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The Honorable Elaine L. Chao
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Ave., S.E.
Washington, DC 20590

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Roskilde, 2019-02-25

RE: Department of Transportation Request for Comments on the Development of Communication Technologies associated with the development and integration of Vehicle-to-Everything (V2X) Technologies [Docket No. DOT-OST-2018-0210; 83 FR. 66338]

Dear Secretary Chao,

The CAR 2 CAR Communication Consortium (C2C-CC) is pleased to provide comments and answers to the above mentioned proceeding.

With best regards

Niels Peter Skov Andersen
General Manager
CAR 2 CAR Communication Consortium

About CAR 2 CAR Communication Consortium

In the CAR 2 CAR Communication Consortium, leading European vehicles manufacturers, equipment suppliers and research institutions join forces for the deployment of cooperative Intelligent Transport Systems and Services (C-ITS). The main objective of the CAR 2 CAR Communication Consortium is the development, testing and deployment of cooperative Systems in Europe based on inter-vehicle and vehicle to roadside short-range communication for improving road safety and road efficiency. Other complementary communication like cellular is considered where required.

The Consortium aims on ensuring the interoperability of cooperative systems, spanning all vehicle classes across brands and borders

The wireless V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure) communication via Vehicular Ad-hoc Network will lead to a safer, more efficient and more comfortable future mobility. It is an inevitable requirement for the long-term vision towards highly automated driving.

The Consortium has been founded in 2002 with the objective of developing European standards for C-ITS, as prerequisite for interoperability of systems improving road safety and road efficiency. Moreover, the CAR 2 CAR members discuss realistic deployment strategies, a roadmap to deployment and business models to speed-up the market penetration. In close collaboration with international stakeholders, especially from the US and Japan, the Consortium pushes the harmonisation of V2X communication standards world-wide

Introduction

V2X DSRC is a decentralized short-range ad-hoc radio system based on WLAN standards and was standardized in the WLAN family as IEEE 802.11p. This standard has been exclusively developed for V2X communications. The design as a pure short-range broadcast system considers the highly dynamical ad-hoc network structure of traveling road users. In contrast bi-directional link connection results in delays for real-time data transfer caused by the increasing distances between the traffic participants due to their movement. Because of this reason the data in DSRC is directly communicated to all road users in the surrounding vicinity ensuring communication latencies in a few milliseconds (typical latency below 2ms and below 5 ms in all scenarios). This concept increases the net data rate of the communication medium.

Continuous developments of the communication mechanisms considered the requirements of the authorities for ensuring security and privacy needs. This resulted in compulsory signing of all message sets (security certificates) and a procedure for changing identifiers (pseudonyms) of the participant to avoid long distance tracking of individual vehicles. A crucial aspect is that V2X DSRC operation is independent of third parties (e.g. cellular infrastructure, backend operators). This fact disburdens or even only enables the proof of functional safety (according ISO 26262) in the automotive area, which is a necessary element for automated driving functions.

Similar to 802.11a the standard IEEE 802.11p uses a 64-channel orthogonal frequency division multiplexing scheme within a channel bandwidth of 10 MHz. This ensures a spectrum efficient operation of the technology. Currently data rates between 3 Mbps up to 27 Mbps have been specified. Lower data rates result in increased robustness of the communication. IEEE 802.11p is designed for an absolute vehicle speed of 260 km/h (and relative speed of two vehicles driving towards each other of 520 km/h).

Currently the IEEE 802.11 Working Group is specifying an evolution of DSRC called Next Generation V2X (NGV) in the IEEE 802.11bd amendment project.

With IEEE NVG further evolution of V2X DSRC (revision of IEEE 802.11p) has been started within the C2C-CC already in 2016 focusing especially on backwards compatibility, co-channel co-existence and interoperability with current DSRC. This is one of the absolute critical requirements for deploying the technology successfully targeting high market penetration. In the Annex “V2X DSRC Performance Parameters and Evolution Path“ some more background is provided.

Currently the following technological innovations within NVG are in standardization, called IEEE 802.11bd:

- LDPC – low density parity check codes
- higher data rates
- receiver diversity

The first point addresses the information theoretical coding of the signals. Contrary to the turbo-codes used by UMTS/LTE the LDPC codes enable higher data rates. These coding schemes have been proposed „High Throughput Phy specification“ as option also for the cognate standards IEEE 802.11n and IEEE 802.11ac.

This context is very important to be known before commenting on the questions of US DoT as the C2C-CC interpretation of such important definitions like interoperability, co-existence, backwards compatibility and fairness is based on this fundamental search for continuity and openness of technology evolution. Consequently, the C2C-CC suggests to adopt following terminology[1]:

Interoperability – Technology A devices to be able to decode at least one mode transmission of Technology B device, and Technology B devices to be able to decode Technology A transmissions

Co-existence – Technology A devices to be able to detect Technology B transmissions (and hence defer from transmissions during Technology B transmissions to prevent packet collisions) and vice versa

Backward compatibility – Ability of Technology B devices to operate in a mode in which they can interoperate with Technology A devices

Fairness – Ability of Technology A devices to have the same opportunities as Technology B devices to access the channel

[1] NGV Terminology (https://mentor.ieee.org/802.11/dcn/18/11-18-1307-01-0ngv-terminology-discussion.pptx)

C2C-CC responses on US DoT questions

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.

The DSRC technology can support all current V2V, V2I, V2P (V2X) applications as well as potential future applications as those envisaged in the C2C-CC Roadmap up to automated driving (see figure 1).

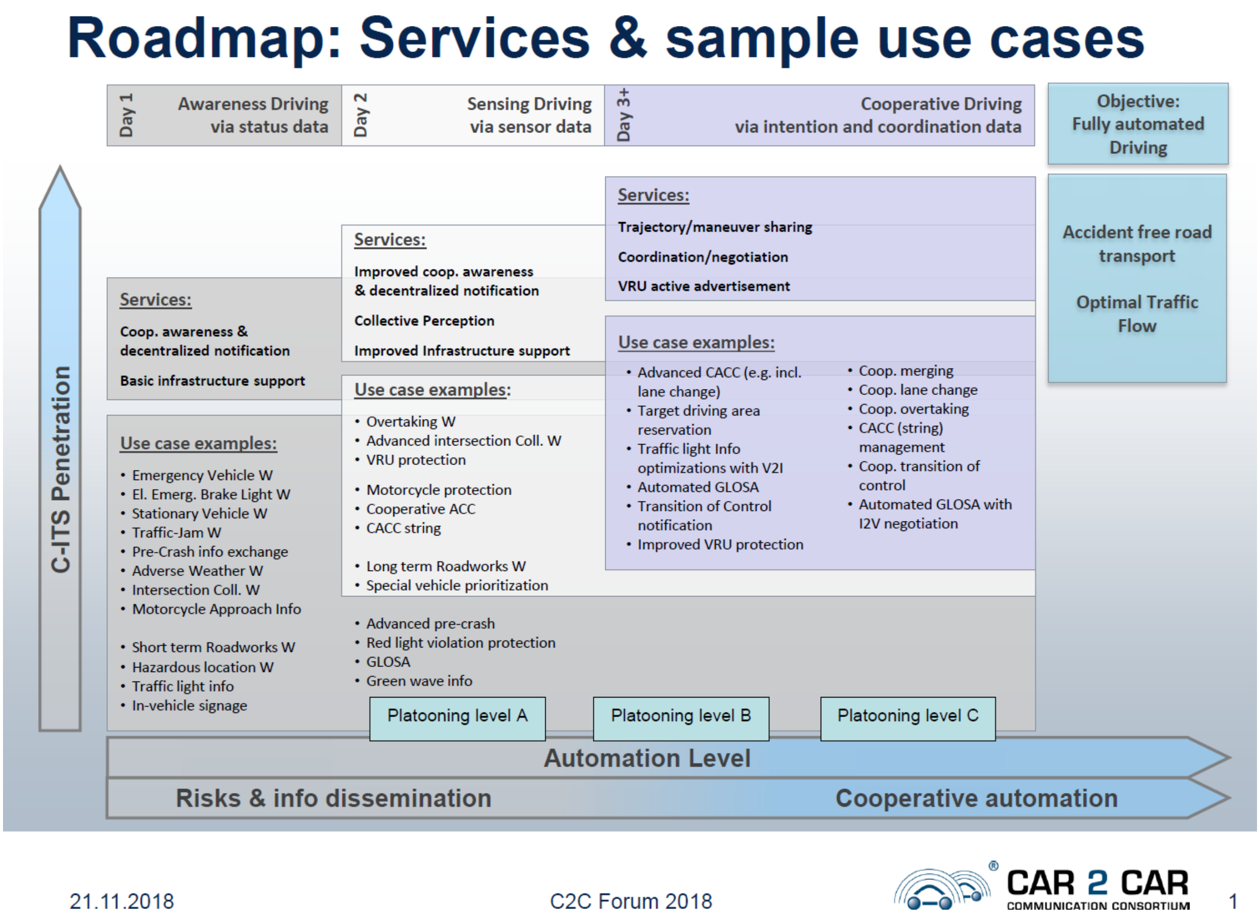

Figure 1: C2C-CC Roadmap of V2X (a.k.a. Cooperative ITS (C-ITS) Applications from initial V2X deployment towards complete cooperative automated driving[2]

The Next Generation V2X (NGV) Task Group of IEEE 802.11 (NGV V2X) is currently developing the 802.11bd specification. The goal of this upcoming amendment is to allow a seamless evolution of DSRC using the same frequency resources in a fair and interoperable manner[3].

[2] Source: C2C-CC website https://www.car-2-car.org/fileadmin/downloads/PDFs/roadmap/CAR2CAR_Roadmap_Nov_2018.pdf

[3] 802.11bd - Amendment: Next Generation V2X (https://mentor.ieee.org/802.11/dcn/18/11-18-0861-08-0ngv-ieee-802-11-ngv-sg-proposed-par.docx)

NGV V2X does not intend to replace or supplant the DSRC amendment, but rather to enhance existing mechanisms by providing new capabilities and features that are compatible with those in the existing amendment. The NGV amendment mechanisms are expected to:

1. Be backward compatible and coexistent with DSRC in all the channels in the 5.9 GHz band.
2. Provide features which are compatible with DSRC features and provide mechanisms that allow existing and future deployed DSRC devices to continue to operate efficiently in the presence of NGV capable devices.[4]
3. Include NGV transmission mechanisms which are detectable by DSRC devices.
4. Enable an NGV capable device to indicate that it is NGV capable.
5. Optionally support operation in the 60 GHz band.

C2C-CC supports the addition of the latest PHY and MAC techniques and positioning capability in an NGV amendment, so that NGV amendment can provide a seamless evolution path for IEEE 802.11-based V2X communications.

On the other hand, the alternative LTE C-V2X technology and its successor NR C-V2X are not able to coexist and are not interoperable in co-channel operation with DSRC and even with each other. Therefore, this requires separate channel allocations which leads to spectrum fragmentation. This fragmentation introduces several disadvantages in contrast to the coexistence evolution path from DSRC to NGV. The none coexistence splitting approach introduces general spectrum inefficiency but also that previous cellular technology legacy blocks the use of new technologies in the same channel. These aspects have large impact on the neutral and flexibility use of any frequency spectrum and does not allow any technology to come to full potential using the full DSRC band.

The use of several technologies for the same information exchange also result in significant additional cost to OEMs, Road operators and consumers. These disadvantages provide a major disincentive for parties interested in deploying V2X systems and jeopardize the success of V2X in general, especially in regions which depend on voluntary deployment (like the US or the EU).

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?

DSRC and NGV can operate in the same spectrum resources (ability of co-channel coexistence) without interference whereas NR C-V2X and LTE C-V2X impose significant interference to each other when operating in the same channel. Both cannot coexist with DSRC in the same channel without causing excessive interference.

If DSRC, LTE C-V2X and NR C-V2X cannot co-exist on the same channel this could result in a technology specific band split. But such a band split would be an inefficient use of the spectrum and would limit any further technology evolution. So far, no new or additional ad-hoc safety use cases are known which DSRC could not support, figure 1 and comment in question 1. There would be no benefit on the one hand, but all technologies couldn't utilize their full potential due to limited spectrum access on the other hand (see also table 1 "Spectrum needs" under question 5).

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[4] Note: The IEEE 802.11 WG does not provide conformance test specifications.

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?

Currently, several so-called “Day-1” applications are being targeted for the initial launching of DSRC technology. However, the deployment of “Day-2” applications (e.g., platooning) will follow soon after. It is therefore crucial that all vehicle manufacturers ensure interoperability within wireless technologies for vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communication, otherwise, the benefits of increasing traffic safety will diminish and the potential of saving lives will disappear.

V2V, V2I, V2P interoperability as stated in the introduction is given if Technology A devices are able to decode at least one mode transmission of Technology B device, and Technology B devices are able to decode Technology A transmissions.

This means that a car equipped with LTE C-V2X technology shall be able to communicate with cars equipped with DSRC technology at least for the very same use case since DSRC is the technology already deployed in the US in 5.9 GHz. The V2V, V2I, V2P interoperability between DSRC and LTE C-V2X needs to be proven having in mind the latency requirement of such safety related applications.

Beside the need of interoperability there is the need of coexistence to share the full V2X spectrum without interfering each other and allowing fair access to spectrum. Therefore, in ETSI a NWI (new work item) is studying co-channel coexistence of LTE C-V2X and DSRC to find appropriate mitigation techniques. First results are expected at the beginning of 2020.

However, in 3rd Generation Partnership Project (3GPP) a New Radio V2X (NR C-V2X) standard is already in development. LTE C-V2X is not seen compatible and interoperable neither with NR C-V2X nor with DSRC, which would lead to require additional spectrum for LTE C-V2X and again for NR C-V2X, as stated by 3GPP[5].

Within the Institute of Electrical and Electronics Engineers (IEEE), the standard 802.11bd is (V2X NVG) being developed which will be fully backward compatible and interoperable with the existing DSRC 802.11p.

C2C-CC supports the need for interoperability within V2X technologies. Ignoring this aspect is a risk for safety on US roads. The usage of two or even more different technologies at 5.9 GHz aiming for the same purpose in the same frequency band that cannot communicate with each other, will not be able to optimally reduce the number of accidents and incidents on US roads. Thus, for any new or emerging technology, including the above-mentioned, interoperability is the key because there needs to be a concept to communicate and understand all other (existing) vehicles. DSRC is already in place and automotive-grade hardware already exists.

[5] According to 3GPP: NR C-V2X is interoperable at the mobile network level where information can be translated and transmitted in the appropriate format, back and forward only

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?

It is important to differentiate between access-layer or radio interoperability and the so called "application" or "system" interoperability. The former allows the exchange of information between two devices employing different technologies on the same frequency resources using compatible means of transmitting and receiving wireless signals (**Fejl! Henvisningskilde ikke fundet.**2). This is the most fundamental and hence most efficient method of interoperability.

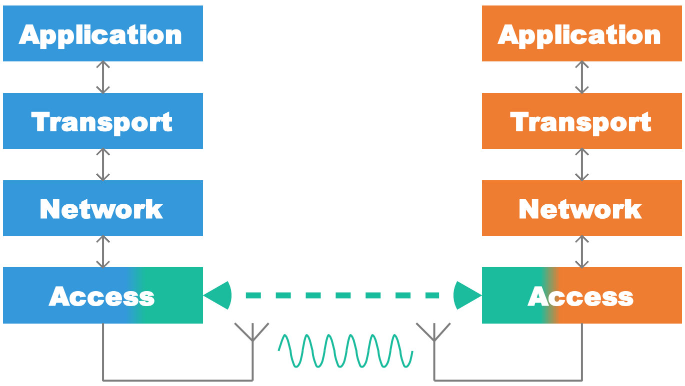

Figure 2. Access-layer interoperability

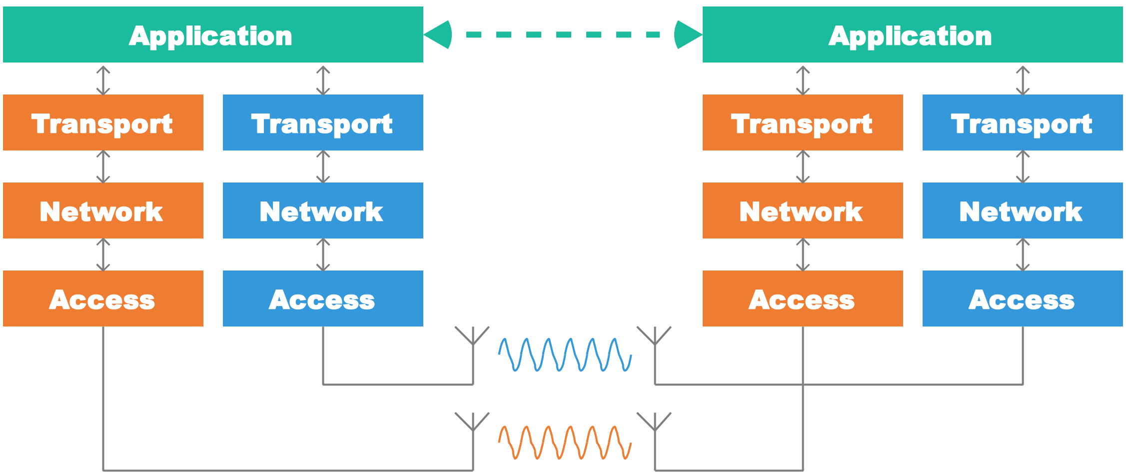

Figure 3. Application-layer interoperability

Other methods of interoperability could be achieved at a higher layer by integrating multiple sub-systems into a single device (**Fejl! Henvisningskilde ikke fundet.**3). The limitations of this approach are:

- Inefficient use of spectrum resources. Each subsystem utilizes a portion of the spectrum to exchange messages, most of which could be duplicated.
- Increased cost of equipment coming from higher complexity on the implementation, integration, testing and certification of such devices.
- Suboptimal performance: Significantly higher latency will be experienced by those systems which makes them unsuitable for safety of life applications.

An efficient implementation (i.e. at the access layer) of interoperability and backwards compatibility between different generations of V2X technologies is feasible and desirable. This approach has been taken by the IEEE NGV Task Group to enhance the incentives for V2X deployment, promote efficient utilization of the scarce spectrum resources and control of the cost to the consumer.

Besides interoperability, backward compatibility is an important aspect to meet requirements for safety of life applications to reach a high penetration of V2X equipped vehicles capable of talking to each other.

C2C-CC understands backward compatibility as the ability for same-channel co-existence PLUS a mode of interoperability at the access layer (as expressed in the terminology stated previously). In that sense NR C-V2X is not backward compatible with LTE C-V2X, because the two technologies employ access layers which are not co-channel coexistent. System-level backwards compatibility is achievable by using simultaneously an LTE C-V2X and a NR C-V2X transceiver, which however is inefficient, sub-optimal and would still require a dedicated spectrum allocation for each technology.

On the other hand, NGV is backward compatible with DSRC as already explained 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? What about other V2X safety applications, such as those involving V2I and V2P communications?

The answer is three-fold in 1) cost aspects 2) possibility to update legacy vehicles 3) spectrum efficiency.

Cost aspects

Europe and the US have adopted a voluntary V2X introduction for private and public stakeholders. Key in accelerating the deployment is to increase benefit/cost ratio for V2X for each stakeholder and its deployment decision.

Increased cost leads to delay in deployment:

The complexity and cost associated with the adoption of additional V2X technologies, irrespective of the specific communications protocol used, is undoubtedly very substantial. At the same time, the expected life-cycle of vehicles and infrastructure is much longer compared to that of most consumer products. These factors have caused vehicle manufacturers and road operators to take a cautious approach on the adoption of DSRC technology.

If a new technology is introduced in the same frequency band offering the same services, then the first impact would be to introduce confusion leading to an unavoidable delay in the deployment of V2X technology in cars and roads. In turn, this will have a direct impact on the safety of human lives on the road every year. Secondly, car manufacturers and road operators will most likely be forced to adopt both technologies, which will result in increased cost and complexity. Eventually this will lead to increased cost to the consumer, however without the latter enjoying any additional benefit.

Possibility to update legacy vehicles

The C-V2X vision is that some use cases will always be supported over LTE C-V2X and others will always be supported by NR C-V2X. By contrast, even a key use case like the BSM can evolve from DSRC to IEEE NGV because NGV devices can make packet-by-packet decisions about whether to transmit in a backward interoperable way or not (based on the capabilities of its neighbors).
3GPP has already defined a newer better NR C-V2X, but they would assign the most important use case to the older LTE CV2X. NR C-V2X was designed to enable new use cases that LTE C-V2X and DSRC cannot support. Up to now no such use cases have been identified. For example, as the development of Collective Perception Message (CPM) at ETSI shows, DSRC can support sensor sharing via the CPM. A

related point is that when the next generation technology shares the same channel with the prior generation, devices already in the field can be updated with new software to support new use cases. This is important for the automotive industry. We cannot afford to have cars that are stuck doing only those functions that were already standardized at the time of manufacturing. If evolution is to be from DSRC to LTE C-V2X to NR C-V2X, all legacy vehicles will be prevented from being updated to support new applications.

Spectrum efficiency

If different technologies and generations of the same technology would be interoperable there is still the issue of co-channel coexistence (relevant for DSRC vs. LTE C-V2X vs. NR C-V2X, not relevant for DSRC vs. NGV) to be able to share the whole V2X spectrum.

The proposal of a technology specific band split would hinder any further technology evolution in the US. With further studies to be done, ITS spectrum could be opened to additional V2X technologies when they have proven co-channel coexistence and interoperability with the deployed technologies and deployed use cases.

A division of the available spectrum resources will lead to a situation where the needs of V2X systems will not be met by either technology in the near future. From a spectrum view, at least the available 75 MHz[6] of bandwidth is required for V2X, regardless of the communication technology. This requirement urges any decision to avoid the duplication of any use case with a second technology and to avoid any spectrum fragmentation.

Spectrum requirements calculated based on relevant safety radius (=minimum required communication range). Relevant for the safety use cases. Depending on the environment in field measured communication ranges can be much longer.
E.g. in urban szenario above 250 m, on highways above 1000 m. Spectrum needs increase in the same proportion as the communication range.

Environment	BSM	SPAT_MAP traffic lights	PSM pedestrians	PCM platooning	CPM collective perception	MCM manoevering	MCM 1)	total spectrum requirement Σ
Urban	10.6	0.1	5.1	3.5	13.0	7.4	7.4	47 MHz
safety relevance radius	100m	100m	50m	100m	100m	100m	100m	
Sub-Urban	9.9	0.0	0.2	3.5	14.7	8.4	8.4	45 MHz
safety relevance radius	150m	150m	50m	150m	150m	150m	150m	
Rural, Highway	9.9	0.2	0.0	8.7	20.4	11.6	11.6	62 MHz
safety relevance radius	500m	500m		500m	500m	500m	500m	
additional requirement for **Truck parking / Tollstation**				**17.5**			**Rural:**	**80 MHz**
safety relevance radius				200m				
additional requirement for **Urban square**			**34.9**				**Urban:**	**77 MHz**
safety relevance radius			50m					

Table 1: US spectrum requirement analysis independent of V2X technology based on known V2X message types and different environments[7]

Fejl! Henvisningskilde ikke fundet. summarizes the spectrum needs[8] of vehicle-to-vehicle, vehicle-to-infrastructure and vehicle-to-pedestrian communication (in the following called V2X) known today. The already known message types[9] of V2X are relevant to realize all V2X applications which are part of the

[6] including a 5 MHz guard band from 5850-5855 MHz.

[7] source C2C-CC white paper "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Automation Applications" https://www.car-2-car.org/documents/

[8] Spectrum needs = $\frac{packet\ size \times periodicity \times ITS\ stations\ in\ comm\ range}{spectrum\ efficiency \times max\ channel\ load}$

[9] BSM Basic Safety Message

V2X roadmap[10], additional messages with additional spectrum needs may come on top of that picture. Some messages like Basic Safety Message (BSM), Messages used by traffic lights (SPAT, MAP), and Personal Safety Message (PSM) cover applications listed in the life saving category of safety in Connected vehicle Reference Implementation Architecture (CVRIA)[11]. Some of them like CPM, MCM, and PCM go beyond CVRIA applications and climb the V2X roadmap towards cooperative automated driving.

The advanced types of applications in direction of V2X supporting automated driving as collective perception, cooperative maneuvering and truck platooning (based on CPM, MCM, PCM) are alone requiring 50 MHz spectrum bandwidth, already occupying five of the existing seven DSRC channels.

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?

The existing DSRC technology is capable to cover all V2I and V2P use cases. V2I and V2P use cases have in general the same interoperability requirements. V2I use cases have typically less stringent requirements on latency except some like red light violation warning.

V2P has high requirements on precise localization of the pedestrians. The issue of location accuracy hinders today´s implementation of V2X into mobile devices more than the choice of a specific communication technology. DSRC as well as LTE C-V2X could be integrated into today´s smart phones.

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?

C2C-CC does not expect impact of different technologies related to security, provided the security protocols, policies and certifications are the same.

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

- The DSRC technology can support all current V2X applications as well as potential future applications: All V2X applications foreseen to support automated driving vehicles are already included in C2C-CC Roadmap (Figure 1). DSRC is capable to support the whole roadmap.

SPAT, Signal, Phase, and Timing (SPAT), ISO/TS 19091:2017
MAP
ISO/TS 19091:2017
Pedestrian protection with Personal Safety Messages (PSM) according to SAE J2735, SAE J2945/9_201703 https://www.sae.org/standards/content/j2945/9_201703/
PCM Platooning Control Message, currently being drafted in the European H2020 project ENSEMBLE (multi-brand truck platooning) https://platooningensemble.eu/ https://platooningensemble.eu/news/using-its-g5-for-efficient-truck-platooning5c1a203e7a226
CPM Collective Perception Message, Draft TS 103 324
MCM Maneuver Cooperation Message, according to ETSI TR 103 578 (draft) "Informative report for the Maneuver Coordination Service"; https://imagine-online.de/en/home/
MCM 1) doubled spectrum resources needed for MCM if message size increases from 400 Byte to 800 Byte due to multiple traces. The requirement between 400 Byte and 800 Byte may change by different situations.

[10] See C2C-CC application roadmap https://www.car-2-car.org/fileadmin/downloads/PDFs/roadmap/CAR2CAR_Roadmap_Nov_2018.pdf

[11] https://local.iteris.com/cvria/html/applications/applications.html

- The Next Generation V2X (NGV) Task Group of IEEE 802.11 (NGV V2X) is currently developing the 802.11bd specification. The goal of this upcoming amendment is to allow a seamless evolution of DSRC using the same frequency resources in a fair and interoperable manner[12] and making full use of latest technology innovations.
- V2X communication technologies are essential for the introduction of automated driving. As automation increases, V2X-equipped road users can generate information about local status, detections, as well as intention and coordination data. Exchanging this information allows intelligent interaction between vehicles and with the infrastructure to coordinate their movements and behavior even in complex traffic situations like urban scenarios.

Will different communication technologies be used in different ways?

- For automated driving, a combination of ubiquitous short-range ad-hoc and medium-long range infrastructure-based communication will be adopted. The prerequisite for selection of a given technology type is reliability based on exhaustive verification in the field.

How?

- The mentioned communication technologies will be used in a complementary way. The ad-hoc technology will support ubiquitous coverage and communication support for local V2V and V2I cooperative automated driving applications. The infrastructure-based technology will provide background support for centralized supporting functionalities like cloud services (e.g. HD map updates).

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?

CAR 2 CAR Communication Consortium (C2C-CC) is convinced that a fast, successful and wide-scale deployment of V2X in the US and the EU is key for reducing the number of fatal accidents and supporting cooperative automated driving to reach the goal of zero fatalities from vehicle collisions.

Existing deployments in Europe and US are based on strong cooperation between vehicle manufacturer, road operators (cities, states) and public authorities. Maturity of technologies – for example the ability to cope with congested driving scenarios - needed to be proved beforehand taking real world testing with large field operational tests into account.. Compliance assessment testing and interoperability testing based on standards (SAE, ETSI test specifications, ETSI plug tests) ensures that all deployed devices interoperate with each other in the field.
C2C-CC is of the opinion that such strong collaboration activities are needed to trust into the capability of technology, use cases, testing and implementations and to successful deploy to save lives on our roads. That is the reason why V2X deployments in US and EU are gaining momentum.

[12] 802.11bd - Amendment: Next Generation V2X (https://mentor.ieee.org/802.11/dcn/18/11-18-0861-08-0ngv-ieee-802-11-ngv-sg-proposed-par.docx)

Deployment Status:
The deployment of DSRC in vehicles has already started **in the United States** in 2017 with General Motors[13] while several other vehicle manufacturers are currently in their commercialization phases (Toyota: launch by 2021[14], GM: further DSRC roll-out[15]). At the same time, most member states in the USA have initiated the DSRC deployment of infrastructure targeting Vehicle-to-Infrastructure (V2I) applications to enhance road safety (Figure 4).

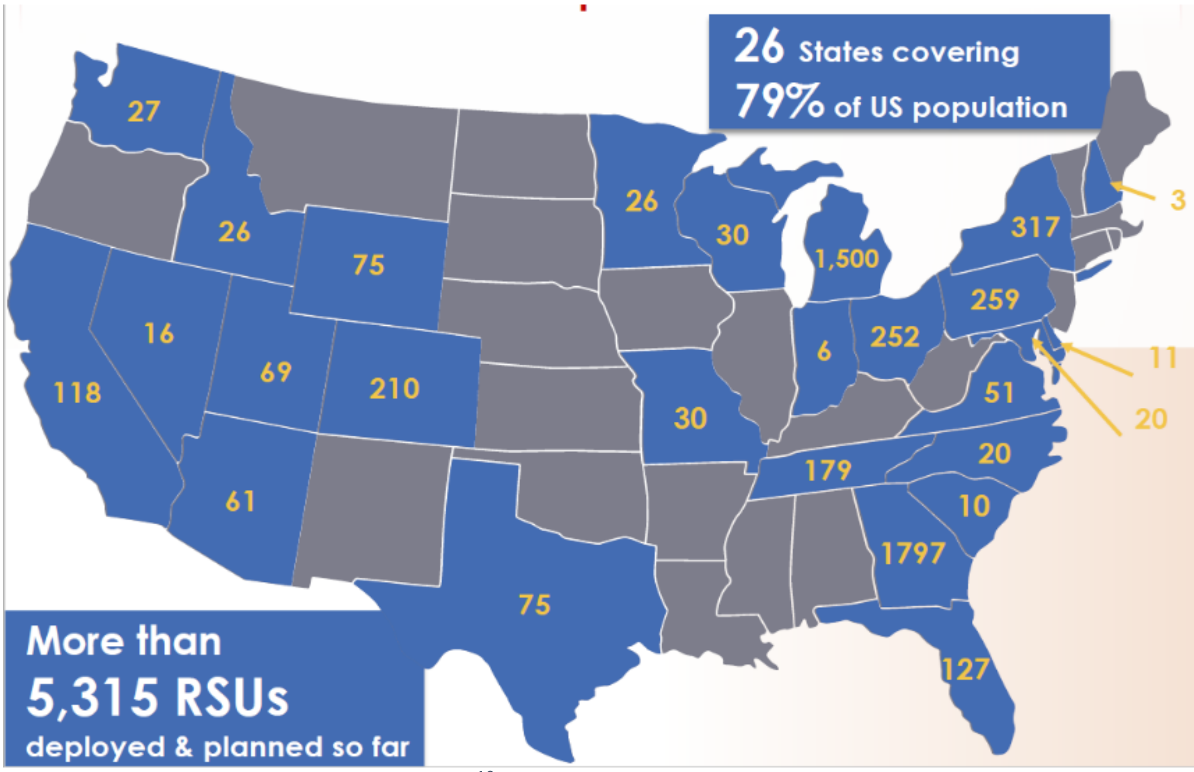

Figure 4: RSU deployment with DSRC in US[16] in mid 2018

In Europe, Volkswagen Group will start in 2019 the mass volume deployment of DSRC-based (pWLAN) V2X technology in its models while member states are equipping RSU at selected traffic hot spots, see Figure 5. In Figure 5 the commercial deployment of mid 2018 is shown while deployment is ongoing in 2019.

[13] https://media.cadillac.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2017/mar/0309-v2v.html

[14] https://corporatenews.pressroom.toyota.com/releases/toyota+and+lexus+to+launch+technology+connect+vehicles+infrastructure+in+u+s+2021.htm

[15] https://media.gm.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2018/jun/0606-its-cadillac.html

[16] source: Toyota presentation on ITS WC Oct 2018, update on C2C-CC Forum Nov 2018, see also https://transportationops.org/spatchallenge

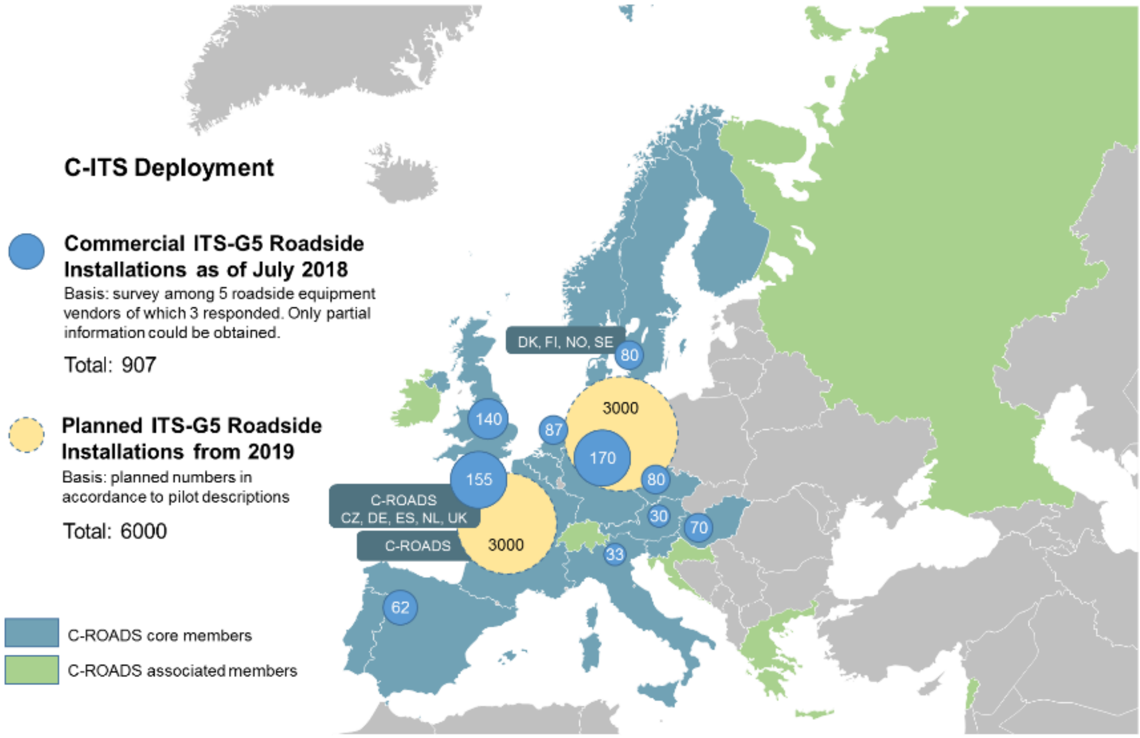

Figure 5: RSU deployment with DSRC in Europe[17]in mid 2018

Harmonization of V2X is key to accelerate deployment

Continuous harmonization between US and EU on V2X is ongoing. USDOT has invested a lot in harmonization over the years with all of the Harmonization Task Groups (HTG1, HTG3, HTG7, etc.). Europe is following that path with the draft Commission Delegated Regulation supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems.

Pushing for further deployment:

Please refer to answer under question 5. Increased cost leads to delay in deployment.

[17] source: CEPT WG-FM https://cept.org/Documents/wg-fm/49131/fm-19-045_pc-summary-for-draft-cept-report-71-on-its

Annex – V2X DSRC Performance Parameters and Evolution Path

V2X DSRC is a decentralized short-range ad-hoc radio system based on WLAN standards and was standardized in the WLAN family as IEEE 802.11p. This standard has been exclusively developed for V2X communications. The design as a pure short-range broadcast system considers the highly dynamical ad-hoc network structure of traveling road users. Bi-directional link connection results in delays for real-time data transfer caused by the increasing distances between the traffic participants due to their movement. Because of this reason the data is directly communicated to all road users in the surrounding vicinity. This concept increases the net data rate of the communication medium. Continuous developments of the communication mechanisms considered the requirements of the Authorities for ensuring security and privacy needs. This resulted in compulsory signing of all message sets (security certificates) and a procedure for changing identifiers (pseudonyms) of the participant to avoid long distance tracking of individual vehicles. A crucial aspect is that V2X DSRC operation is independent of third parties (e.g. cellular infrastructure, backend operators). This fact disburdens or even only enables the proof of functional safety (according ISO 26262) in the automotive area, which is a necessary element for automated driving functions.

Similar to 802.11a the standard IEEE 802.11p uses a 64-channel orthogonal frequency division multiplexing scheme within a channel bandwidth of 10 MHz. This ensures a spectrum efficient operation of the technology. Currently data rates between 3 Mbps up to 27 Mbps have been specified. Lower data rates result in increased robustness of the communication. IEEE 802.11p is designed for an absolute vehicle speed of 260 km/h (and relative speed of two vehicles driving towards each other of 520 km/h).

During the past years V2X DSRC has passed extensive communication tests followed by testing of applications in large field operational tests (Safety Pilot) and has already reached the phase of deployment. The results provided empirical data prooving the operation in real environment. The results show that typical latency of the data transmission on physical layer level is below 2 ms. Furthermore, verification prooved the capability of the technology to handle more than 1,000 vehicles within 300m coverage.

With IEEE NVG further evolution of V2X DSRC (revision of IEEE 802.11p) has been started within the C2C-CC in 2016 focusing especially on backwards compatibility and interoperability with current DSRC. This is one of the absolute critical requirements for deploying the technology successfully to ensure high market penetration. Currently the following technological innovations are within NVG in standardization:

1. LDPC – low density parity check codes
2. higher data rates
3. receiver diversity

The first point addresses the information theoretical coding of the signals. Contrary to the turbo-codes used by UMTS/LTE the LDPC codes enable higher data rates. These coding schemes have been proposed „High Throughput Phy specification“ as option also for the cognate standards IEEE 802.11n and IEEE 802.11ac.

The receiver diversity shall compensate physical propagation effects in real environments. The concept uses more than one receiver link with one antenna for each link. The antennas are arranged in such a distance that destructive interference due to multi-path propagation becomes less critical on receiver side. An extension to MIMO technology – which is based on a fundamental different principle than receiver diversity – was considered as not constructive due to the high speeds of the road users and the broadcast modus of V2X. This is caused by the channel estimation methods of the MIMO technology, which can only be applied efficiently for slow moving users.

On the basis of these future developments, V2X IEEE NVG, now called IEEE 802.11bd, will be developed further also compared to LTE C-V2X. While V2X DSRC is already being serially integrated in vehicles and on the roads LTE C-V2X currently exists solely on paper.