An Overview of Standardization efforts for enabling Vehicular-to-Everything Services

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An Overview of Standardization efforts for enabling Vehicular-to-Everything Services

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Abstract —The Third Generation Partnership Project (3GPP) has been working on developing specifications on Machine to Machine Communications (M2M) and on the emerging Internet of Things (IoT) bringing light into the associated service and network requirements. This paper presents a special form of M2M/IoT communication, where at least one communication device is part of a vehicle that automatically communicates with other vehicles, pedestrians and Road Side Units (RSU). The initial efforts towards the so called Vehicular-to-Everything (V2X) specifications are based on group communications and on proximity service features, both originally developed for mission critical communications. Such standardization efforts are enhanced and also integrated in the new service model enabled by 5G systems for supporting verticals, with the automotive industry being one of the major players. This paper provides a comprehensive study elaborating the current standards for enabling V2X considering the co-existence of 3GPP, oneM2M and ETSI Multi-access Edge Computing (MEC), while analyzing potential open challenges.

Index Terms – V2X, 3GPP, OneM2M, MEC, ProSe, IoT, MBMS

I. INTRODUCTION

The original objective of Information Communication Technologies (ICT) was to address human communications. However, in recent years, the communication forms become more diverse including people-to-object and object-to-object communications without human intervention. These types of communications commonly referred to as Internet-of-Things (IoT), or alternatively know as Machine-to-Machine (M2M) communications [1], introduce a new era, where "smart things", potentially in huge numbers, i.e. 1 billion by 2020 [2], are interconnected to each other via the Internet. IoT and particularly "smart things" are expected to collect and analyze data, facilitating a wide variety of intelligent services that will continue to bring about profound changes in people's daily life [3, 4, 5].

This emerging IoT paradigm has been introducing new applications in many different domains such as Smart Home, Smart Health, Smart Cars, etc. In recent years, there has been a rapid movement toward using IoT in the vehicular domain, e.g., vehicle-to-human, vehicle-to-vehicle, and vehicle-to-transportation infrastructure, also referred to Vehicular-to-Everything (V2X). Thanks to the IoT technology, evolving vehicles are expected to revolutionize transportation supporting safer, faster, and more entertaining smart objects, rather than being just a mobility unit. However, this does not come without cost. Radio communication technologies should be enhanced to enable these service attributes. In addition, various new features for vehicle communications have to be supported from the core network. As many stakeholders are involved in the automotive industry, a well-defined service layer is an essential part to provide a globally available vehicular IoT services. To realize these requirements, this paper analyzes various global V2X related standards groups focusing on 3GPP, oneM2M [6] and ETSI Multi-access Edge Computing (MEC) [7] considering comprehensive solutions that combine different specifications.

The work in 3GPP was triggered by the end of 2014, with other standardization bodies already being active in this area. A non-exclusive list of these standardization organizations include ETSI ITS (Intelligent Transportation System), US SAE (Society of Automotive Engineers), IEEE, GSMA Connected Living, C-ITS project in Korean Ministry of Land, Infrastructure and Transport, SAE-China, C-ITS, C2C-CC, ACEA, ERTICO, ACEM, etc. While those organizations already defined specifications on intelligent transport services and associated message exchanging, the scope of 3GPP focused on the exchange means of those messages in order to support different types of V2X applications and services. 3GPP has already specified direct communications between User Equipment (UE) for public safety purposes, a technology that can also enable vehicle-to-vehicle communications. In addition, 3GPP established further improvements on the Multimedia Broadcast Multicast Service (MBMS) [8] for mission critical communications,

* The work was carried out while being at NEC Laboratories Europe, Germany

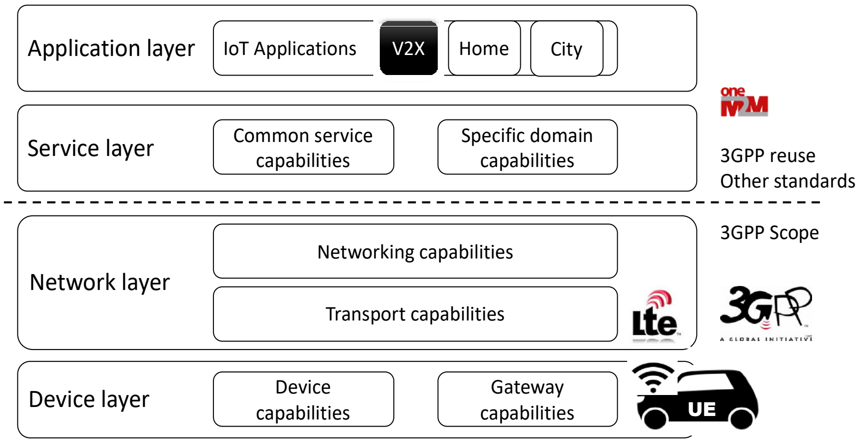

Figure 1: An architecture overview for V2X

which can also be used for broadcasting of safety messages among vehicles. Four ways of communication were discussed and considered during the specification work including the following:

- V2V: Vehicle-to-Vehicle
- V2P: Vehicle-to-Pedestrian (e.g., handheld terminal)
- V2I: Vehicle-to-Infrastructure application, where the architecture includes a RSU (Roadside Unit) implemented in a base station, i.e. evolved Node B (eNB) in 3GPP terminology, or a stationary UE
- V2N: Vehicle-to-Network, where network means an application service/server, which is defined by an upper service layer, e.g., oneM2M

In this article, we review the standardization activities considering the most relevant work items related with V2X. Key issues, requirements and potential solutions, with a significant impact on the emerging 3GPP networks and on the oneM2M service layer, are highlighted elaborating how the V2X features can be exploited by IoT services. In particular, the following features are introduced in this paper (as illustrated in Figure 1):

- Architecture Enhancements for V2X
- Radio Access Network (RAN) related enhancements, investigating whether the PC5 and Uu interface can support V2X unicast and broadcast traffic
- Multi-access Edge Computing for the local MBMS
- Service layer for V2X analyzing how V2X applications and services are connected to the 3GPP core network for utilizing given V2X features
- Multimedia broadcast multicast services
- A new V2X related interface for supporting device to device communications

The set of features introduced in this article is not an exhaustive list, but a representative selection of the important work items on M2M/IoT related topics in 3GPP Release 14.

The rest of the paper is structured as follows. First, we introduce the architecture enhancement for V2X (Section II). Then we present various enhancement features on RAN (Section III), Mobile Edge Computing (Section IV), MBMS (Section V) and PC5 interface (Section VI). Finally, we provide the outlook including with a brief discussion (Section VII) and summary considering also future V2X related standardization work in 3GPP (Section VIII).

II. 3GPP Architecture Enhancements for V2X

The V2X features specified in 3GPP TS 23.285 [9] offer two independent modes of operation for a UE in a vehicle in order to transmit and receive data:

- Vehicle-to-Vehicle, via a direct communication interface, called PC5
- Through the conventional Long Term Evolution (LTE) radio interface LTE-Uu to an eNB

These two modes of operation fulfill different use cases and scenarios and can also be used in combination. The PC5 interface was specified during the work on Proximity Services (ProSe), see 3GPP TS 23.303 [10]), which provided public safety UEs the option to communicate directly. However, commercial equipment was excluded mostly due to the lack of operator control with respect to charging and legal interception. The ProSe feature offers with the PC5 interface additional functionality like discovery of other UEs [11], which is not utilized for V2X communications. V2X is a subscription service in 3GPP, i.e. a UE must have a subscription in the Home Subscriber Server (HSS) with relevant information, which allows a UE to be authorized in order to perform V2X communication over the PC5 reference point and it’s PC5-AMBR. Further the subscription information contains the list of the Public Land Mobile Networks (PLMNs) where the UE is authorized to perform V2X communication over the PC5 reference point.

The following new functional entities are introduced into the two architectures with corresponding reference points to the existing entities:

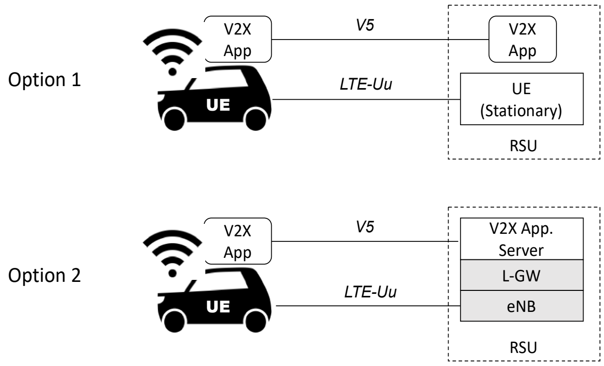

Figure 2: RSU as stationary UE (Option 1) and enhanced eNB (Option 2)

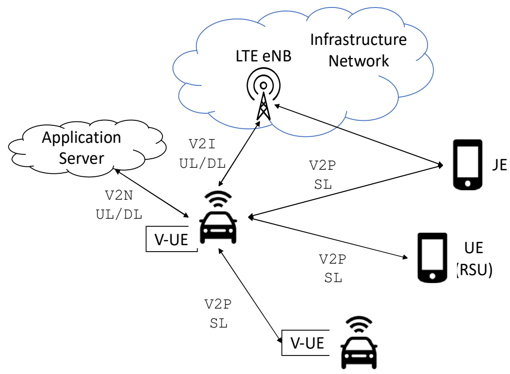

Figure 3: V2X Scenarios [12]

- V2X Control Function: Currently there is only one logical V2X Control Function per PLMN. In roaming scenarios with local breakout in the Visited PLMN (VPLMN), the deployment of a local V2X Control Function offers the UE the following information in order to use the V2X Service:
  a) PLMN specific parameters including authorization information, PLMNs in which the UE is authorized to use MBMS and V2X Application Server address information
  b) Parameters for the case when the UE is "not served by E-UTRAN", i.e., radio parameters with Geographical Area(s) where the UE needs to use PC5 interface
- V2X Application Server (AS): The V2X AS is receiving data form the V2X UEs and is transmitting it to other V2X UEs via unicast or multicast means (MBMS). The V2X AS is responsible for mapping geographic data to the appropriate target serving area in form of ECGI(s) or MBMS SAI(s) for broadcast and to instruct the BMSC to (de)allocate TMGIs and MBMS bearers. The V2X AS provides a V2X version of the User Service Description (USD) to the UE, e.g., via the V2 interface (V2X AS – V2X UE), which includes the necessary information for the UE to use MBMS for V2X communication and V2X Application Server Discovery

For Vehicle-to-Infrastructure applications, the infrastructure that includes a RSU (Roadside Unit) can be implemented in an eNB or a stationary UE. Figure 2 shows such two options and the elements that are part of the RSU in both cases.

III. RAN ENHANCEMENTS

A detailed study for adopting the LTE-Advanced radio access network to support V2X type of services is presented in [10, 12], while the potential V2X scenarios are illustrated in Figure 3. The key areas investigated are the enhancements required for enabling V2V, V2P and V2I/N communication, using either the PC5 (sidelink / SL) or Uu (uplink/downlink UL/DL) interface. The V2I paradigm includes the vehicle communicating with the infrastructure nodes such as LTE eNB or RSU. For V2V support using PC5 interface, enhanced radio resource allocation are needed in terms of the resource pool, resource selection/allocation as well as handling high Doppler scenario and synchronization. From a Uu interface perspective, both MBSFN and SC-PTM type of transmissions were considered as potential enablers, which require enhancements, e.g., in terms of enhanced user localization, latency reduction, etc. Similar enhancements were foreseen for V2I/N and V2P type of traffic too, with enhancements required in broadcasting as compared to unicast.

In terms of the system enhancements from an LTE SL perspective, resource allocation, physical layer structure and synchronization are the key target areas, which require standardized solutions in order to address effectively the V2X requirements. In relevant discussions it was concluded that the current standardized Uu interface can support V2X traffic efficiently. Some of the possible enhancements for the broadcast transmissions are – support for single cyclic prefix (CP), Hybrid ARQ (HARQ) feedback for SC-PTM and MBSFN, and location information from active mode UEs for optimizing broadcast transmission areas. The single CP adopted in V2X communication for supporting enhanced mobility, is expected to be shorter than the extended CP, using normal CP as a performance baseline.

Since reliability is a key requirement for V2X, the enhancement of HARQ for SC-PTM and MBSFN type of radio resource-efficient transmissions would be a significant RAN enhancement. Traditional broadcast cannot natively support feedback and retransmissions to ensure packet delivery. Hence, such enhancements are essential for improving the reliability of the V2X RAN. Support for Semi-Persistent Scheduling (SPS) enhancements, related to the UL and SL transmissions is another key enhancement for V2X [13]. The eNB could configure up to 8 possibly simultaneously active SPS with different parameters for V2X SL communication. Location/geographic information reporting for active mode UEs is expected to be performed on higher layers above the radio one. From a radio resource selection perspective, with the help of advanced sensing mechanisms, the pedestrian UEs could use random resource selection using a resource pool that is shared with V-UEs. The stage-2 description of the related enhancements is presented

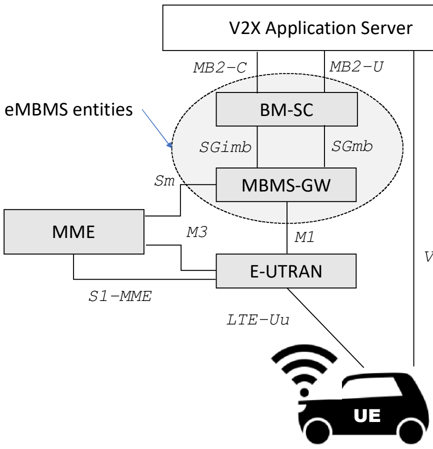

Figure 4: eMBMS-based V2X architecture

in [13], concentrating on physical, medium access and radio resource control layers of RAN for supporting V2X services.

IV. Multi-access Edge Computing for V2X

ETSI MEC introduces an open cloud environment in a close proximity to the RAN accessible by third parties in an effort to overcome the shortcomings of centralized cloud computing in terms of latency and throughput [7]. By offering data intensive tasks, critical communication services, e.g., road safety, and content via the MEC platform in close proximity to the vehicles and end users, mobile operators can fulfill stringent performance requirements, while reducing congestion bottlenecks in their core network. MEC can also provide the opportunity for developing new services, bringing innovation in the V2X businesses.

The role of MEC in V2X can facilitate traffic congestion indications and warnings from other vehicles directly or through the network and provide a bird's eye view between vehicles and pedestrians almost in real-time, ensuring safety. In addition, on board cameras or sensors incorporated in road materials can feed information to MEC platforms, which can enable video analytics to enhance road safety by rapidly warning drivers for potential accidents. Car manufacturers can also use MEC offering damage detection services via an on-board IoT system and smart city services, e.g., indicating fuel refill and free parking locations. The entertainment industry can also take advantage of the MEC to offer on-board videos as well as augmented reality and virtual reality services. The MEC platform can also assist MBMS by offering RAN analytics and user context information to the network layer.

The key component for the successful adoption of MEC is the development of the platform architecture and the associated Application Provide Interfaces (API) [14]. Currently 3GPP is studying the MEC interfaces towards the RAN to enable radio analytics, context-awareness, etc. The use of an MEC platform for vehicular communications may bring some challenges in terms of service continuity due to frequent service migration, and alternations in radio and traffic load. For assuring service continuity, orchestrating MEC services across a set of platforms is a significant aspect for assuring efficient network resource utilization and performance guarantees. A study on the MEC orchestration elaborating the ongoing and emerging key technologies as well as the main open challenges is provided in [15].

Table 1. Low latency requirements for V2X

Attribute	Description
Latency	• For V2V/P application – 100 ms max • For V2V Pre-crash sensing application –20 ms max
Message size	50-300 bytes (not including security related components)
Frequency	10 messages per second per UE or per RSU max
Absolute speed	250 km/h

V. MBMS for V2X

The V2X service requirements, as specified in TS 22.185 [16], call for the use of broadcast as a way to deliver critical messages to a large number of UEs simultaneously with minimum latency. Since low latency is one of the critical requirements for many of the V2X services, the 3GPP MBMS capability was considered well suited for efficient message delivery.

The broadcast service called Cell Broadcast Service (CBS) was offered in early GSM systems (around 1991, prior to 3GPP formation) by ETSI for lower data rate services, e.g., text messaging, advertisement, etc. Since the formation of 3GPP in 1996, the evolution of GSM standard was handed over to 3GPP, and the broadcast service has seen a continuous enhancement. In Release 6, a new service called MBMS was introduced for UMTS which could deliver any type of data, not just text oriented messages as in CBS. This allowed the use of same radio resource to stream same video to a large number of users at the same time, resulting in an improved network performance. Then came the enhanced MBMS (eMBMS) in Release 8 and 9 for LTE, with better usage of network and radio resources, and paving the way for penetration of mobile broadband services (e.g. mobile TV, video streaming, video conferencing, etc.). Release 10 introduced the eMBMS-SFN for Single Frequency Network (SFN) in LTE, which got deployed widely by operators allowing them to compete directly with the well-known Digital Video Broadcasting (DVB) technology.

MBMS has been considered as a key enabler for public safety service provisioning in GCSE-LTE [17, 18], with new services being supported at each new release. Due to the ongoing enhancements of MBMS over several releases, and its ability to meet the low latency requirements of V2X, it is considered a suitable technology for delivery of V2X messages between UEs. The LTE low latency requirements for V2X applications between UEs, as specified in TS 22.185 [16], are described in Table 1.

Figure 4 describes eMBMS-based V2X Architecture. The eMBMS entities include Broadcast Multicast Service Center

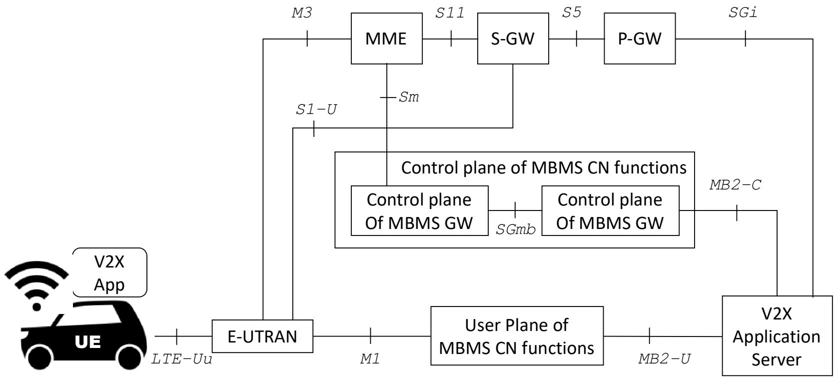

Figure 5: MBMS architecture for V2X [9]

(BM-SC) and MBMS-Gateway (MBMS-GW). BM-SC is the entry point for 3rd party content providers to initiate MBMS bearer services within the PLMN for UEs and can be used to schedule and deliver MBMS transmissions. The details of BM-SC and MBMS-GW are contained in TS 23.246 [8]. To achieve greater MBMS latency improvements, the V2X AS may provide the BM-SC with Local MBMS information, i.e., M1 interface information including transport network IP Multicast Address, IP address of multicast source and C-TEID, as well as MB2-U interface information including IP address and UDP port number for the user plane.

Figure 5 shows the user plane MBMS CN functions operating closer to E-UTRAN for efficient transfer of V2X messages, to further achieve lower latency. The user plane of MBMS can transmit user data received from V2X AS over MB2-U interface, and IP multicast distribution of MBMS user plane data to E-UTRAN over the M1 interface. The V2X message reception via MBMS includes:

- V2X messages that can be broadcasted via the MBMS in which the V2X AS transfers V2X messages via MBMS bearer service as shown in Figure 4
- For MBMS reception of V2X messages, USD per PLMN for V2X services is required for each UE

For MBMS latency improvements, localized MBMS can be considered for localized routing of V2X messages destined to UEs. The localized MBMS deployment options is as follows:

- To move the MBMS CN functions (e.g., BM-SC, MBMS-GW) closer to the eNB.
- To move the user plane of MBMS CN functions (BM-SC, MBMS-GW) closer to the eNB

In V2X communications, the V2X AS gathers a lot of information about the road conditions from several sources (UEs, RSUs, traffic lights, etc.). When it determines that important information about the road conditions (e.g., accident avoidance) need to be delivered to a large number of vehicles within a specific geographic region in a timely manner, the 3GPP eMBMS capability can be used. This was one of the main reasons to use the 3GPP eMBMS capability for V2X services, as it is able to broadcast messages in an efficient manner to large number of UEs at the same time.

During the V2X architecture studies in 3GPP TSG-SA SWG2, the following key issues related to MBMS were tackled:

- How to translate the broadcast area identifiers (or geographical location), which is available at different protocol layers of car-to-car communication systems into MBMS services areas or list of ECGIs (E-UTRAN Cell Global Identifier).
- Improvements necessary for eMBMS to meet the end-to end V2X latency requirements (e.g., by localizing certain functions of the eMBMS architecture).

VI. PC5 INTERFACE FOR V2X

Car-to-car or V2V communication is based on the ProSe [10] as illustrated in Figure 6, which highlights the relevant reference points and has the following characteristics:

- Connectionless communication
- V2X message exchange is via PC5 user plane
- Support of IP based and non-IP based V2X messages, but no IPv4 support for IP-based messages

A V2X UE supports the ProSe procedures for service authorization and one-to-many ProSe direct communication transmission over the PC5 interface. The V5 reference point between the V2X applications in the UEs is not yet specified in 3GPP.

The PC5 mode can also operate in hybrid mode with MBMS. In this operation mode, a UE always transmits the V2X messages via PC5, but UE can receive V2X messages via either the PC5 or MBMS mode. A stationary RSU acting as a UE receives V2X messages via PC5 and forwards to V2X AS via V1 interface. The V2X messages processed by the V2X AS can be distributed to UEs via the MBMS system as required.

In hybrid mode, a UE can directly receive V2V messages from other UEs in close proximity, while the mobile network

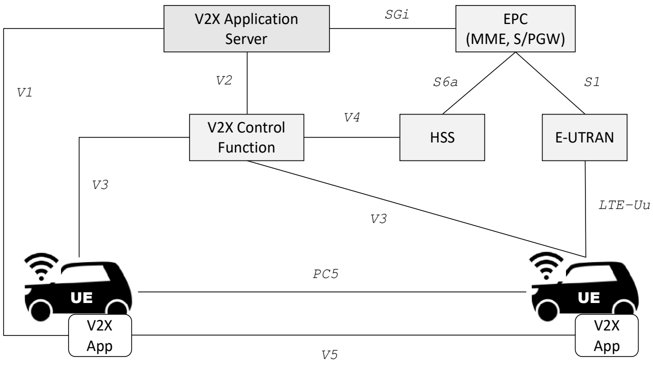

Figure 6: Vehicle to Vehicle communication architecture

provides information from an extended range and satisfies the needs of soft safety (e.g. situational awareness at range) or enables advanced driving assistance applications. Such applications are useful especially in high density areas where a UE may not be able to reliably receive V2X messages directly from distant UEs over PC5.

VII. Outlook

The introduced V2X contents specified in the set of 3GPP normative specifications are still being progressed and enhanced in the upcoming Release 15 considering also the new radio access network, which is under discussion for the "5G" Next Generation system. The 3GPP Service Aspects and Requirements group (i.e., SA1) is studying several additional aspects, which were not progressed in the initial phase of the work, including:

- Car as mobile office/home
- Comfortable semi-autonomous and fully autonomous d riving
- Services for commercial road users

While the first version of V2X in 3GPP considers only LTE access, a new objective is to support V2X services in multiple 3GPP RATs (e.g., LTE, New RAT (NR)) and network environments. The interoperability with non-3GPP V2X technologies (e.g., ITS-G5/DSRC/ITS Connect) is also considered and should be studied.

VIII. Conclusion

In this article, we introduced the recent 3GPP standards activities in the areas of the V2X. Many new features and issues have been developed and are currently under development. In particular, activities and specifications working on: (1) general architecture enhancements for V2X, (2) RAN enhancements for investigating interfaces that support unicast and broadcast traffic (3) MEC for service performance enhancements and the local MBMS (4) service capabilities and MBMS related to V2X features and (5) a new interface for vehicular devices, were reviewed.

Standardization for LTE-based V2X, including the technologies described in this paper is expected to be completed at the second quarter of 2017 as one of the work items for the LTE Release-14 version. Subsequently, the standardization of the advanced V2X based on LTE is expected to be one of the work items for Release-15, which will also consider further standardization work for V2X based on a 5G new radio as a study item.

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