V2X, 5G or any future technology) operate in the same spectrum band or even the same channel without interference? Why or why not? If there are any technical challenges to achieving this goal, what are they and how can they be overcome?**

Medium access control protocols for DSRC and LTE C-V2X are different. This implies that turning on both technologies in the same channel would result in neither technology performing as expected. For that reason, we do not believe that the two technologies can and should operate in the same channel of the 5.9 GHz spectrum band allocated for transportation applications. We believe, however, that DSRC and C-V2X OBUs can operate in adjacent or non-adjacent channels of the 5.9 GHz ITS band.

Ford and its partners have recently tested DSRC basic safety operation in CH172 while at the same time high-load C-V2X transmissions were present in 20 MHz wide CH183 without any impact observed on BSM reception in CH172. It was also shown that under the tested conditions the 20 MHz C-V2X deployment impact on the DSRC communication in CH178 and CH180 is no worse than the impact from DSRC communication in the same upper 20 MHz. Regardless of communication technology, an RF transmitter operating in close proximity of an unintended RF receiver (e.g., in an adjacent channel) might create interference and these special cases need to be understood for future technology deployments.

3. **To what extent is it technically feasible for multiple V2X communications technologies and protocols to be interoperable with one another? Why or why not? Can this be done in a way that meets the performance requirements for safety of life applications, as they were discussed in the V2V NPRM? What additional equipment would be needed to achieve interoperability or changes in standards and specifications? What is the projected cost of any necessary changes? How soon can these changes and equipment prototypes be available for testing?**

It is technically impossible to achieve radio level (PHY/MAC) interoperability between V2X communications solutions that belong to distinct families of technologies (DSRC is 802.11, while C-V2X is cellular). Simply put, the distinct waveforms of the radio signals cannot be reconciled by such devices.

How can we then achieve functional interoperability if the devices themselves cannot communicate directly? Typically, in this case a common translation or interworking point would be necessary to “translate” between the two or multiple technologies. One promising option is to deliver focused geo-fenced interoperation through road side units (RSUs) that implement multiple V2X technologies and perform translations between two or more distinct radio interfaces. Ostensibly this can be done in geo-fenced areas that present the highest risk to vehicle occupants – for example at busy intersections or dangerous arterials where visibility is poor and the non-line of sight benefits of V2X are useful. This approach incurs the lowest societal costs for such services as the number of road side units that would need to be deployed is many orders of magnitude less complex than trying to manage this in vehicles.
We again can look at how the cellular industry has rapidly evolved while delivering ever improving internet capability. In this case the “mediator” are cell towers that serve multiple evolving technologies (for example 2G, 3G and 4G devices), allowing new phones to make a connection with older ones. Federal authorities and road operators (for example State DOTs and the Independent Owner Operator community) can play a significant constructive role in providing such capability to advance safety while encouraging innovation on our roadways.
It is this approach that has allowed the telecommunications industry to rapidly evolve over the last couple of decades and deliver ever increasing wireless internet capability. Such a solution of course is not a panacea – interoperability would exist only where RSU have been deployed, ostensibly in places where such interoperability is truly beneficial.

4. **To what extent is it technically feasible for different generations of the same V2X communications technologies and protocols to be interoperable with one another? Why or why not? Can this be done in a way that meets the performance requirements**

**for safety of life applications? What additional equipment or changes in standards and specifications would be needed to achieve interoperability? What is the projected cost of any necessary changes?**

Traditionally, subsequent generations of 3GPP or cellular technology were backwards compatible in the sense that the old devices could continue to communicate with the same type of devices as well as the new devices. For example, a 4G phone can operate in 2G and 3G networks by virtue of having silicon that spans all cellular technology generations. This is reciprocal and commercially viable only within the same family of technologies (in this case cellular).

With CV2X devices, it is similar; the current generation will be able to communicate with the next generation called 5G CV2X. This is possible because the new device will be running previous releases or generations of the standard. The set of services defined for the older generations of the technology (for example safety applications that utilize the Basic Safety Message) will continue to function in a way that meets the performance requirements for safety.

5. **Even if they are interoperable across different technologies and generations of the same technology, would there be advantages if a single communications protocol were to be used for V2V safety communications? What about other V2X safety applications, such as those involving V2I and V2P communications?**

In advanced deployments, with large V2V device penetration it would be advantageous to have a single technology. However, in the critical early years of deployment, it could be argued that the advantages would be limited, with non-V2V (for example V2I and potentially V2P) benefits being dominant. This is a consequence of the long lifespan (low replacement rate) of typical vehicles on the road and the nature of safety use cases supported by infrastructure that include non-vehicle stakeholders (e.g. vulnerable road users).

Technologies that have the market support to be rapidly infused with V2X technology can potentially bring about safety benefits much sooner. Vehicles connected using cellular modems, cellular infrastructure and personal devices (such as phones) utilizing C-V2X in particular are noteworthy opportunities for such acceleration. Arguably, only CV2X can facilitate the V2P application effectively by bringing the technology available in all hand held devices, like smart phones that already use cellular technology. Moreover, given the aggressive deployment schedules for 5G infrastructure, it makes more sense to deliver C-V2I technology by leveraging such deployments with short-range communication capability (LTE CV2X) rather than building and maintaining separate networks.

6. **How would the development of alternative communication technologies affect other V2I and V2P communications, such as those supporting mobility or environmental applications? Do these applications have the same or different interoperability issues as V2V safety communications? Do different V2X applications (e.g., platooning) have different communication needs, particularly latency?**

V2X technologies will only be successful if they can be deployed harmoniously with technologies prevalent in the smart cities of tomorrow. A vehicle communication system that is built separately will likely suffer from lack of acceptance by the broader society and the necessary investments to sustain it. The broad range of protagonists in the V2X environment will almost certainly generate communication requirements different from those developed for V2V. These needs will continuously evolve. To be successful without forfeiting the benefits of the new technologies to address these evolving needs, we need to focus on interoperability at the semantic (application) layer of the V2X technology stack. We call this functional interoperability. The opportunity cost of a stricter interoperability concept over time will result in less safety benefits, not more.

V2P communications will be one of the key components to achieve safer smart cities. CV2X devices have a roadmap that includes this functionality in smartphones in the near future. There are concerns with interoperability for DSRC roadside units that are already deployed but recently state DOTs have approached Ford in using CV2X for V2I applications. If the current deployment allows, there may be the ability to retrofit current RSUs with solutions compatible to both technologies.

7. **Do different communication technologies present different issues concerning physical security (i.e., how to integrate alternative communication technologies into vehicle systems), message security (i.e., SCMS design or other approaches), or other issues such as cybersecurity or privacy? Would these concerns be affected if multiple but still interoperable communication technologies are used rather than one?**

In today's industry, privacy is always a concern no matter what communication platforms and protocols are used. Vehicle security requirements are typically independent of the vehicle hardware requirements and are determined by the intended level of resilience against physical attackers and impacted by the required computational performance. As to the SCMS design, it is technology agnostic, which would support DSRC, LTE C-V2X, NR C-V2X or any other future V2X communication technology support. The SCMS provides security objectives including privacy, unlinkability, authenticity, integrity and confidentiality regardless of the communication technology. Due to the differences in architecture and operation of an LTE C-V2X or NR C-V2X, based network there may be opportunities to change the architecture and operations of the SCMS. These opportunities could reduce complexity and, therefore, potentially be more cost effective to allow for broader implementations. Currently, the industry could see potentially no difference in requirements between the communication technologies to achieve the goal of implementing V2V technology into the vehicle ecosystems.

8. **How could communications technologies (DSRC, C-V2X, 5G or some other technology) be leveraged to support current and emerging automated vehicle applications? Will different communication technologies be used in different ways? How?**

C-V2X can help unlock the full potential of self-driving technology by serving as an additional source of data about city infrastructure, traffic, construction, vulnerable road users, and emergency vehicles that will solve for some of the more challenging road interactions. Combination of 5G data rates and latencies that are anticipated beyond 2022 coupled with Mobile Edge Computing may provide additionally sensory data that could improve the driving experience and safety of self-driving vehicles.

9. **How could deployments, both existing and planned, assess communications needs and determine which technologies are most appropriate and whether and how interoperability could be achieved?**

Pilots and demonstrations with local DOTs and Smart Cities initiatives will provide a realistic environment to test and assess CV2X technology and its ability to integrate various modes of communication in a seamless manner. Coexistence of both safety and other V2X applications can be tested as well as limited congestion scenarios. Realistic interference conditions can be created to assess communication system resilience.

Properly adjusted current and future pilot deployments will allow for further innovation and rapid deployment of new features for improving driver safety, traffic efficiency and the transportation experience of drivers in areas governed by DOTs and Smart Cities.