This document comprises Applied Information Inc.'s response to the Request For Comments on V2X Communications Docket Number: DOT-OST-2018-0210.

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Response to USDOT RFC on V2X Communications

By

Applied Information Inc.

FINAL

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1. *Please provide information on 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.*

Item	DSRC	LTE C-V2X	5G
Current network Deployment/availability	Limited to Pilot and Test sites	Throughout the United States	None
Responsibility for maintenance	Multiple Government agencies (See Note (1) below)	Telecommunications agencies	Telecommunications agencies
Funding for deployment of networks	Not defined	Private sector; uses existing networks	Private sector; will use to-be-deployed networks
Current capacity of networks for largescale deployment	Inadequate	Adequate	None
Communication range for direct infrastructure to vehicle communications	Line of sight often proves inadequate for many road network- based applications	Cellular communications not available in certain rural areas and so may require additional equipment	Cellular communications not available in certain rural areas and so may require additional equipment
Plans to equip new vehicle fleet	Toyota has announced plans	Smartphone applications make	Ford has announced that all of its vehicles

	to equip vehicles in 2021; Volkswagen by 2019	benefits possible in all vehicles immediately. Ford has announced that all of its vehicles will be produced with LTE connectivity in 2019. Multiple vehicle manufacturers plan deployment in 2019. (See note (2)) below)	will be produced with C-V2X by 2022. Audi, BMW, Daimler, Ford, Tesla, Toyota and Ducati are currently working on integrating the technology into their fleets.
Speed for supporting short-range (>100m) safety applications	Adequate but not suitable for V2V close-range collision avoidance	Adequate	Adequate
Ability to use virtualization as a strategy	Not possible	Supported. For example, BSM can be virtualized for all vehicles at dangerous locations in the road network.	Supported
Experience with Pilot deployments	Difficulty in deployment in the infrastructure due to interoperability issues and the limited number of equipped vehicles	Ease of deployment due to simpler interfaces and ability to use ubiquitous smartphone platform in the vehicle (See Note (3) below)	None
Security	Systems yet to be set-up for universal use	Multiple levels of security exist	Multiple levels of security anticipated

Additional notes:

(1) History has shown that the private sector is far more capable and has been much more successful in implementing publicly accessible communication networks and the applications they support than local government agencies.

(2) The Next Generation Mobile Alliance (NGMN) in its submission to the European Commission entitled "*NGMN Recommendations on Cooperative Intelligent Transport Systems (C-ITS)*" dated November 22, 2018 stated:
    - "To date, NGMN members have provided cellular connectivity to more than 30 million vehicles worldwide, which is used for a variety of safety related use cases (e.g. distribution of end of traffic jam warning, black ice warnings, etc.). It is expected that in the near future every vehicle will be equipped with cellular connectivity. This is a good and market driven basis for the deployment of further C-V2X technology and services."
        - 181122_NGMN_recommendations_to_EC_on_C-ITS.pdf

(3) Applied Information now has over 12 months experience in cellular V2X using current 4G technology. The concept has been proven, and to the observer is indistinguishable from DSRC.

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?*

    - Operations in the same band are possible by allocating channels, but operations in the same channels should be avoided

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?*

- While technically feasible, it is acknowledged that on-going maintenance of software-based mobile devices is only feasible through over-the-air (OTA) updates. This is common practice with cellular devices. This is particularly important where a mix of standards means that concurrently operating communications methods are prone to requiring updates caused by changes in the standards of other methods. DSRC lacks cloud/internet connectivity for back-up, resulting in a flawed design.

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?*

   - See the response to question (3), above.

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?*

   - The requirement to have multiple types of radio equipment be installed on a vehicle is impractical. Vehicles have multi use cellular radios installed already. It is an insurmountable problem to compel that single-use, government designed radios will be installed, calibrated and maintained in vehicles and have any hope of getting fleet adoption.

   What about other V2X safety applications, such as those involving V2I and V2P communications?

   - DSRC has failed to address V2P communications. The use by C-V2X of smartphones as the mobile device automatically provides connectivity to pedestrians and bicyclists who are currently enjoying the benefits in Applied Information's CV deployments using the TravelSafely mobile applications

6. *How would the development of alternative communication technologies affect other V2I and V2P communications, such as those supporting mobility or environmental applications?*

   - See the response to question (5), above.

   Do these applications have the same or different interoperability issues as V2V safety communications?

   - Different. A key example is the use by DSRC of GPS-based close range collision avoidance systems. NHTSA has stated that the accuracy required of the GPS for such an application is 1.5 meters. In an April 7, 2017 submission to NHTSA in response to the Administration's Proposed Rule: "Federal Motor Vehicle Safety Standards: V2V Communications" Applied Information submitted an analysis of alarm generations based upon passing vehicles in three different lane locations: center, right of center and left of center. The analysis used the NHTSA proposed accuracy requirement of GPS for such an application of 1.5 meters.

     The analysis showed that In the common collision situation(which is the primary focus of the NPRM), where vehicles pass each other on normal width road lanes, there will be more false alarms than real alarms, and there will be more missed alarms than real alarms, due to the inherent accuracy limitation of underlying GPS technology.

     The full text of Applied Information's submission to NHTSA can be found at:

     https://www.regulations.gov/document?D=NHTSA-2016-0126-0139

   Do different V2X applications (e.g., platooning) have different communication needs, particularly latency?

   - Yes, especially those requiring low latency. This is often erroneously quoted as a benefit of DSRC. DSRC latency is 100ms at the application level. When examining C-V2X latency, it is necessary to recognize that C-V2X comprises two communication methods:

     - Direct C-V2X, which includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P). This provides enhanced communication range and reliability in a dedicated ITS 5.9 GHz spectrum that's independent of a cellular network.
     - V2N, which represents network communications that flow through the entire cellular/LTE network.in the traditional mobile broadband licensed spectrum.

4G LTE latency is in the range of 200-300ms for V2N communications which is entirely adequate for all valid safety applications. Direct C-V2X does not flow through the cell network, so it would be even faster than this.

- The specific V2V cases often quoted do not stand-up to close analysis when taking into account the accuracy of GPS communications. (see discredited short range safety application referenced above in response to Question 6).

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? `*

   - Yes. These security concerns are already managed by the cellular networks, but have yet to be finalized for widescale deployment with DSRC

   Would these concerns be affected if multiple but still interoperable communication technologies are used rather than one?

   - Yes. They would be more complex and likely multiplied

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?*

   - The anticipated ubiquity of vehicles with cellular-based communications (see note (2) in the response to Question 1) would incorporate automated vehicles. The ability to convey real-time and near-future information such as traffic signal status, incidents ahead etc. to automated vehicles emphasizes the benefits to be gained from taking advantage of available cellular communications. For an example of work zone warning (where temporary reduced speed limits would be in force) see https://www.youtube.com/watch?v=XKAARuk_9mA)

- Cellular also enables the possibility of communications between automated vehicles and pedestrians (V2P) and bicyclists (V2B) so providing solutions from which all road users can benefit. Such benefits have already been realized through Applied Information's cellular-based mobile application *TravelSafely*. (see https://www.youtube.com/watch?v=m-NJpP896Ts for a demonstration of V2B)

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?*

    - This question is best answered by showing some of the results of Applied Information's use of LTE C-V2X in infrastructure and vehicle-based deployments in 2018. Note that driver, bicyclist and pedestrian interfaces are provided though Applied Information's smartphone application *TravelSafely*. (Ignore the commercial/sales aspects of the videos referenced, but consider the reality that these connected vehicle systems and applications are already being deployed using existing cellular technologies):
        - The current installation base can be viewed at: http://map.travelsafelyapp.com/
        - *TravelSafely* operates on the basis of information collected and delivered using LTE C-V2X communications in the following locations:

            1. Marietta, GA
            2. City of Atlanta, GA
            3. City of Johns Creek, GA
            4. Gwinnett County, GA
            5. Gainesville, GA
            6. Tuscaloosa, AL
            7. Cullman, AL
            8. Mobile, AL
            9. Cary, NC
            10. Apex, NC
            11. Richmond, VA
            12. MDOT, MA
            13. Delaware DOT, DL
            14. Quakertown, PA
            15. Greenville, NY
            16. New Haven, CT
            17. Providence, RI
            18. Quincy, MA
            19. Avon, IA
            20. Columbus, IA
            21. Elkhart, IN
            22. Lawrence, KS

23. Gulfport, MS
24. New Orleans, LS
25. City of Sugarland, TX
26. Missouri City, TX
27. Harris County, TX
28. Fort Bend, TX
29. Mansfield, TX
30. Fort Worth, TX
31. Arlington, TX
32. Plano, TX
33. Frisco, TX
34. Odessa, TX
35. Wichita Falls, TX
36. Clovis, NM
37. Broomfield, CO
38. Salt Lake City, UT
39. Anaheim, CA
40. Carlsbad, CA
41. Portland, OR
42. Coeur d' Alene, ID
43. Big Island, Hawaii

This list emphasizes the immediate benefits obtainable through adoption and use of LTE C-V2X and stands in contrast to the relatively limited number of DSRC-based deployments in the US.

- Notable City-wide deployments comprise:
  - Marietta GA – 200 connected devices all C-V2X:
    - https://www.youtube.com/watch?v=GRKjwCCPYKg&index=4&list=PLHMYeJ4DhPORIlJU8k7QP7wLg8sQ-o3eN
  - Tuscaloosa AL- 85 connected devices both C-V2X and DSRC
- Notable Pilot Deployments include:
  - North Avenue, Atlanta GA – Both C-V2X and DSRC:
    - https://www.youtube.com/watch?v=6I8Ksxpcr4k&list=PLHMYeJ4DhPORIlJU8k7QP7wLg8sQ-o3eN
  - Anaheim, CA – SPaT messaging, and virtualized speed and school zones Both C-V2X and DSRC
- Some results documented in videos:
  - V2P and V2B:
    - https://www.youtube.com/watch?v=hyexn6eAZoI&index=6&list=PLHMYeJ4DhPORIlJU8k7QP7wLg8sQ-o3eN
  - Connected Vehicles and traffic signals:

- https://www.youtube.com/watch?v=j3PfXR4aWI0&list=PLHMYeJ4DhPORIlJU8k7QP7wLg8sQ-o3eN&index=14

- The deployments referenced are all readily available for review at any time, by any agency/DOT wanting to verify the results of these implementations as they are operational deployments, not just research test beds. Please contact Applied Information to arrange site visits, or to get a contact at the applicable local authority:

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- Applied Information has more than 8,000 devices deployed with LTE C-V2X technology that can become part of the connected vehicle IoT at no additional cost above the base application (equipment monitoring and control). Through these projects, Applied Information has demonstrated the ability of the existing cellular network to provide connectivity between a vast range of infrastructure-based traffic safety related devices and their users: traffic signals, school beacons, , transit, DMS signs, work zones etc. with emergency responders and the traveling public. None of these deployments have required DSRC or 5G as all work as required using existing 4G with standard smart phones as in-vehicle and mobile devices.

- Driver bicyclist and pedestrian interfaces are provided though Applied Information's smartphone application *TravelSafely* .

- The RFC references a need to " imagine the future". That really is not necessary beyond imagining communicating directly with the (automated) vehicle rather than through the driver. The focus can and should be on "what can be done now" by using the cellular communications technologies already at hand, widely deployed, commercially available and well supported.