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Subject: Public Consultation on Radio Spectrum Policy Program

General comments:

The CAR 2 CAR Communication Consortium welcomes the opportunity to comment the draft "RSPG Opinion on a Radio Spectrum Policy Programme (RSPP)" in Chapter "3.3 Transport" addressing the future spectrum requirements and needs for Intelligent Transport Systems (ITS) with the focus on road ITS.

"3.3. Transport

- *Member States should ensure the availability of spectrum for public transport purposes and implement relevant EU Decisions for FRMCS and ITS urban rail supported by coherent European standardisation initiatives (including for example FRMCS receivers). Member States should support the development, where appropriate, of any additional spectrum measures such as cross border coordination or sharing with others usages or use of innovative 5G services, including commercial networks, if compatible with other non-spectrum EU regulations.*
- *European Commission and Member States should monitor ITS market developments and evolution of European standards and technology supporting ITS usage in order to maintain efficient usage of EU harmonised spectrum. Due to technology neutrality implemented in spectrum regulation, any support to a particular ITS road technology remains at the initiative from European Commission.*
- *European Commission and EU Member States should support*
    - *the development of connectivity on-board (cars, trains, aircraft) based on EU harmonised spectrum.*
    - *the development of autonomous vehicles based on ITS and other EU harmonised spectrum."*

CAR 2 CAR Communication Consortium generally find the paragraph positive however have concerns with the sentence found in "Chapter 3.3 Transport" above "*Due to technology neutrality implemented in spectrum regulation, any support to a particular* ***ITS road technology remains at the initiative from European Commission.***" Our strong opinion is that the last part of the sentence is not belonging to the spectrum policy work as treated in RSPG. Spectrum regulation exercises technology neutrality in order to not favor technologies. There exist several ITS road technologies, thus, there is a competition among these. For achieving interoperability and backward compatibility, it can be of importance to mandate specific technologies under for example the ITS Directive (2010/40/EU)[1] but that belongs to the regime of DG MOVE. To this end, we suggest changing the sentence above to "***Spectrum regulation for ITS should be technology neutral***".

CAR 2 CAR Communication Consortium and its members are currently deploying and further developing C-ITS road use cases. In this context, it is key that adequate radio spectrum resources are identified and made available, ideally on a cross-regional, harmonised and protected basis. Particularly in the 5.9 GHz road safety ITS spectrum, CAR 2 CAR Communication Consortium supports ITS as an application of land mobile service that protects existing radio services in the same band and in adjacent bands. Our industry would like to provide the following perspective:

- Road ITS should be able to use the whole ITS band in a flexible and technology neutral way as a consecutive band. Any segregation of road ITS technologies in spectrum would lead to a significant reduction of spectrum efficiency and consequently to increased spectrum needs.
- Polite spectrum access with decentralized control (decentralized congestion control DCC, CSMA/CA, duty cycle) can increase the spectrum efficiency as already considered in ECC/DEC/(08)01[2]. We see e.g. ITS duty cycle per single device as key for efficient use of spectrum and for a fair access to spectrum per ITS device; a long-term 1% duty cycle per device and per hour and a short-term 3% duty cycle per device and per second is necessary for C-ITS.
- C-ITS applications currently in specification in ETSI TC ITS follow the principle of data minimization and data economy for spectrum efficiency and privacy reasons. In contrast to "raw sensor data" sharing, the Collective Perception Service (ETSI TS 103 324), currently being specified by ETSI TC ITS, follows these efficiency principles. For this purpose, the generation of a Collective Perception Message (CPM) is tied to the quality of detected objects (such as pedestrians, bicyclists, scooters, motorcycles and other vehicles) rather than simply sharing every measurement from every sensor of an ITS station. This not only reduces the resulting channel utilization but also distributes the computational effort of fusing several sensor measurements from the same station (vehicle or roadside unit) into distinct objects. The CAR 2 CAR Communication Consortium has published a "Technical Report on CPM Object Quality"[3] on how to agree on common object quality metrics between multiple ITS stations from different vendors, which will be contributed to the corresponding ETSI TC ITS working group for the CPM.
- Overall spectrum needs estimation of 140 MHz are envisioned for the future, see more details in Annex A.4:
    - For the next decade, we see the existing 70 MHz for road ITS as sufficient to support the CAR 2 CAR Communication Consortium's roadmap (see Figure 1) and spectrum needs (see Table 3), given that connected automated vehicles (CAV´s, see definition in Annex A.1) are not in majority in the overall vehicle fleet in Europe. The statement is only valid under the following assumptions:
        - No band split in the 5.9 GHz
        - Efficient spectrum sharing solution with Urban Rail ITS in 5915-5925 MHz is found for V2V applications
        - The potential use of the road ITS band 5855-5875 MHz for specific safety-related ITS applications

[1] ITS Directive (2010/40/EU), see also European Commission's C-ITS Strategy COM (2017) 766 and 5G Action Plan COM (2016) 588 in footnote 29: 'Motorways and national roads, and railways, in line with the definition of Trans-European Transport Networks. Where appropriate 5G will operate in seamless co-existence with technologies already being deployed, in particular short-range communication for vehicle-to-vehicle and vehicle-to-infrastructure (ITS-G5), under a complementarity principle.'

[2] See ECC DEC (08)01 footnote 4 "…This means that technologies are allowed to use the spectrum regulations for safety related ITS for 5875–5925 MHz when they support sufficiently polite spectrum access and/or interference mitigation which allows sharing of the spectrum in principle…"

[3] CAR 2 CAR Communication Consortium "Technical Report on CPM Object Quality" https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2089_CPM_ObjectQuality_V1.pdf

        - For most efficient use of spectrum V2X messages are generated only if required and necessary content is adapted by application layer to the minimum. V2X messages change dynamically in sending rate and message size over time with an aperiodic behaviour[4]. All CAV related messages such as CPM, MCM, VAM, deploy comparable dynamic generation rules as CAM.
    - Beyond that and CAV´s being the majority of vehicle fleet the today´s CAR 2 CAR Communication Consortium roadmap and its current applications, especially for Collective Perception Message (CPM) and Maneuver Coordination Message (MCM), a typical capacity of 140 MHz will be needed (see table 2 in combination with table 5).
- CAR 2 CAR Communication Consortium identifies the need for a safety-related band below 1 GHz, to facilitate strategic control information exchange between CAVs using a longer communication range but also to enable a redundant communication channel for supporting higher functional safety levels, see Table 2.
- The existing 63,72-65,88 GHz ITS band is foreseen for very short-range, high-data throughput communication and complements the 5.9 GHz for applications such as platooning, Infrastructure-to-Vehicle (I2V) data communication or cooperative high precision positioning, also mentioned in Table 2.

The incumbent wireless communication technology ITS-G5 is already broadly deployed for safety services in the 5.9 GHz band. In 2019, 6000 km of roads[5] were already equipped with roadside units (RSU) facilitating safety using cellular connectivity as well as ITS-G5. Since March 2020, ITS-G5 supporting road traffic safety is a default feature of VW Golf 8 and ID and by the end of 2021, 750 000 Golf 8 and ID will have reached the European market[6].

ITS-G5 vehicles deployed in Europe complement the crash avoidance of advanced driver assistance systems (ADAS) with short-range ad hoc communication (Vehicle-to-Vehicle V2V, Vehicle-to-Infrastructure V2I, Vehicle-to-Pedestrian V2P) reducing traffic fatalities and traffic injuries, see further explanations in Annex A.1. ADAS rely upon line-of-sight sensors such as radars and cameras, which detects changes in the environment faster than the human driver but they are bound to line-of-sight. ITS-G5 provides the ears and mouth to ADAS and can “see” beyond physical barriers within milliseconds.

While ITS-G5 supports the entire CAR 2 CAR Communication Consortium roadmap with its current and coming C-ITS applications, IEEE is developing the next generation of IEEE 802.11p[7] communication technology called IEEE 802.11bd[8], which is designed to be interoperable, backward compatible and co-channel coexistent to ITS-G5 delivering innovations which can enhance future applications.

We recognize that sharing and cooperation with other ITS users such as urban rail, rail, and ship, is possible. However, it is essential for our automotive industry that access to certain frequency channels are not blocked longer than necessary for safety-related applications. The most future-proof and spectrum efficient solution to prevent vehicles from transmitting in certain geographical areas on a given frequency channel would be to dynamically transmit messages directly to vehicles in the vicinity of a protected zone. The application of for example a database containing protected zones needs to be updated (who should be responsible for that, what about data integrity) and old vehicles might not have the same information as new vehicles etc. There are many problems associated with a database solution and the most spectrum and cost efficient solution is to transmit messages in relevant geographical areas at relevant times instead. See

[4] An analysis of this behaviour for the broadly used ETSI Cooperative Awareness Message CAM is given in IEEE “Empirical Models for the Realistic Generation of Cooperative Awareness Messages in Vehicular Networks” .
[5] Martin Böhm, C-ROADS, “Status of C-ITS infrastructure deployment across Europe,” presented at CAR 2 CAR Communication Consortium Forum, online, November 3, 2020.
[6] Source: IHS Markit, 24 Feb 2021
[7] ITS-G5 is the European name of IEEE 802.11p
[8] http://www.ieee802.org/11/Reports/tgbd_update.htm

CAR 2 CAR Communication Consortium white paper "Urban Rail integration into ITS-G5"[9] and ETSI TS 103 724 "Intelligent Transport Systems (ITS); Facilities layer function; Protected Zone Message (PZM); Release 2"[10] for more information.

About the Car 2 Car Communication Consortium

Enhancing road safety and traffic efficiency by means of Cooperative Intelligent Transport Systems and Services (C-ITS) is the dedicated goal of the CAR 2 CAR Communication Consortium. The industrial driven, non-commercial association was founded in 2002 by vehicle manufacturers affiliated with the idea of cooperative road traffic based on Vehicle-to-Vehicle Communications (V2V) and supported by Vehicle-to-Infrastructure Communications (V2I). The Consortium members represent worldwide major vehicle manufactures, equipment suppliers and research organisations. Over the years, the CAR 2 CAR Communication Consortium has evolved to be one of the key players in preparing the initial deployment of C-ITS in Europe and the subsequent innovation phases. CAR 2 CAR members focus on wireless V2V communication applications based on ITS-G5 and concentrate all efforts on creating standards to ensure the interoperability of cooperative systems, spanning all vehicle classes across borders and brands. As a key contributor, the CAR 2 CAR Communication Consortium works in close cooperation with the European and international standardisation organisations such as ETSI and CEN.

If you have any questions about this comment, please feel free to contact me.

On behalf of the CAR 2 CAR Communication Consortium

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[9] CAR 2 CAR Communication Consortium white paper "Urban Rail integration into ITS-G5" https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR2053_Urban_Rail.pdf

[10] https://docbox.etsi.org/ITS/ITSWG1/70-Draft/WG1947/ITS-001947v004.docx

Annex A

A.1 Relationship for crash avoidance between short-range ad hoc communication and advanced driver assistance systems

Advanced driver assistance systems (ADAS) in vehicles have played a significant role in reducing the number of accidents on roads. Table 1 provides figures on how many crashes ADAS can avoid for different driving scenarios[11]. Up to 50% of the investigated driving scenarios can avoid crashed with the help from ADAS.

Table 1: Driving maneuvers and corresponding crash avoidance potential by ADAS

	All crashes	Severe crashes
Turning-in/crossing vehicle	16.3%	21.2%
Turning with oncoming vehicle	2.2%	4.1%
Turning with rear-end crash	3.8%	2.4%
Longitudinal traffic with real-end crash	21.9%	15.1%
Longitudinal traffic with lane-change crash	6.1%	3.1%
Total	50%	46%

V2X communication such as V2V, V2I and vehicle-to-pedestrian (V2P), complements the ADAS based on line-of-sight sensors by providing additional information, e.g., object detection, vehicle intentions, vehicle speed, acceleration information, as well as other status information. V2V message types like Cooperative Awareness Message (CAM), Collective Perception Message (CPM) and Maneuver Coordination Message (MCM) are used to communicate directly between V2X vehicles. Short-range ad hoc communication extends the range of ADAS beyond line-of-sight, thus, reduces the occurrences of accidents. The same is applicable to prevent accidents between vehicles and vulnerable road users (VRU). With state-of-the-art ADAS, 55% of all incidents with VRUs could be avoided[12] and this figure would increase with the addition of V2X sensor detecting dangerous situations beyond physical barriers.

A.2 Definition of connected automated vehicles

Connected automated vehicles (CAVs) are vehicles with V2X communication capability blended with automated functionality beginning at SAE level 2+ up to level 5. The latter consists of a combination of ADAS using sensors such radar, camera, and lidar (line-of-sight technologies). The V2X communication extends the awareness horizon of ADAS by charting both location and intention of other road users such as vehicles, and it has the ability to “see” beyond other objects in real-time (non-line-of-sight).
V2X communication provides ears and mouth to the automated vehicle and enables cooperative ITS where the end users are not only consuming information but also providing. V2X communication is essential for bringing automated driving to the streets. V2X communication enables applications intended to improve road traffic safety and boost road traffic efficiency on all SAE levels.

A.3 Objectives and radiocommunication requirements for CAVs

CAV development is an evolution and not a revolution. CAVs will exist side-by-side with other non-automated road users for the foreseeable future. Different use cases and levels of automation have different requirements. SAE level 1 and level 2 automation systems are already on the market illustrated through, e.g., adaptive cruise control and lane keep assistance systems, these are solely based on line-of-sight sensors such camera and radar. Ad hoc V2X communication based on IEEE 802.11p as part of IEEE 802.11-2016 are deployed in roadside units and serial vehicles in all three regions Europe (ITS-G5), US (WAVE) and Japan (ITS Connect) for increasing road traffic safety by extending the awareness horizon for the driver (increasing the time to react on dangerous events). Next step is to marry ADAS with ad hoc V2X communication and include

[11] BASt, German Federal Highway Authority. “Requirements to ADAS from the road safety perspective”, 2007. https://www.bast.de/BASt_2017/DE/Publikationen/Archiv/Infos/2007-2006/11-2007.html.

[12] European H2020 research project PROSPECT, PROactive Safety for PEdestrians and CyclisTs, analyse and tested in-vehicle perception ADAS to protect VRUs, finalized 2018. Deliverable D2.3, https://ec.europa.eu/inea/en/horizon-2020/projects/H2020-Transport/Safety/PROSPECT.

the ad hoc V2X communication as a new sensor to the overall sensor fusion framework towards V2X enhanced ADAS.
In the CAV domain, vehicles will support step-by-step more functionalities. Once the ad hoc V2X sensor is included in the sensor set, new V2X enhanced ADAS features will be enabled such as cooperative ACC that can avoid rear-end collisions as well as increase road traffic efficiency (closer spacing between vehicles and reduced fuel consumption). The only mature technology for ad hoc V2X communication is IEEE 802.11p (ITS-G5, WAVE, ITS-Connect). All proposed applications in the CAV domain (e.g., platooning, collective perception, manoeuvre coordination) are fully supported by IEEE 802.11p based V2X technologies. The applications, however, cannot be supported by one single radio on one frequency channel. The necessary exchange of data for supporting CAV applications needs at least 70 MHz of spectrum.

Higher layer including application layer requirements

CAV requirements (higher layer requirements):
Ad hoc V2X communication will be an essential part for CAVs. Nevertheless, there are many other parts in the CAV domain that needs more attention such as functional safety, robust positioning, sensor fusion, machine learning, high definition maps etc. All parts need to be carefully orchestrated to make CAVs happen. In this respect, communication is just one piece in this giant puzzle.
It takes around 3-5 years for adding a new feature to a vehicle, this long product development cycle is due to the rigorous process of placing safe products on the market. Vehicles have an average lifetime of 12 years. Given the long product development cycles and expected life-time, legal certainty is of utmost importance for vehicle manufacturers. For example, a sudden removal of spectrum resources cause much headache and creates insecurities resulting in unwillingness to make necessary investments for realizing certain technologies. Further, new technology for inclusion in vehicles needs to be mature when the product development starts and it needs to be available for the coming 15 years.
IEEE 802.11p supports already today CAV requirements especially in terms of latency. Draft IEEE 802.11bd will enhance the robustness of the physical layer thereby increasing the reliability at longer distances (the information horizon will increase for the automated vehicle). IEEE 802.11p supports a latency below 1 ms.

The IEEE 802.11p based ITS-G5 communication technology support the required performance criteria's for CAV applications. This is now proven with Collective Perception and Manoeuvre Coordination Services which are successfully tested and implemented for CAV with IEEE 802.11p based ITS-G5 in IMAGinE[13] .

The IEEE has initiated IEEE P802.11-Task Group BD - "Enhancements for Next Generation V2X"[14] which includes "Automated Driving Support" and "Sensor Sharing" use cases, as well as the "Basic Safety" use cases currently supported by IEEE 802.11 and IEEE 1609.x WAVE standards. The IEEE 802.11bd standard is planned for completion by the end of 2021.

Regarding vehicle-to-network (V2N) cellular connectivity, CAVs are more in need of better coverage of existing deployment of 4G networks then 5G and better cross-border functionality. OEMs design CAVs for surviving without network coverage.

A.4 Spectrum requirements for CAV radiocommunication and C-ITS application roadmap

Spectrum bandwidth needed

One of the initial major considerations related also to [Question ITU-R 261/5] is to determine whether the 5 850-5 925 MHz spectrum indicated in Recommendation ITU-R M.2121-0 is suitable and sufficient to support CAV communication requirements.

[13] Research project IMAGinE; https://imagine-online.de/en/home/
The IMAGinE (Intelligent Maneuver Automation – cooperative hazard avoidance in realtime) project is developing innovative driving assistance systems for cooperative driving. Cooperative driving refers to road traffic behaviour in which road users cooperatively plan and execute driving maneuvers. Individual driving behaviour is coordinated with other road users and the overall traffic situation based on automatic information exchange between vehicles and infrastructure. Critical situations can be avoided or mitigated, thereby making driving safer and more efficient.
[14] http://www.ieee802.org/11/Reports/tgbd_update.htm

CAVs require spectrum dedicated to safety-related communication and spectrum needs to be physically uncorrelated to provide fully redundant communication conditions. Table 1 summarizes spectrum needs for CAVs besides the spectrum available for cellular connectivity such as 4G/5G, which is subject to another spectrum regime.

Table 2: Current and future spectrum needs for CAVs

Frequency band	Status/description	Current availability	Future requirements CAV
5.9 GHz	Main spectrum today for deployment of road traffic safety and efficiency applications	5.9 GHz is already identified and 70-75 MHz of bandwidth is allocated in several parts of the world	As a minimum 70 MHz of spectrum is required for CAVs, see table x in present document, around 140 MHz is required as a typical need
mmWave	Short-range, high-capacity and low-latency communication potentially combined with radio location capabilities	Europe has an allocation of mmWave for ITS at 60 GHz	At least 2 GHz in bandwidth for enabling high transfer rates
< 1 GHz	For long range strategic control information between CAVs, redundant communication channel to enable certain functional safety levels	Japan has an allocation at 760 MHz band for road traffic safety	At least 10 MHz

70 MHz spectrum band for transportation safety

A spectrum study[15] (2020) shows that deployed as well as planned applications for increasing road traffic safety towards cooperative automated driving may consume more than 70 MHz. This study only takes the applications' needs of bandwidth in MHz into account and it is communication technology agnostic. Table 3 summarizes the results of this study by tabulating different message types and their spectrum needs in MHz given three different scenarios (urban intersection, suburban intersection, highway fast traffic). The results show that the 7x10 MHz channels are required for existing and planned safety applications, thus preserved spectrum is a necessity.
Table 4 explains the different message types found in Table 3, which are already well defined and specified in standardization bodies.

Table 3: Minimum Spectrum needs for different message types for a single communication technology implementation

message type	urban	suburban	Highway
CAM cooperative awareness message	9	10	10
DENM decentralized environmental notification message	4	2	1
SPATEM signal phase and timing**, MAPEM** road/lane topology and traffic maneuver **, IVI** in-vehicle-information and other I2V messages	1	1	1
VAM VRU awareness message	4	0.2	2
PCM platooning control message	3	6	10
CPM collective perception message	23	26	24
MCM maneuver coordination message	23	26	24
Minimum basic spectrum needs in MHz	**67**	**72**	**72**
total number of 10 MHz channels required	**7**	**7**	**7**

[15] CAR-2-CAR Communication Consortium Spectrum Study: "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"

Applications based on V2X communication are introduced in steps, where so-called day one scenarios increasing the information horizon for the driver are introduced first. Day one scenarios or basic safety applications are intended to inform the driver about impending dangerous situation and the driver needs to react accordingly. Day two scenarios intend to increase the information horizon for the vehicle and day-two applications involve for example truck platooning and cooperative adaptive cruise control (CACC).

Figure 1 shows the roadmap CAR 2 CAR Communication Consortium has developed to plan for reaching true cooperative automated driving with reduced number of accidents, increased road traffic efficiency with decreased environmental footprint. The roadmap shows C-ITS applications starting with awareness driving over sensing driving with CPM towards higher levels of cooperative automation including the message types MCM and PCM detailed in Table 2, three phases of C-ITS deployment:

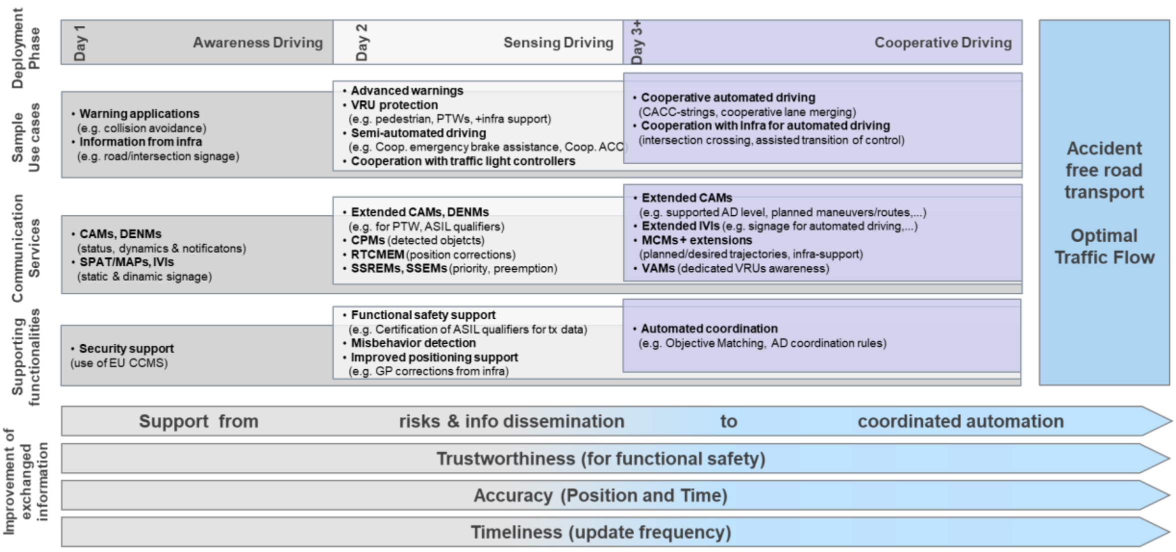
- awareness driving (day-1) (CAM, DENM, I2V, VAM)
- sensing driving (CPM)
- cooperative automated driving (MCM, PCM)

Table 4: Explanation of different message types defined in ETSI TC ITS and ISO

Phases of V2X application roadmap Fejl! Bogmærke er ikke defineret.	**Message types[16] (Europe)**	**Abbreviations explained**	**Examples of applications based on the message types**
Awareness driving	CAM, DENM	Cooperative Awareness message, Decentralized Environmental Notification Message, Basic Safety Message	Intersection Collision Warning Emergency Vehicle Warning Dangerous Situation Warning Stationary Vehicle Warning Traffic Jam warning Pre-/Postcrash Warning
	SPaTEM, MAPEM, IVI	Signal Phase and Time, MAP message, In-Vehicle-Information message	Enabling Infrastructure-to-Vehicle Communication at e.g. traffic lights
	VAM	VRU Awareness Message, Personal Safety Message	VRU warning for (C-ITS) equipped Vulnerable Road Users
Sensing Driving / sensor sharing	CPM	Collective Perception Message	Overtaking Warning Extended Intersection Collision Warning Vulnerable Road User Warning for non-equipped VRU´s Cooperative Adaptive Cruise Control Long-term Road Works Warning Special Vehicle Prioritisation
Cooperative Driving with Coordinated maneuvering and cooperative automated driving	MCM, PCM	Maneuver Coordination Message, Platooning Control Message	(Static or dynamic) Platooning Area reservation Cooperative Merging Cooperative Lane Change Cooperative Overtaking

[16] CAM, Cooperative Awareness Message, specified in ETSI EN 302 637-2
DENM, Decentralized Environmental Notification Message, specified in ETSI EN 302 637-3
SPATEM, Signal, Phase, and Timing, ISO/TS 19091:2017
MAPEM, road/lane topology and traffic maneuver ISO/TS 19091:2017
VAM, Vulnerable Road User (VRU) Awareness Message ETSI TS 103 300-3, 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 draft specification in ETSI TR 103 298, 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 ETSI TS 103 324, ETSI TR 103 562
MCM Maneuver Coordination Message, according to ETSI TR 103 578 (draft) "Informative report for the Manoeuvre Coordination Service"; https://imagine-online.de/en/home/

Figure 1: CAR 2 CAR Communication Consortium roadmap for V2X application



The spectrum needs for CPM and MCM have been further studied[17] [18] and Table 5 and Table 6 provide a detailed summary. The parameters to calculate the spectrum needs can vary to some degree within a certain range. The column "Min" reflects the minimum spectrum needs for today's implementations to enable CPM and MCM life-saving applications and those are identical to the values in above table 3. But for CAVs, it is recommended to choose at least the typical instead of the minimum values of the parameters in Table 5 and Table 6, because all values between best and worst case can occur in realistic scenarios (see column "typical"). This future setting "typical" for CPM and MCM explains the additional spectrum needs of 70 MHz (difference of typical and min for CPM, MCM) plus 70 MHz (min values acc. to table 3 for all message types) equals 140 MHz for C-ITS as mentioned in table 2.

Table 5: Spectrum needs calculation for Collective Perception with CPM

CPM		Min = current parameter setting	Max = future estimation	Typical parameter setting
Packet Size (Including security, payload, overhead) in Bytes	Message size changes depending on number of detected objects, including vehicles, pedestrians, cyclists, all seen by the in-vehicle-perception sensors such as cameras and radars	1000	1900	1450
Periodicity in Hz	Dynamic, up to 10 Hz			
Periodicity	in urban	3	5	4
Periodicity	in suburban	6	10	8
Periodicity	in highway	10	10	10
Communication range in m	in urban	150	300	225
	in suburban	150	500	325
	in highway	500	1000	750
Number of ITS stations in communication range	In urban	320	640	480
	In suburban	180	360	270
	In highway	100	200	150
Spectrum efficiency		0,55	0,6	0,575
Max allowed channel load		0,6	0,75	0,675
Spectrum efficiency x max allowed channel load		0,33	0,45	0,39

[17] Continental, July 10th 2020, published on US FCC website, https://ecfsapi.fcc.gov/file/10710018216099/Ex-Parte%20-%20July%2010%202020.pdf

[18] With spectrum needs in MHz = (Packet Size x Periodicity x ITS Stations in Communications Range) / (Spectrum Efficiency x Max Channel Load)

Spectrum needs in MHz for CPM	**Urban**	**23**	**108**	**57**
	Suburban	**26**	**122**	**65**
	Highway	**24**	**68**	**45**

Table 6: Spectrum needs calculation for cooperative maneuvering with MCM

MCM		Min = current parameter setting	Max = future estimation	typical
Packet Size (Including security, payload, overhead) in Bytes	Message size changes depending on number of detected objects, including vehicles, pedestrians, cyclists, all seen by the in-vehicle-perception sensors such as cameras and radars	1000	1300	1150
Periodicity in Hz	Dynamic, up to 10 Hz			
Periodicity	in urban	3	5	4
Periodicity	in suburban	6	10	8
Periodicity	in highway	10	10	10
Communication range in m	in urban	150	300	225
	in suburban	150	500	325
	in highway	500	1000	750
Number of ITS stations in communication range	In urban	320	640	480
	In suburban	180	360	270
	In highway	100	200	150
Spectrum efficiency		0,55	0,6	0,575
Max allowed channel load		0,6	0,75	0,675
Spectrum efficiency x max allowed channel load		0,33	0,45	0,39
Spectrum needs in MHz for MCM	**Urban**	**23**	**74**	**46**
	Suburban	**26**	**83**	**51**
	Highway	**24**	**46**	**36**