V2X communications for infrastructure-assisted automated driving

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***Abstract*— Cooperative automated vehicles (CAVs) are expected to accommodate growing mobility demands with lower environmental impact and increased road safety. In urban scenarios, C-ITS will eventually permit the road infrastructure to meet these goals by monitoring, supporting and orchestrating CAVs' movements. For this purpose, V2X communications to concurrently guide CAVs at signalized intersections, consider platoons and inform about presence of non-cooperative road users are needed, among others. The design of these V2X communications is not trivial as it has to take into account application requirements as well as key aspects like backward compatibility and interoperability in already deployed scenarios. This paper will describe the V2X solutions adopted by the EU funded project MAVEN in this regard. By smartly extending or profiling current and new standard message sets, these solutions are suitable for real-road experiments and provide potential for future industrial adoption.**

Keywords—Cooperative automated vehicles, V2X communications, infrastructure-assisted automated driving

I. Introduction

Highly and fully automated vehicles, especially when connected to the C-ITS infrastructure, can effectively accommodating growing mobility demands while still ensuring lower environmental impacts and increased road safety. An increase of driving automation functions in newly released car models is already a visible trend. At the same time, the C-ITS technology deployment is about to start in 2019 [1]. The combination of automated driving and C-ITS is expected to be a key enabler for coordination of cooperative automated vehicles (CAVs) [2], and will eventually permit road infrastructure to monitor, support and orchestrate their movements. The validity of this paradigm has been recently proved by various EU funded projects. As demonstrated by these initiatives, identifying Vehicle-to-Vehicle and to Infrastructure (V2X) communications and message sets suitable for this purpose is paramount. AutoNet2030 (http://www.autonet2030.eu/) developed and validated algorithms for interactive CAVs control using mainly V2V relying on ETSI ITS G5 radio technology [3]. For example, a cooperative lane merging service is proposed where, based on exchanged requests and repliess, CAVs can create a gap and let a vehicle from a side lane merge into it. A similar approach for negotiating maneuvers at highway merging zones is proposed by AdaptiVe (https://www.adaptive-ip.eu/). V2V is also enabler for distributed coordination and control of CAVs closely driving in platoons or convoys for better road utilization. In this context, Autonet2030 presented a V2V convoy communication control service allowing CAVs to build and maintain convoys on multiple lanes. Similarly, in iGAME (http://www.gcdc.net/), V2V messages are proposed to make two platoons from parallel lanes merge into a single target lane. Recently, platooning has been demonstrated as a valid option for urban traffic optimization [4]. Another way to foster cooperative automated driving is using V2X for sharing object detections made with local sensors. This so called collective perception approach, well defined and validated in [5], aims at increasing CAV applications' safety by providing improved awareness of local surrounding going beyond local sensing capabilities (e.g. before being able to detect it with its own sensors, a CAV is informed by its preceding vehicle that a car is coming from the opposite direction).

Despite very valuable, the above mentioned contributions address mostly inter-vehicle coordination and control and consequently focus on V2V communications only. Nevertheless, in the future era of cooperative automated driving, road infrastructure applications will still cover the role of monitoring and orchestrating road traffic, especially in urban areas. This will be done with means, like traffic light signaling, that shall keep serving pre-existing cooperative and non-cooperative manually driven vehicles. In this context, the EU H2020 project MAVEN (Managing Automated Vehicles Enhances Network, http://www.maven-its.eu/) is developing infrastructure-assisted traffic management solutions for CAVs at signalized cooperative intersections (CIs) for increasing urban efficiency and safety. Thanks to V2X, CIs exchange information with CAVs, that are in turn extended to consider it in their perception and planning logic. To ensure backward-compatibility, MAVEN extends current C-ITS, e.g. cooperative SPAT/MAP traffic light signaling. Autonet2030 also proposes a method for priority-based coordination of CAVs at CIs [6]. Here, priorities to distinct incoming CAVs are assigned based on their V2I requests. However, this method is incompatible with (cooperative) traffic lights and hence cannot support signalized intersection control in the ramp-up phase where CAVs will coexist with manually driven (cooperative and non-cooperative) vehicles. MAVEN addresses, among others, Infrastructure-to-Vehicle (I2V) interactions for signalized intersection control, inclusion of urban platoons and collective perception application. This paper describes the V2X services and message sets developed for this purpose and highlights how they address important aspects like backward-compatibility and real-world interoperability in already deployed scenarios. Consideration of these aspects is necessary to enable real-road experiments and transfer of MAVEN solutions into next-generation deployments.

II. MAVEN Use Cases and Requirements

As mentioned, MAVEN targets a hierarchical traffic management where CAVs can be smartly guided by the infrastructure to enhance urban roads efficiency and safety. V2X communication is used to exchange needed information from infrastructure to CAVs (I2V) and vice-versa (I2V). In this context, MAVEN focuses on the following use case classes:

1) *Situational I2V interactions including speed and lane change advices at signalized CIs*

2) *Urban platooning*

3) *Inclusion of non-cooperative vehicles and vulnerable road users (VRU)*

For each case class, the functional and communication requirements are identified to drive the design of the communication services described in Section III.

The use case class of situational I2V interactions defines negotiations between CIs and CAVs. As first negotiation phase (Fig. 1a), an isolated CAV and/or a platoon continuously transmit information describing intentions (e.g. planned route at the intersection) or vehicle/platoon characteristics (e.g. desired speed, platoon size, etc.). As this information is collected, the CI continuously updates its queue model and re-optimizes its traffic light signal timing, which results in transmitting I2V advisories for CAVs or platoons to adapt speed and/or change lane (Fig. 1b). As last negotiation phase, CAVs and/or platoons communicate if the advisories can be executed (Fig. 1c). This feedback on CAV compliance with the provided advisory is used by the CI to put priority at its validity and "freeze" the signal timing re-optimization (e.g. ensuring that the traffic light stays green till the platoon has passed at the suggested speed). Speed advisories at CIs can be disseminated using standard Signal Phase and Timing (SPAT) messages [7]. A definition of the intersection topology transmitted in standard MAP messages [7] is also needed. Through this, CAVs compute the relevance of the received advices respect to their position and distance to the stop line. If the advice is relevant, they decide whether adapting the speed or preparing to stop by also considering the local environmental situation (e.g. presence of other vehicles in front). In general, SPATs contain speed advices applying to a group of parallel ingressing lanes. Since a more granular intersection control is wanted in MAVEN, implementation solutions for lane-specific speed advices are needed. With regard to lane change advices, it has been found that simply instructing CAVs to change on the lane with highest speed advice would result in traffic light timing oscillations. For this reason, a specific I2V message able to influence CAVs individually is needed. All the mentioned V2I and I2V messages shall be transmitted at least every second and broadcasted so that traffic light planning and current CAV intentions are known to everyone. In fact, although CAVs are centrally coordinated by the CI in a way not to create conflicting situations, sharing CAV intentions and feedbacks to advisory compliance leaves the possibility open for additional V2V coordination, if needed.

Urban platooning, addressed in the second use case class, is very different compared to other developments targeting highways. As shown in [8], flexibility is one of the key requirements for urban platoons. Based on a common distributed algorithm and V2V exchanged information, individual CAVs shall form platoons, manage their operation (joining, leaving, etc.), and control their motion. In this sense, MAVEN platooning can be seen as an extended Cooperative ACC [9], where every CAV closely follows its preceding one by still controlling its speed, distance, and possible emergency reactions. Yet, the platoon leader has the central role of communicating platoon properties to the CI. In terms of V2X requirements, CAVs need to broadcast local information (e.g. planned route, desired speeds, acceleration/braking capabilities, etc.) to detect platoon initialization opportunities with other CAVs. Moreover, to ensure backward-compatibility, CAVs are requested to be still "overheard" by pre-MAVEN cooperative vehicles and infrastructure. To support them, CAVs shall keep broadcasting CAM messages [10] on the ITS G5 channel SCH0 [3], designated by the car industry to support the "Day1" C-ITS deployment [11]. Finally, precise control of platooning CAVs requires receiving more detailed information (e.g. planned trajectory of preceding vehicles) than what included Day1 CAMs, and with a higher frequency. As such information is useless for pre-MAVEN systems, it can be transmitted on another ITS G5 channel to save bandwidth on the SCH0.

The third MAVEN use case class requires CAVs to cope with presence of non-cooperative vehicles and VRUs in their automated driving tasks. As such traffic participants are not always detectable by CAVs (e.g. in Fig. 1d, pedestrians are hidden around the corners), a mechanism is needed to create awareness of their presence. Retrofitting these traffic participants with V2X-complatible portable devices would not be a reliable solution. Position accuracy limitations at those devices would in fact negatively impact CAVs algorithms. For this reason, the already mentioned Collective Perception (CP)

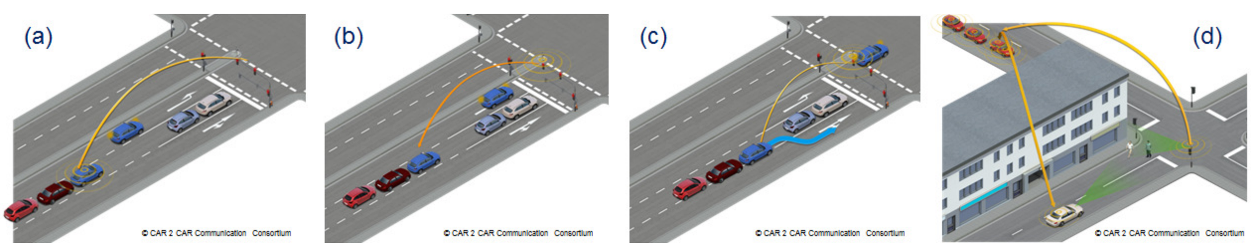

Fig. 1 MAVEN I2V interaction (a-c) and Collective Perception approach (d)

approach is used in MAVEN, and extended to let CIs participate (Fig. 1d). To do so, the MAVEN CP needs to accommodate different object description representations at CAVs and CIs resulting from the use of distinct coordinate systems. Since the CP objective is to inform as many vehicles as possible about varying situations of locally detected objects, broadcast messages are needed. Moreover, since those situations can change very dynamically, CP messages shall be periodically updated and retransmitted with a frequency not lower than that of standard Day1 CAMs.

III. MAVEN Communication Services

To address its functional and communication requirements, MAVEN has designed dedicated V2X communication services. As MAVEN also intends to realize real-road experiments with CAVs and CIs prototypes, commercially available V2X communication modules compatible with the latest versions of C-ITS standards are adopted. These modules have been extended to support the MAVEN CAV communication architecture of Fig. 2, which in turn is compliant to the standard ETSI ITS architecture [12] and supports exchange of V2X messages over the ETSI ITS G5 technology [3]. The network and transport layers are fully ETSI compliant, which provides a straightforward approach for real-road tests interoperability. On the contrary, the ETSI ITS Facilities layer has been extended to accommodate the MAVEN V2X communication services. These services either extend pre-existing standard services, e.g. Cooperative Awareness [10] and SPAT/MAP services [7], or are created from the scratch like the CP service or the Lane Change Advisory service. The Message Management module implements the functionalities to manage transmitted and/or received V2X messages, including co/decoding and information processing. As it can be seen, the CA and CP services are used in CAVs for both receiving and transmitting sessions. On the transmitting path (dotted arrows), these services populate messages by taking information received from the automated driving logic and locally stored in the Vehicle State Database. On the receiving path (solid arrows), the CA and CP services decode received messages and pass data to the Local Dynamic Map (LDM), where local management is done before passing it to the automated driving logic. The SPAT/MAP and Lane Change Advisory services are used on CAVs only on the receiving path for message decoding and processing. Relevance check of received data with respect to CAV position is performed in the LDM. In the following, the MAVEN communication services and the associated implementation solutions are described. ASN.1 definitions and further details can be requested at http://www.maven-its.eu/.

A. CAM extensions

MAVEN supports CAVs' interactions and platooning in an efficient and backward-compatible way by defining ETSI ITS CAM [10] extensions: MAVEN CAVs and CIs will be able to process the whole extended message, pre-MAVEN cooperative vehicles and infrastructure will discard the extensions yet processing the rest of the received message. As indicated in Fig. 3, two separate extended CAMs are defined (the MAVEN extensions are highlighted in light grey):

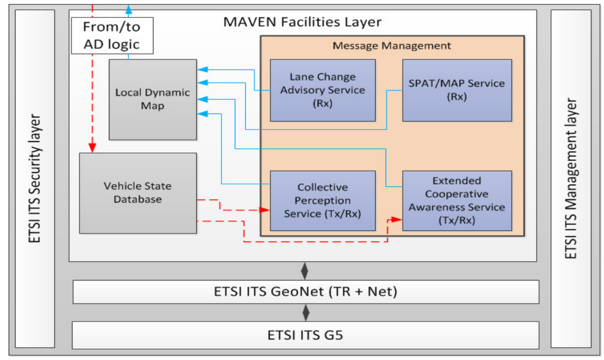

Fig. 2 MAVEN CAV communication architecture

1) Extended CAM on SCH0: carries information (planned route, accelaration/braking capability, etc.) for CAVs to detect opportunities to initialize a platoon, as well as CAV and/or platoon features (planned route, platoon ID, participants, etc.) usable by CIs to perform traffic light signal timing optimization. As indicated in Fig. 3, this information is contained in an optional special vehicle container called *MAVENAutomatedVehicleContainer*, and hence ensures backward-compatibility with pre-existing Day1 systems. As this container is appended to standard CAMs, the generation rules for this message are exactly the same as specified in [10]. The *MAVENAutomatedVehicleContainer* is appended to CAMs with low frequency (i.e. every 500ms), applying exactly the same rules for the inclusion of the *BasicVehicleContainerLowFrequency* [10].

2) Extended CAM on SCHx: carries needed information to manage and control platoons of MAVEN CAVs in a distributed manner. It is transmitted at a fixed higher frequency [10-30Hz] and using a separate ITS G5 channel not to overload Day1 systems on the SCH0 (the same approach is suggested in other R&D projects [6] and pre-standardization studies [9]). Its transmission is triggered during the platoon initialization phase. Then, the message is populated following the distributed platoon logic running at individual vehicles [8]. An *AutomatedVehicleContainerHighFrequency* is always

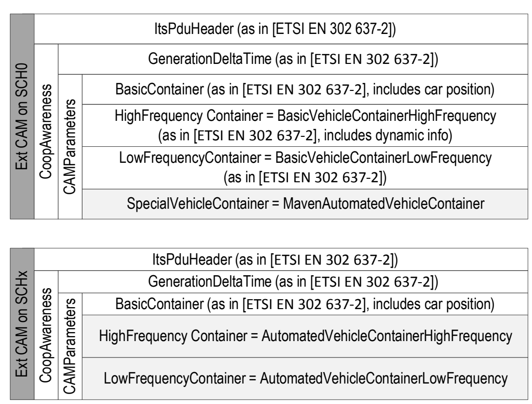

Fig. 3 MAVEN extended CAMs structure

transmitted to carry important information that CAVs consider for controlling and executing close-following driving. The *AutomatedVehicleContainerLowFrequency* is included every *n* messages, mostly with information reflecting the platooning state machine running at each vehicle and used for distributed platoon management [8]. The suitable generation rate for these CAMs as well as the best value for the parameter *n* are currently object of investigation in MAVEN. Here, simulations are performed in order to quantify MAVEN platooning performance by varying values of design parameters. From a communication point of view, the selection of CAM as a periodic broadcast message (instead of for example request/reply unicast messages) makes sense for MAVEN platooning. As explained in Section II, the C-ACC-like vehicle control and platoon management is executed independently at each individual vehicle following a common distributed protocol. Adopting dedicated messages instead of small extensions of already deployed messages would imply additional channel load (due to the overhead of lower layers' protocol headers).

B. *Lane Change Advisory*

The MAVEN lane change advisory service assists CAVs in selecting optimal ingressing lanes when approaching an intersection. This permits CIs to more evenly distribute and more rapidly serve incoming traffic demands. For this purpose, it was considered using SPAT-based lane-specific speed advices and letting CAVs automatically change to the lane with the highest speed. However, this would imply lane advice oscillations when too many vehicles follow the same advice. Therefore, a new Lane change Advice Message (LAM) was introduced to provide individualized advices. To foster interoperability, the LAM was designed in a way to reuse many elements of current SAE J2735 [7] and ETSI ITS dictionaries [13]. Intersection topologyl information is referenced from MAP messages, which prevents sending it twice. A sample application scenario is shown in Fig. 4, where the CI wants to instruct the CAV with StationID 2 to merge to lane 1. If both vehicles before and after the gap are CAVs, the LAM can optionally provide information about them. In this way, the interested CAVs can initiate V2V maneuvering coordination. Optimal time and space information for CAVs to start the lane change maneuver can be also optionally included in LAMs. However, it is provided only when the CI has sufficiently precise situational awareness. For situations where lane 1 is already full, the CI can simply advise the target lane: it will be up to the CAV to try to find a gap and eventually comply with the advice. The LAM structure is shown in Fig. 5. Optional

Fig. 4 Lane change scenario

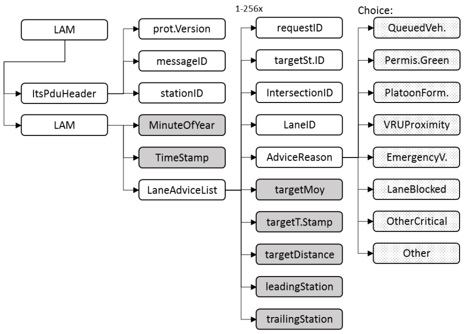

Fig. 5 MAVEN Lane Change Advice Message structure

fields are marked in grey, mandatory ones in white. A lane advice list containing up to 256 vehicle- or platoon-specific advices is used. For each single advice, the target vehicle, lane, and intersection are mandatory to eliminate any ambiguity of advisory relevance. The reason for the advice is also mandatory, so that CAVs can assess the criticality of the situation. The advice reason shall be chosen among several options. In this way, and given that the LAM is broadcasted, non-targeted CAVs get aware about currently active lane advices and can anticipate reactions or establish cooperative maneuvering.

C. *SPAT/MAP for lane-specific speed advisory*

Although benefiting from the lane change advisory service, CIs will not completely balance traffic at ingressing lanes. Routing and/or vehicle class restrictions can still cause imbalances. To mitigate this effect, and let incoming CAVs pass without stopping on lanes with different occupancy levels (e.g. Fig. 1a), lane-specific speed advices are needed. At signalized intersections, traffic on parallel ingressing lanes is often subject to same traffic light signals (referred as signal groups - SGs). In general, the MAP message indicates the SG associated to these lanes. The SPAT refers to this SG to provide a lane group-applicable speed advice. With current SPAT/MAP profiling [14], it is impossible to signalize distinct speed advices to such lanes. Current SPAT specifications only allow indicating queue length information on parallel lanes with same SG. To overcome this limitation, MAVEN decided not to propose SPAT/MAP standards modifications, but instead a new profiling. Extra SGs are introduced and used for SPAT/MAP signaling at parallel ingressing lanes that would initially be associated to the same SG. The concept is illustrated in Fig. 6. The two central lanes are subject to the same traffic light SG2. However, for SPAT/MAP signaling, SG2 is referred with two distinct identifiers: SG1 for the rightmost lane and

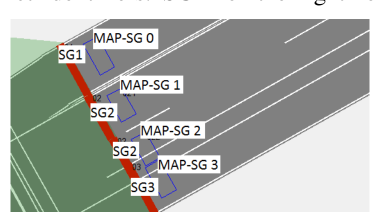

Fig. 6 SG assignation for lane-specific speed advisory

SG2 for the leftmost. The SPAT can now use these identifiers to provide lane-specific speed advisories on the lanes. In this way, a simple approach for CI-CAVs interoperability is achieved, which facilitates real-world implementation. This approach is not in contrast with current profiling definitions [14] and can be easily deployed.

D. Collective Perception Service

Collective Perception (CP) uses CP messages (CPMs) to transmit data about locally detected objects (i.e. non-cooperative traffic participants, obstacles and alike) to improve situational awareness. By exploiting the increasing sensing and communication capabilities of future vehicles, CP is considered by the car industry as a natural key enabler for cooperative automated driving applications [2]. For this reason, CP standardization has been recently started at ETSI ITS [15]. ETSI CPMs foster sustainability and interoperability by transmitting abstract representations of detected objects instead of type- and vendor-dependent raw sensor data. In addition, CPMs abstract descriptions can derive from detections made by single sensors or be result of local sensor fusion algorithms, which provides implementation flexibility. Since the ETSI CP was initially introduced for V2V applications only, MAVEN actively contributed to the standardization to address the requirements of its urban infrastructure-assisted approach. First of all, MAVEN intends using CP for traffic safety by sharing detections useful for this scope. Traffic signs and light detections as well as road participants far for the carriageway are not considered as such. On the contrary, static objects occupying the carriageway and dynamic traffic participants that are or can enter the drivable area (e.g. VRUs crossing the road) are in scope. To transmit only useful detections, dedicated filtering logic is applied at CPMs transmitters. Moreover, to accommodate CP descriptions of object detected by roadside units (RSUs) at MAVEN CIs, the whole service had to be extended. Detected object descriptions are shared referred to the coordinates system of the CPM originating station. In the case of a vehicle, xy axes take origin from its center-front and change direction as the vehicle moves. This is not suitable for static RSUs. Here, the adopted coordinate system is centered on a reference point placed at the CI with xy aligned to east and north, respectively, as for SPAT/MAP representations. Receiving stations map received object descriptions onto their local coordinate system. To allow this mapping, originating stations shall always transmit data about their coordinate system (e.g. reference point, and for CAVs also speed, orientation, etc.). Besides this, they shall communicate their detection capabilities in terms of installed sensors' fields of view (FoV). When receiving a CPM with no object detected in a given direction, a CAV can make a cross-check by analyzing the FoV information: if it says that the originating station has

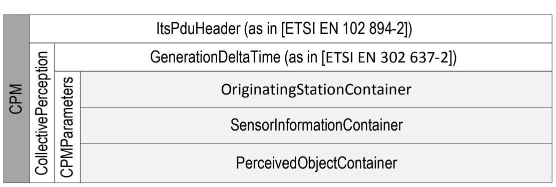

Fig. 7 MAVEN/ETSI CPM structure

no sensors covering that direction, objects can be actually present in reality. The above mentioned CP operation is supported by the CPM message structure depicted in Fig. 7. This includes three containers:

1) Originating Station Container: carries originating station information required by receivers for local mapping of object detections. It includes a *BasicContainer* specifying the reference point position and originating station type (vehicle or RSU), as well as a *StationData* container to be chosen by originating station type. The *OriginatingVehicleContainer* option indicates vehicle dynamic properties such as heading, speed, acceleration, orientation, etc.). The *OriginatingRSUContainer* option contains an identifier of the intersection where objects shall be detected. As this identifier is the same as in MAP messages, detected objects' positions can be matched to MAP-like intersection topology representations, which in turn supports CI safety applications.

2) Sensor Information Container (optional): describes the originating station's detecting capabilities at separate installed sensors or as overall sensor fusion. For this purpose, it includes a list of *SensorEntries*, each specifying a sensor identifier and type. A *SensorEntry* can be further specified, selecting among alternative representations. The *VehicleSensor* and *StationarySensorRadial* options allow specifying mounting position, opening angles and ranges for vehicle and RSU sensors, respectively. On the contrary, other RSUs-tailored options allow explicitly specifying position and shape of regions where detections are possible at a CI.

3) Perceived Object Container (optional): consists of a list of *ObjectData* each providing description of a detected object. Each object is assigned an identifier allowing its tracking at receivers. The identifier of the sensor with which the object is detected is also included. This permits retrieving the corresponding sensor information from the Sensor Information Container. *ObjectData* specifies time of measurement, as well as object distance from the reference point of the originating station's coordinates system. To enable correct interpretation of this information at the receiving side, *ObjectData* also contains the object's reference point position considered for distance calculation. Several other description elements are optionally allowed as long as provided by the used sensors. These are relative speed/acceleration, yaw angle, dimensions, dynamic status, object classification etc. For implementation of use cases requiring matching of objects onto MAP-like intersection topology representations, a *MatchedPosition* data field is introduced. This includes the identifier of the lane where the object is detected, as well as its distance from the start of the lane. The lane belongs to the topology described by MAPs for the intersection identified in the *OriginatingRSUContainer.*

In MAVEN, a CPM periodic generation method is adopted with fixed generation period chosen in the range [200-1000ms]. Every subsequent CPM contains the Originating Station Container. The optional Sensor Information Container is included after 1000ms from its last inclusion. The optional

Perceived Object Container is included if at least one object is detected and updated over subsequent transmissions.

IV. Functional Verification

To verify the functional correctness of MAVEN V2X communication services, a small test bench composed by two Cohda MK5 OBUs [16] and a controlling PC is used. The PC hosts the Cohda SW development kit needed to implement and run applications for V2X service transmissions and receptions on OBUs. It also supports a SW simulating vehicle positions, which are fed to OBUs for the correct execution of their applications. The verification method is described in Fig. 8. MAVEN V2X communication services extend the standard Facilities supported by OBUs (Fig. 2). A test application is implemented and installed on them. At the transmitting side, it populates V2X service messages following MAVEN ASN.1 definitions, encodes and transmits them. At the receiving side, it decodes messages. Reception captures are analyzed on a MAVEN-customized version of wireshark, as well as with xml representations automatically generated by the OBUs. This permits verifying that messages respect the defined formats and extensions, and are transmitted on the wanted ITS G5 channels. As an example, Fig. 9 shows a wireshark screenshot of received MAVEN CAMs extensions. As it can be seen, it indicates consecutive CAM receptions over parallel ITS G5 channels and data elements set according to the definitions of Section III.A.

V. Conclusions and Future Work

MAVEN V2X services can satisfy infrastructure-assisted automated driving needs. Lane change and lane-specific speed advisories are delivered with a novel V2X service and a dedicated SPAT/MAP profiling, respectively. This enables CIs to more granularly and efficiently serve CAVs demands at intersections. Backward-compatible CAM extensions permit CAVs to interact with CIs for communication of vehicles plans and features, or to notify compliance to received advices. CAM extensions also enable a distributed V2V algorithm for initiation, management and control of urban CAV platoons. Finally, ongoing collective perception standardization is adapted for consideration of VRUs and non-cooperative vehicles at CIs. Dedicated test bench verifications prove technical functionality from a communication point of view. This prepares future work on integration of V2X services in CAV and CI prototypes for road testing and evaluation of MAVEN use cases .

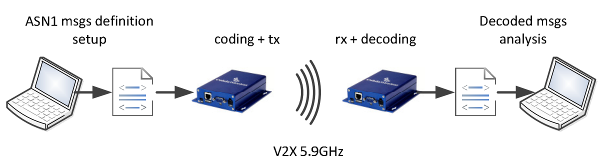

Fig. 8 Functional verification method for V2X communication services

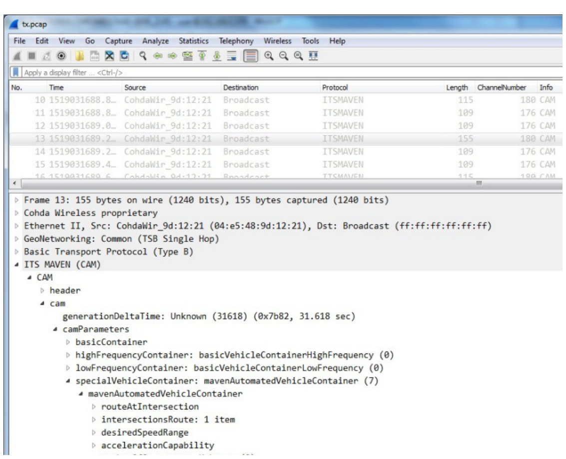

Fig. 9 Receptions analysis on MAVEN wireshark

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References

[1] https://www.c-roads.eu/platform/about/news/News/entry/show/c-its-cooperation-between-c2c-cc-and-c-roads-platform-1.html

[2] Car-2-Car Communication Consortium, "Updates of the C2C-CC Roadmaps", keynote presentation at the 2017 Car2Car Forum, Nov. 2017, https://www.car-2-car.org/index.php?id=283

[3] ETSI ES 202 663 Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band, V1.1.0

[4] Faraj et al., "Platoon-based autonomous vehicle speed optimization near signalized intersections", proc. of 2017 *IEEE IV Symposium (IV), 2017*

[5] H. J. Günther et al., "Realizing collective perception in a vehicle," 2016 IEEE Vehicular Networking Conference, 2016, pp. 1-8

[6] AutoNet2030 deliverable D3.2 – "Specifications for the enhancement to existing LDM and cooperative communication protocol standards", 2015

[7] SAE J2735_201603, Dedicated Short Range Communications (DSRC) Message Set Dictionary, March 2016

[8] Schindler, J., Dariani, R., Rondinone, M., Walter, T., "Dynamic and Flexible Platooning in Urban Areas", Accepted for the AAET conference 2018, March 2018

[9] ETSI TR 103 299 v0.1.5, Intelligent Transport System (ITS); Cooperative Adaptive Cruise Control (CACC); Pre-standardization study

[10] ETSI EN 302 637-2 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service, V1.3.2 (2014-11)

[11] Car-2-Car Communication Consortium, "C2C-CC Basic System Profile", Rel 1.2.0, Sept 2017

[12] ETSI EN 302 665 ITS Communication Architecture, v1.1.1 (2010-09)

[13] ETSI TS 102 894-2 Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary V1.2.1 (2014-09)

[14] http://www.smartmobilitycommunity.eu/talking-traffic-dutch-profiles-and-itf

[15] ETSI draft TS 103 324 V0.0.12 Intelligent Transport System (ITS); Vehicular Communications; Basic Set of Applications; Specification of the Collective Perception Service, (2017-09)

[16] http://www.cohdawireless.com/solutions/hardware/mk5-obu