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GENERAL ASPECTS

ITU-APT Foundation of India (IAFI)

THE USE OF TERRESTRIAL COMPONENT OF IMT FOR CELLULAR-VEHICLE-TO-EVERYTHING APPLICATION

(QUESTION ITU-R 262/5)

1 Background

ITU-R Working Party (WP) 5D is working towards a new report on "The use of the Terrestrial Component of IMT for [Cellular-Vehicle-to-Everything] Application". The working document on C-V2X was developed in the WP 5D 34th meeting in February 2020 and further progress on working document PDNR ITU-R M.[IMT.C-V2X] continued in WP 5D 37th meeting. The current working document is included in Attachment 3.3 to the Chairman's report (Attachment 3.3/ Document 5D/TEMP/287).

As described in the Question ITU-R 262/5, WP 5D is invited to study several aspects including 1) specific applications supported by IMT, 2) technical characteristics 3) operational aspects and 4) capabilities. With regard to the first question, it has been seen that C-V2X using IMT systems is having more emerging applications, taking into account global trends, market demands and technology readiness.

It may be noted that the WP 5A is the lead group responsible for the ITS and CAV (Connected and Automated Vehicles). The new report ITU-R M.[IMT.C-V2X] from WP 5D will help WP 5A towards its Preliminary Draft New Report ITU-R [M.CAV], as according to the workplans it is expected that new report ITU-R M.[IMT.C-V2X] from WP 5D will be completed before the one in Working Party 5A.

WP 5D meeting #38 is expected to continue developing the document to progress the work.

2 Proposal

In this contribution, we provide proposals for merging or choosing between the multiple text proposals in the working document. IAFI proposal is highlighted with phrase {New Proposal} for easy reference in the attached Annexure 1.

ANNEXURE 1

ATTACHMENT 3.3

Source: Document 5D/TEMP/287

[Editor's note: This working document is consolidated version: C2C-CC, Japan, China, Korea, Qualcomm, and 3GPP]

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT
NEW REPORT ITU-R M.[IMT.C-V2X]

The use of the Terrestrial Component of IMT for [Cellular-Vehicle-to-Everything] Application

(Question ITU-R 262/5)

(YYYY)

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[Editors's note: Chapter 7 has been moved to Annex-XXX1]

[Editor's note: This Working document is consolidated version: Japan, China, Korea, and 3GPP]

[Editor's note: On 8 October 2020, it is reviewed for scope. The other parts were not reviewed]

Scope

{Editors' note: Original sentence in 5D/360}

This report addresses the mutual relationship between IMT technologies and Cellular-Vehicle-to-Everything (C-V2X) as a specific application and elements of functions in IMT technologies that are used to realize C-V2X application.

Further, the report provides details on Overview on Usage of IMT technology, use cases, Relationship between IMT and C-V2X, Characteristics and Capabilities supported by IMT, and Case Study associated with C-V2X for the various scenarios including eMBB, mMTC, and URLLC of terrestrial component of IMT.

[Editor's note: This document should be improved in terms of ITU-R view point with referring the scope and in the sense of more general]

1 Introduction

[Editor's note: This section addresses overall information on C-V2X as emerging applications by IMT systems.]

This report provides information on the application of terrestrial component of IMT system in C-V2X (Cellular Vehicle-to-everything) as a specific application under Question ITU-R 626/5, "Usage of the terrestrial component of IMT systems for specific applications". The capabilities of IMT technologies are applicable to specific applications. [There are already such kinds of Reports as on PPDR (Public Protection and Disaster Relief) and audio-visual application.]

It is noted that usages relevant to vehicle communication are also indicated in the Report ITU-R M.2445 "ITS usage" whose contents are attached to Annex X. Some use cases indicated in the following section are also seen in Report ITU-R M.2445.

{Editors's Note: The following 2 paragraphs to be review and received input incorporated incl. check consistent terminology for C-V2X}

{Editor's note: Proposal from C2C-CC}

In this report C-V2X is considered as an ITS application in the sense of the ITU-R Report M-2445. Only IMT based V2X communication technologies (LTE based V2X and/or 5G-V2X) are considered as part of the present report. LTE base V2X and other V2X communication technologies capable of implementing V2V, V2I, V2P type ITS applications like V2X (ETSI ITS-G5), IEEE V2X (WAVE) or ARIB V2X (ITS Connect) and their successor technologies are considered in ITU-R report M. 2445. IMT based V2X consist of cellular communication components (called uu interface) and ad hoc short-range communication (called PC5 interface).

The report provides details of the use cases and the relationship between IMT and C-V2X as ITS application. The use case studies included in the report will derive the characteristics and capabilities supported by IMT and will take into account various scenarios including eMBB, mMTC and URLLC as part of the terrestrial component of IMT.

2 Relevant ITU-R Recommendations and Reports

Recommendation ITU-R M.1890 Operational radiocommunication objectives and requirements for advanced Intelligent Transport Systems

Recommendation ITU-R M.2083 IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond

Recommendation ITU-R M.2084 Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications

Recommendation ITU-R M.2121 Harmonization of frequency bands for Intelligent Transport Systems in the mobile service

Report ITU-R M.2228 Advanced intelligent transport systems (ITS) radiocommunications

Report ITU-R M.2441 Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)

Report ITU-R M.2444 Examples of arrangements for Intelligent Transport Systems deployments under the mobile service

Report ITU-R M.2445 Intelligent transport systems (ITS) usage

Handbook on Land Mobile (including Wireless Access) – Volume 4: Intelligent Transport System

[Editor’s note: More to be added]

3 Acronyms

[Editor’s note: To be added]

BSM	Basic Safety Message
CCSA	China Communications Standards Association
C-SAE	China- Society of Automotive Engineers
C-ITS	Cooperative Intelligent Transport Systems
C-V2X	Cellular Vehicle to everything
ICV	Intelligent Internet connected vehicle
ITS	Intelligent transport systems
MEC	Multiple-Access Edge Computing
OBU	On-board Unit
OTA	Over The Air
PC5	Proximity-based Communication (Interface) 5 interface between the ITS stations used for V2X sidelink communication
RSI	Road Side Information
RSM	Road Safety Message
RSU	Road Side Unit
SDO	Service Data Objects
Sidelink	radio link between the ITS stations for direct communication
SPAT	Signal Phase Timing Message

V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to everything
VRU	Vulnerable Road User

4 C-V2X as specific ITS application supported by IMT technology

[Editor's note: This section addresses overview and use cases for C-V2X using IMT technologies from relevant industry and external organizations as well as ITU-R members.]

4.1 Overview on Usage of IMT technology in C-V2X

[Editor's note: This section summarizes how to use IMT systems for C-V2X applications in several groups and organizations outside ITU-R as well as ITU-R Members. It will clarify the relationship between C-V2X and IMT]

{Editor's note: this general overview comes from 3GPP TS 22.185, it is needed to have the reference number}

4.1.1 Types of V2X application support in 3GPP

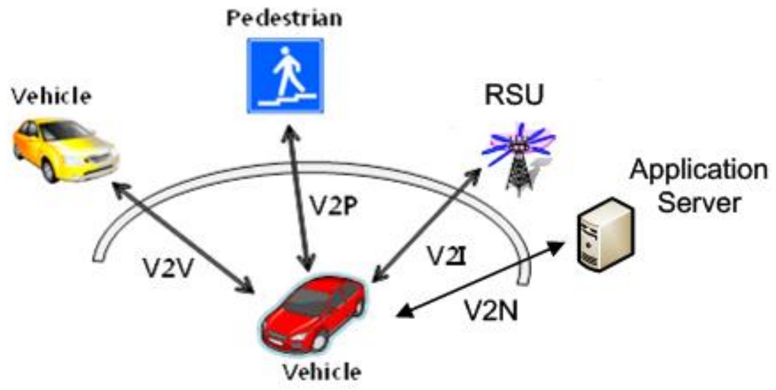
4.1.1.1 General

The C-V2X applications [described in the 3GPP specification], referred to as Vehicle-to-Everything (V2X), contain the following four different types:

- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
- Vehicle-to-Network (V2N)
- Vehicle-to-Pedestrian (V2P)

FIGURE 4.1.1-1

Types of V2X applications (V2V, V2P, V2N and V2I)



These four types of V2X applications can use "co-operative awareness" to provide more intelligent services for end-users. This means that entities, such as vehicles, roadside infrastructure, application server and pedestrians, can collect knowledge of their local environment (e.g., information received from other vehicles or sensor equipment in proximity) to process and share that knowledge in order to provide more intelligent services, such as cooperative collision warning.

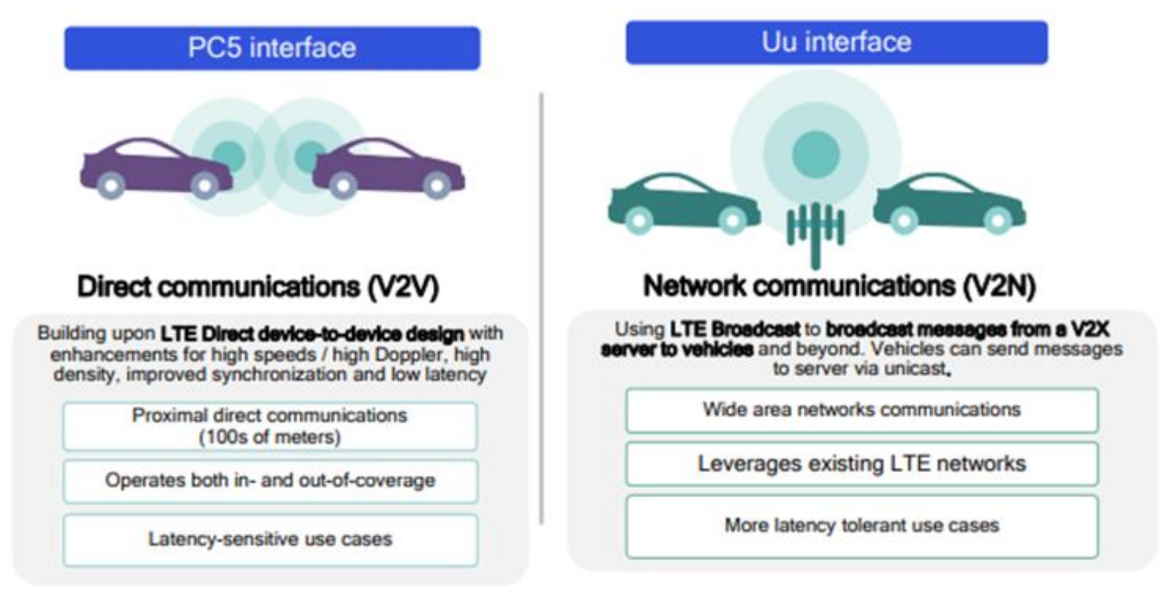
These intelligent transportation services and the associated message sets have been defined in automotive SDOs outside 3GPP.

3GPP only handles the transport of these messages to support different types of V2X applications.

[redacted]

[redacted]

[redacted]



4.1.1.2 Vehicle-to-Vehicle (V2V) application

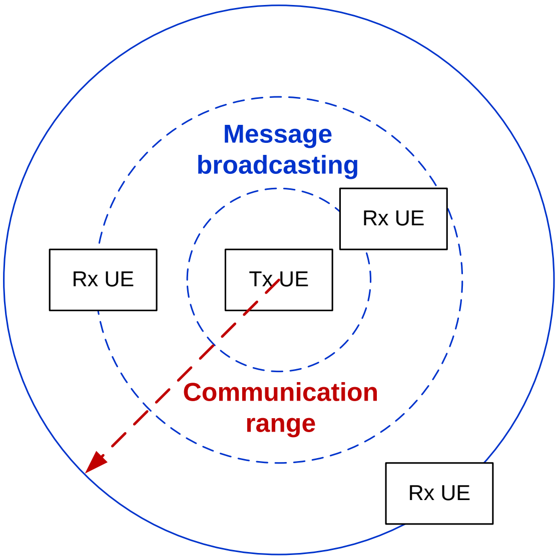
V2V applications expect UEs that are in proximity of each other to exchange V2V application information. 3GPP transport of messages containing V2V application information requires the UE to have a valid subscription and authorization from a network operator. Transport for a valid subscriber is provided whether the UE is served or not served by RAN.

The UE supporting V2V applications transmits messages containing V2V application information (e.g. location, dynamics, and attributes). The message payloads may be flexible in order to accommodate varying amount of information.

3GPP transport of message containing V2V application information is predominantly broadcast-based as illustrated in Figure 4.1-2. Such 3GPP transport includes the transport between UEs directly and/or, due to the limited direct communication range, the transport between UEs via infrastructure supporting V2X communication, e.g., RSU, application server, etc.

FIGURE 4.1.2-1

Broadcast-based V2V communications



4.1.1.3 Vehicle-to-Infrastructure (V2I) application

The UE supporting V2I applications transmits messages containing V2I application information to an RSU or locally relevant application server. The RSU and/or the locally relevant application server transmit messages containing V2I application information to one or more UEs supporting V2I applications.

A locally relevant application server serves a particular geographic area. There can be multiple application servers serving overlapping areas, providing the same or different applications.

4.1.1.4 Vehicle-to-Network (V2N) application

The UE supporting V2N applications communicates with an application server supporting V2N applications. Both parties communicate with each other via the EPS.

4.1.1.5 Vehicle-to-Pedestrian (V2P) application

V2P applications expect UEs that are in proximity of each other to exchange V2P application information. 3GPP transport of messages containing V2P application information requires the UE to have a valid subscription and authorization from a network operator. Transport for a valid subscriber is provided whether the UE is served or not served by E-UTRAN.

The UE supporting V2P applications transmits messages containing V2P application information. It is expected that V2P application information can be transmitted either by a UE supporting V2X application in a vehicle (e.g., warning to pedestrian), or by a UE supporting V2X application associated with a vulnerable road user (e.g., warning to vehicle).

3GPP transport of messages containing V2P application information includes the transport between UEs directly and/or, due to the limited direct communication range, the transport between UEs via infrastructure supporting V2X communication, e.g., RSU, application server, etc.

NOTE: The main difference between 3GPP transport of messages with V2P and V2V application information is due to the properties of the UE. A UE supporting V2P applications used by pedestrian might, for example, have lower battery capacity, the radio sensitivity might be limited, e.g. due to antenna design, and therefore it may not be able to send messages with the same periodicity as UEs supporting V2V application, and/or receive messages.

{Editor's note: V2V, V2I, V2P applications are supported by PC5 interface and V2N applications are supported by Uu interface. It may be needed to describe in the overview section}

4.2 3GPP Use Cases

[Editor's note: This section summarizes use cases for C-V2X]

{Editor's note: LTE-V2X and NR-V2X use cases come from 3GPP TR 22.885 and 22.886}

In the 3GPP TR 22.885[1] as study on LTE support for V2X services and TR 22.886[2] as study on enhancement of 3GPP support for 5G V2X services have recommended use cases of C-V2X. They describe C-V2X use cases, pre-conditions, service flows, post-conditions, and potential Requirements.

3GPP TR 22.885 and TR 22. 886 describe a set of C-V2X use cases, introduced over Rel-15 and Rel-16.

In some use cases, application messages relevant to V2V, V2I, and V2N communications could be used for their transmission. It is thought that V2V is used for the immediate transmission of service information in a small area and V2I or V2N is used for the delivery of service information in a relatively larger area. On the other hand some use cases requiring wider frequency band use V2N service through Uu interface, not PC5 interface.

An appropriate communication type within four V2X communication types would be selected to apply those use cases depending on the design of the service. So there is a case that plural communication types are indicated for each use case in the most right column of the following tables. IMT cellular system is used for applications relevant to V2N service application by use of characteristics of IMT-2020 such as low latency, high speed, and so on.

In Table XX, the use case and the description are listed for LTE support for V2X services

[Editor note: The use cases of C-V2X from 3GPP input are described in Section 4.2.1 where it observes that some use cases defined in 3GPP TR 22.886 are not included, such as *Information sharing for partial/ conditional automated platooning*. For these excluded use cases and other provided but potential not fully supported cases, it would be good to know whether those use cases can be met by the current IMT technologies. In this way, WP 5D can decide whether this type use cases provided by all the organizations can be included in this report. Hence, in order to make this report be a guideline about C-V2X without unnecessary misunderstanding, it would be good to achieve corresponding information/clarifications from the organizations who provided the materials. And then WP 5D can discuss how to deal with the corresponding use cases in the report at this stage based on those information/clarifications.]

1 TR 22.885 – LTE support for V2X services.

2 TR 22.886 – enhancement of 3GPP support for 5G V2X services.

TABLE XX

Use cases in LTE support for V2X services

Use cases	Description	Types of V2X application
Forward Collision Warning	The FCW application is intended to warn the driver of the HV in case of an impending rear-end collision with a RV ahead in traffic in the same lane and direction of travel. Using the V2V Service, FCW is intended to help drivers in avoiding or mitigating rear-end vehicle collisions in the forward path of travel.	V2V,
Control Loss Warning	The CLW application enables a HV to broadcast a self-generated control loss event to surrounding RVs. Upon receiving such event information, a RV determines the relevance of the event and provides a warning to the driver, if appropriate.	V2V,
V2V Use case for emergency vehicle warning	Emergency vehicle warning service enables each vehicle to acquire the location, speed and direction information of a surrounding emergency vehicle (e.g. ambulance) to assist safety operation like allowing ambulance path to get free.	V2V,
V2V Emergency Stop Use Case	This use case describes vehicles V2V communication used in case of emergency stop to trigger safer behaviour for other cars in proximity of the stationary vehicle.	V2V,
Cooperative Adaptive Cruise Control	This use case describes the scenario whereby a vehicle with V2V capability joins and leaves a group of corporative-adaptive-cruise-control (CACC) vehicles. This provides convenience and safety benefits to participating vehicles and also has societal benefits to improve road congestion and fuel efficiency.	V2V,
V2I Emergency Stop Use Case	This use case describes V2I communication where a Service RSU notifies vehicles in vicinity in case of emergency stop to trigger safer behaviour.	V2I,
Queue Warning	In a lot of situations, a queue of vehicles on the road may pose a potential danger and cause delay of traffic, e.g. when a turning queue extends to other lanes. Using the V2I Service, the queue information can be made available to other drivers beforehand. This minimizes the likelihood of crashes and allows for mitigation actions.	V2X, V2V, V2I,
Road safety services	V2X messages are delivered from one UE supporting V2I Service to other UEs supporting V2I Service via an RSU which may be installed on the road side. The RSU receives V2X messages transmitted from UEs supporting V2I Service and transmits the received V2X messages to UEs within a local area. A UE receives V2X messages transmitted by the RSU. After processing the received V2X messages, the UE notifies the driver of relevant information.	V2I,
Automated Parking System	The Automated Parking System (APS) contains a database which provides real-time information to vehicles in a metropolitan area on availability of parking spots, be it on the street or in public parking garages. Connected vehicles help maintain the real-time database of the occupancy of parking spaces, which can be accessed by means of smartphones and connected vehicles. APS allows a driver to reserve an available parking space, be guided to it via a navigation application, and make a hands-free payment for parking.	V2X, V2I
Wrong way driving warning	This use case describes V2V communication used between 2 vehicles driving in opposite directions warning wrong way driving and trigger safer behaviour for cars in proximity.	V2V
V2X message transfer under MNO control	This use case describes the scenario where a given UE supporting V2V Service sends V2X messages to other surrounding UEs and the given UE is under E-UTRAN coverage.	V2V,
Pre-crash Sensing Warning	The pre-crash sensing warning application provides warnings to vehicles in imminent and unavoidable collision by exchanging vehicles attributes after non-avoidable crash is detected.	V2V,

Use cases	Description	Types of V2X application
V2X in areas outside network coverage	This use case describes V2X communication when one or more vehicles are located in an area not served by E-UTRAN which supports V2X Service.	V2X, V2V
V2X Road safety service via infrastructure	This use case describes the scenario where infrastructure nodes such as RSUs and traffic safety servers generate and distribute traffic safety-related messages for road safety.	V2N, V2I,
V2N Traffic Flow Optimisation	This use case describes vehicles V2N (Vehicle-to-Network) communication to a centralised ITS server referred here to as “entity” to optimise traffic flow when approaching intersections. This use case addresses the situation when approaching the vehicle has to stop even though there are no other cars around at an intersection or has to slow down because of explicit traffic lights signal absence. Depending on the traffic situation which is based on the vehicles' periodically transmitted messages this entity will provide, via LTE network entity, a green light to a car when approaching the intersection and an indication of speed at which the green light will be met without having to stop or miss the green light phase.	V2N, V2I,
Curve Speed Warning	Curve speed warning application alerts the driver to manage the curve at an appropriate speed.	V2I,
Warning to Pedestrian against Pedestrian Collision	This use case is to provide information to vulnerable road users, e.g. pedestrian or cyclist, of the presence of moving vehicles in case of dangerous situation. As a result, warnings are provided to vulnerable road users to avoid collision with the moving vehicle.	V2P,
Vulnerable Road User (VRU) Safety	This use case describes the scenario whereby a vehicular and a pedestrian are both equipped with V2P capabilities, and the vehicle detects the pedestrian's presence and alerts the driver, if an imminent threat is present. This capability extends the safety benefit of V2X to pedestrians and other vulnerable road users, e.g. bicyclists, wheelchair users, etc.	V2P,
V2X by UE-type RSU	This use case describes the scenario where UE supporting V2X discovers and communicates with UE-type RSU.	V2X, V2V, V2N,
V2X Minimum QoS	This use case describes the scenario where E-UTRA(N) resource is not enough for every UEs 10 Hz V2X message transmission. In addition, this use case includes the scenario where emergency vehicle is supported.	V2N,
Use case for V2X access when roaming	Mary is taking a road trip across the country. She has a car equipped with V2X capability, with service from her home network operator. On her journey, Mary encounters a traffic jam in town not served by her home network provider. The town has deployed V2X capabilities to redirect traffic jams caused by a major infrastructure construction project. The V2X capabilities must be able to communicate with devices associated with multiple service providers.	V2X, V2V,
Pedestrian Road Safety via V2P awareness messages	A pedestrian carries a UE, which is able to transmit awareness and safety related V2P broadcast messages.	V2P,
Mixed Use Traffic Management	There are a number of variables to be taken into account in a scenario involving different types of vehicular traffic.	V2X, V2I,
Enhancing Positional Precision for traffic participants	To obtain their position vehicles usually use a GNSS such as GPS, Galileo, Beidou, and Glonass. However, the publicly available precision for a position fix for the most common system GPS is just around 15 m, better values can be obtained and dependent on the radio conditions and are thus not guaranteed.	
Privacy in the V2V communication environment	The privacy or anonymity in the V2V communication environment is a requirement deemed very important for user adoption of the V2V system.	V2V,

Use cases	Description	Types of V2X application
V2N Use Case to provide overview to road traffic participants and interested parties	This use case describes a general use case for V2N communication that exercises the strength of 3GPP networks of providing excellent coverage.	V2N, V2V,
Remote diagnosis and just in time repair notification	A road side unit (RSU) having the capability to access an internet will enable any passing by vehicle to report about its current functional state to a local/remote diagnosis center and to receive "Just in time repair notification" if having subscribed to such service.	V2N, V2I,

[In 3GPP Rel. 15, eV2X use cases had been developed and are recommended in TR. 22.886. In Table YY, the use cases and description of enhancement of 3GPP support for 5G V2X services are listed.

In Rel. 16, 3GPP studied new and enhanced V2X (eV2X) use cases, captured in TR. 22.886, which can be grouped in the following main areas:]

[**Vehicles Platooning** enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven.

Advanced Driving enables semi-automated or fully-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or maneuvers. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.

Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.

Vehicle quality of service support enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions. The benefits of this use case group are offerings of smoother user experience of service.]

TABLE YY

Use cases in enhancement of 3GPP support for 5G V2X services

Use cases	Description	Types of V2X applications
eV2X support for vehicle platooning	Platooning is operating a group of vehicles in a closely linked manner so that the vehicles move like a train with virtual strings attached between vehicles.	V2X (V2V, V2N)
Information exchange within platoon	When the vehicles are travelling on the road, they can dynamically form a platoon. The platoon creator is responsible for platoon management.	V2I, V2V,
Automotive: sensor and state map sharing	Sensor and state map sharing (SSMS) enables sharing of raw or processed sensor data to build collective situational awareness.	V2I, V2X
eV2X support for remote driving	Remote driving is a concept in which a vehicle is controlled remotely by either a human operator or cloud computing.	V2X
Automated cooperative driving for short distance grouping	Cooperative driving allows a group of vehicles to automatically communicate to enable lane changing, merging, and passing between vehicles of the group and inclusion/removal of vehicle in the group in order to improved safety and fuel economy.	V2V, V2I,
Collective perception of environment	Vehicles can exchange real time information (based on vehicle sensors information or sensor data from a capable UE-type RSU) among each other in the neighbour area.	V2X, (V2V)
Communication between vehicles of different 3GPP RATs	Depending on the choice of OEMs, while some vehicles are equipped with modules supporting only LTE, other vehicles may be equipped with modules supporting NR (New Radio). If a vehicle of NR cannot talk to a vehicle supporting LTE, the vehicle supporting LTE can be regarded as another vehicle of no V2X capability.	V2N, V2V
Multi-PLMN environment	Although required communication condition, e.g. for immediate message transfer, is set high for some of eV2X use cases, such condition needs to be met regardless of whether or not all the involved UEs and UE-type RSUs are subscriber of the same PLMN	V2X
Cooperative collision avoidance (CoCA) of connected automated vehicles	To enable vehicles to better evaluate the probability of an accident and to coordinate manoeuvres in addition to usual CAM, DENM safety messages, data from sensors, list of actions like braking and accelerating commands, lateral as well as longitudinal control are exchanged amongst vehicles to coordinate in the application the road traffic flow through 3GPP V2X communication.	V2X
[Information sharing for partial/ conditional automated driving]	[This use case is interpreted as an automated driving at the level of SAE Level 3 and Level 2 automation, where non-short inter-vehicle distance (e.g. >2sec * vehicle speed) is assumed and abstracted/coarse data exchange is sufficient.]	[V2X, (V2I)]
[Information sharing for high/full automated driving]	[This use case is interpreted as an automated driving at the level of SAE Level 4 and Level 5 automation, where non-short inter-vehicle distance (e.g. >2sec * vehicle speed) is assumed and high-resolution data exchange is required.]	[V2X, (V2I)]

Use cases	Description	Types of V2X applications
[Information sharing for partial/ conditional automated platooning]	[This use case is interpreted as an automated platooning at the level of SAE Level 3 automation, where short inter-vehicle distance (e.g. <2sec * vehicle speed) is assumed and abstracted/coarse data exchange is sufficient.]	[V2X, (V2I)]
[Information sharing for high/full automated platooning]	[This use case is interpreted as an automated platooning at the level of SAE Level 4 and Level 5 automation, where short inter-vehicle distance (e.g. <2 sec * vehicle speed) is assumed and high-resolution data exchange is required.]	[V2X, (V2I)]
Dynamic ride sharing	This use case enables a vehicle to advertise willingness to share capacity with another road user and for a pedestrian to indicate intent to travel in a ride share.	V2X, (V2P)
Use case on multi-RAT	The user starts a V2X application, and a message from that application needs to be transmitted to other cars nearby. The V2X UE supports multiple radio access technologies (RATs), including LTE and 5G New RAT (NR). The V2X UE should choose the best technology to support the given application of interest.	V2X
Video data sharing for assisted and improved automated driving (VaD)	The visual range of the driver is in some road traffic situations obstructed, for instance by trucks driving in front [26]. Video data sent from one vehicle to the other can support drivers in these safety-critical situations.	V2X, (V2V)
Changing driving-mode	According to a vehicle cooperation level, driving-mode can be classified generally into three classes (autonomous, convoy, and platooning). Nontrival traffic scenario requests for switching into the other driving-mode.	V2V
Tethering via Vehicle	This use case enables a vehicle to provide network access to occupants, pedestrians etc.	V2X, (V2P)
Use case out of 5G coverage	A UE supporting V2X application is equipped with a multi-RAT modem (5G, LTE).	V2X,
Emergency trajectory alignment	Emergency Trajectory Alignment (EtrA) messages complement cooperative automated driving to assist the driver in hazardous and challenging driving situations to further increase traffic safety.	V2X (V2V)
Teleoperated support (TeSo)	Teleoperated Support (TeSo) enables a single human operator to remotely control automated vehicles for a short period of time. {Editor's note:C2C-CC wants to delete the below sentence} A remote driver undertakes the control of the vehicle and drives remotely the vehicle, in an efficient and safe manner, from the current location to the destination.	V2X (V2N)
Intersection safety information provisioning for urban driving	The traffic accident occurs at the intersection where the vehicle and pedestrians are crowded. This provides safety information to the vehicles to prevent traffic accident and assist cooperative automated driving function when the vehicles pass through the intersection.	V2X (V2I)
Cooperative lane change (CLC) of automated vehicles	On a multi-lane road, a lane change manoeuvre could be initiated by a vehicle. Cooperative Lane Change V2X scenario involves vehicles exchanging their intended trajectories to coordinate their lateral (steering) and longitudinal controls (acceleration/deceleration) to ensure a smooth manoeuvre.	V2X (V2V)

Use cases	Description	Types of V2X applications
Proposal for secure software update for electronic control unit	A car Electronic Control Unit (ECU) is a generic term for a software module that controls the electronics within a car system; this could be anything from the steering wheel to the brakes and with automated car driving and this becomes a key part of the car that will possibly need regular software updates.	V2I
3D video composition for V2X scenario	This use case consists of multiple UEs supporting V2X application moving in an area. Those UEs take a video of the environment by their camera, and send this video to a server, which can be in the cloud or in the near the UE point of attachment to enable edge computing in order to create a single 3D video of the environment.	V2X (V2I, V2N)
QoS aspects of advanced driving	Based on the implementation or approach taken by each manufacturer or the environment where each vehicle is located, whether to engage automated driving or not needs to be controlled by the V2X service either in the vehicle or in the cloud of remote back-end.	V2X
QoS aspect of remote driving	Remote Driving applications allow a remote driver that is not sitting in the vehicle to undertake the control of the vehicle and drive remotely the vehicle, in an efficient and safe manner, from the current location to the destination.	V2X
QoS Aspect for extended sensor	The extended sensor use cases are composed of sensor data collection to construct local dynamic map and the state map sharing, sensor data shared to extend sensor range, different all round video data shared for automatic drive.	V2X
Different QoS estimation for different V2X applications	QoS estimation will help V2X applications e.g. automation driving, intelligent traffic system, to get the communication system connection capability in advance which is very important for them to compute and adjust in advance to right working mode to guarantee safety and service availability	V2X

4.3 Additional Use cases / Other Use cases

[4.3 Use cases classified from the aspect of usage object]

[Editor's note: This section addresses potential use cases of C-V2X by IMT systems.]

The typical C-V2X use cases can be information sharing, traffic efficiency assistance, driving safety assistance and even for advanced autonomous driving from usage object perspective. And among them, some use cases can be combined together to construct more complicated C-V2X services.

Supporting by the IMT technologies, and with the evolution from vehicle-road to vehicle-road-pedestrian -cloud coordination, it is expected that during future 1-3 years, the following C-V2X typical use cases will be fully developed.

Note: In the following use cases, the mentioned IMT system includes two kinds of wireless connections: Uu and sidelink.

Typical C-V2X use cases can be divided into information services, traffic efficiency and driving safety.. Moreover, these use cases aim for multiple objects on or near the road.

With the evolution from vehicle-infrastructure to vehicle-infrastructure-pedestrian-cloud coordination, it is expected that in the coming years, C-V2X use cases will be fully developed.

Note: The mentioned IMT system includes two wireless interfaces, Uu and sidelink.

[redacted]

[redacted]

4.3.1 OTA (Over The Air)

The use case is based on the V2X OTA platform and IMT system. When the Uu signal is good, the vehicle obtains the upgrade software package through the wireless network; when the Uu signal is poor; the vehicle obtains the upgrade software package through sidelink connection from the proximity RSU which is the smart roadside equipment and can be upgraded with V2N.

OTA through sidelink connection, on the one hand, can shorten the time for downloading software packages; on the other hand, it can extend the coverage scope of the upgrade.

The use case is based on the V2X OTA platform and IMT system. Nominally, with good Uu connectivity , the vehicle obtains upgraded software via the wireless network; however, when the Uu signal is poor; the vehicle obtains the upgrade software package through sidelink connection from the proximity RSU which is the smart roadside equipment and can be upgraded with V2N.

[redacted]

[redacted]

4.3.2 In-Vehicle Entertainment (IVE)

The use case concerns the entertainment content delivery to the passengers of a moving or stationary vehicle.. The content may include video, gaming, virtual reality (VR), office work, online education, advertisement, etc.

4.3.3 High definition map collecting & sharing

[4.3.3 Local high definition map collecting & sharing]

The use case is for vehicles to get HD map which is real-time updated and more accurate. Vehicles equipped with LIDAR or other HD sensors can collect environment around themselves, and share the information with a HD map provider (e.g., cloud server). The HD map provider analyzes the collected information and merges or combines them to build a regional HD map. This allows the construction of HD maps that are dynamically updated and also with more accurate information.

The use case is for vehicles to obtain real-timeHD map information. Vehicles equipped with LIDAR or other HD sensors can collect local environment, and share the information with a HD map provider (e.g., cloud server). The HD map provider analyzes the collected information and merges or combines them to build a regional HD map. This allows the construction of HD maps that are dynamically updated and with more detailed and temporally accurate information.

4.3.4 ETC (Electrnic Toll Collection)

This use case is proposed a new service method that utilizes the on-board unit (OBU) as the payment terminal, through sidelink connection of IMT system, to pay for the expenses incurred by the vehicle on the road and the goods or services consumed by the vehicle owner.

4.3.5 Vehicle Inbound and outbound

Vehicle inbound and outbound is suitable for vehicle entrance or exit on highways, expressways and other road sections, as well as lane changing scenario. It can assist the road management. Under the premise of ensuring safety, by selecting reasonable time, position and speed of inbound and outbound and lane changing, the impact of vehicles on the main line traffic flow is reduced, and the traffic efficiency of the road is improved.

By selecting reasonable time, position and speed of merging and exiting, to include lane change, the impact of vehicles on the main line traffic flow is reduced, and the traffic efficiency of the road is improved.

When the host vehicle (HV) and the remote vehicle (RV) are located on both sides of the ramp entrance/exit respectively:

– in the case of the roadside unit (RSU) and multi-edge computing platform (MEC) are deployed:

  - MEC and RSU calculate the driving policy and RSU delivers the instructions to guide the vehicles on both sides through sidelink connection of IMT system. HV and RV then follow the instructions;
  - RSU delivers the perception information of the driving environment through sidelink connection of IMT system, and HV and RV make their own decisions based on the perception information received.

– In the case of no RSU deployed, HV and RV transmit vehicle information to each other through sidelink connection of IMT system. The vehicle calculates the driving policy by itself and broadcasts the result.

4.3.6 Intersection traffic

In intersection traffic use case, the host vehicle (HV) drives to the intersection. The HV sends vehicle driving information to the corresponding V2X application server (either in the MEC or in the cloud). The V2X server generates traffic dispatch information for the HV according to the received vehicle information, the traffic control phase information of the target intersection, the driving information reported by other vehicles, and the perception information reported by the roadside sensors, etc. and send the traffic dispatch information to the HV;

Alternately, the Or HV obtains the perception information of roadside sensors, other vehicle information, and cloud information of the V2X server through IMT system, and generates scheduling information

Then the HV controls the HV to pass through the intersection according to the traffic dispatch information, combined with the surrounding environment information sensed by the V2X function and other on-board sensors.

[In this use case, the vehicle reasonably adjusts its driving state according to surrounding vehicle information, traffic signal information, road condition information, maps and other information to facilitate traffic efficiency in a safe manner.]

[In this use case, the vehicle reasonably adjusts its driving state according to surrounding vehicle information, traffic light information, road condition information, maps and other information to avoid idle roads and wasting unnecessary time. Under the condition of ensuring safety, the traffic efficiency of intersections is maximized.]

4.3.7 Dynamic Lane Management

This application is aiming for release the congestion problem of intersections. The dynamic lane division at the intersection is utilized to realize the real-time and reasonable allocation of the space resources of the intersection entrance lane. Through the real-time communication between the vehicles within the intersection range and the roadside unit (RSU), the roadside unit collects the status data of the connected vehicle (CV, Connected Vehicle), including position, speed, steering, etc., to determine the traffic demand in each direction of the intersection in real time. Based on this, the edge computing platform (MEC) adjusts the lane function of the entrance lane, and sends the result to the vehicle, which improves the operation efficiency of the intersection through dynamic lane management.

It is mainly for the scenarios where the intersection demand changes frequently and fluctuations in each flow direction are large. Compared with the existing fixed lane management method, dynamic lane management can match the traffic demand of each flow direction in real time, provide sufficient queuing space for each flow direction vehicle to the greatest extent, and reduce the queue length and the number of secondary queuing.

This application addresses the congestion problem at intersections, where in dynamic lane assignments at the intersection is utilized to realize the real-time allocation of the time space resources of the intersection entrance.. Through the real-time communication between the vehicles within the intersection range and the roadside unit (RSU), the roadside unit collects the status data of the connected vehicle (CV, Connected Vehicle), including predicted position, speed, steering, to determine the traffic demand in each direction of the intersection in real time. Based on this, the edge computing platform (MEC) or local RSU adjusts the lane function of the entrance lane, and sends the result to the vehicle.

Compared with existing fixed lane management methods, dynamic lane management can match the traffic demand of each flow direction in real time, provide sufficient queuing space for each flow direction vehicle, and reduce queue lengths.

4.3.8 Dynamic optimization of traffic signal timing

It refers to the V2X service server at the intersection that optimizes the phase duration or phase sequence of signal timing based on real-time vehicle data. If possible, it can be optimized based on the background data and plan of the central subsystem.

It is suitable for signal control optimization of signal control intersections and signal control ramp entrances of ordinary roads and highways in cities and suburbs.

This use case is suitable for signal control optimization of signal control intersections and signal control ramp entrances of ordinary roads and highways in cities and with suburban road type.

4.3.9 Flexible management of dedicated highway lanes

In order to meet the rapid traffic demand of emergency vehicles, a dynamic dedicated lane is generated to improve the travel condition of emergency vehicles. When an emergency vehicle drives on the dedicated lanes, it broadcasts the current status and clearing distance, in some case, RSU can either broadcasts the occupancy status of the section. After the nearby vehicles receive the relevant information, it will detect whether it is within the clearing distance of the emergency vehicle, if it is yes, it will leave the dedicated lane. This application is suitable for road traffic management of highways, expressways and other sections.

In order to meet the need for emergency vehicles to have traffic priority, a dynamic dedicated lane is generated to improve the passage of emergency vehicles. When an emergency vehicle drives on dedicated lanes, it broadcasts the current status and clearing distance. When available, nearby RSU can also broadcast the occupancy status of the section. Because nearby vehicles receive the relevant information, the will detect whether they are within the clearance distance of the emergency vehicle. If so, those other vehicles will leave the dedicated lane. This application is suitable for all road types

4.3.10 Group start

4.3.2.6 Group start

With this use case, vehicles with some level of automation form a group to jointly start at traffic light. A traffic control center or local RSU provides tactical and strategic information to coordinate the activity.

A traffic control center or the RSU identifies several vehicles which intend to cross an intersection on a similar path at similar time. One of these entities assigns the role of the group leader to the first vehicle approaching the intersection and instructs this vehicle and other participating vehicles on which spot at the intersection the vehicles should occupy. The traffic control center or the RSU considers vehicle capabilities in terms of dynamics, sensor capabilities, planned route, and communications properties into account when composing the groups.

4.3.11 Fleet management

In this application, the leading vehicle is usually in the front of the fleet which obtains information such as traffic environment, information from the V2X service cloud and surrounding vehicles to form a fleet driving strategy, thereby implements the dynamic management of the entire fleet and ensuring safe and efficient travel of the fleet. This application is suitable for urban and suburban roads under network coverage.

In this application, the leading vehicle is usually in the front of the fleet which obtains information such as traffic environment, information from the V2X service cloud and/or surrounding vehicles to form a fleet driving strategy, thereby implementing the dynamic management of the fleet and ensuring its safe and efficient travel,. This application is suitable for urban and suburban roads,.

4.3.12 Platooning

Platooning is to connect trucks traveling in the same direction through wireless technology. The leading vehicle is responsible for fleet management and driving. The trailing vehicle can receive driving information such as acceleration, braking of the preceding vehicle, and improve driving efficiency. Usually the leader of the fleet is driven by a man, followed by multiple unmanned member vehicles based on real-time information interaction and maintaining a stable inter-vehicle distance at a certain speed.

Platooning is to connect trucks traveling in the same direction through wireless technology by using a constant spacing policy, usually with short headways. The leading vehicle is responsible for fleet management and driving. The trailing vehicles receive driving information such as acceleration, braking of the preceding vehicle and from the leading vehicle.

4.3.13 Real-time Navigation

It provides accurate, real-time, and efficient travel path planning for traveling vehicles through IMT communication system, including driving sections, driving lanes, etc., thus traveling vehicles can drive on the "best" route, improving travel efficiency. It can also provide real-time Eco-driving suggestions and parameters such as vehicle speed, real-time acceleration, optimized following plan, and better lane change plan which enable traveling vehicles to drive in the "best" driving mode and improve the efficiency of vehicle energy consumption and travel safety. On the whole, it can optimize the overall and local transportation system to enhance user experience.

When traveling with an electric vehicle (EV), it also need to consider battery power, starting point and destination location, charging station (CS) information, and traffic information to plan and dynamically adjust the travel route and charging route of the electric vehicle.

This use case provides accurate, real-time, and efficient travel path planning for traveling vehicles through the IMT communication system, including driving sections, driving lanes, etc., thus traveling vehicles can drive on the "best" route, improving travel efficiency. It can also provide real-time eco-driving suggestions and parameters such as vehicle speed, real-time acceleration, optimized following plan, and a better lane change plan. These enable traveling vehicles to drive in an optimal driving mode and improve the efficiency of vehicle energy consumption and travel safety. On the whole, it can optimize the overall and local transportation system..

When traveling with an electric vehicle (EV), this use case also considers battery power, origin and destination locations, charging station (CS) information, and traffic information to plan and dynamically adjust the travel route and charging route of the EV.

4.3.14 VRU recognization[recognition]

Vulnerable Road User recognition enables nearby VRU to be detected and the information be transmitted to vehicles as soon as possible. VRUs inclue pedestrians, cyclists, and power-driven two-wheelers.

Vulnerable Road User recognization refers to recognize VRU nearby and warn traffic accidents as earlier as possible. The types of VRUs are including pedestrians, cyclists, and power-driven two-wheelers etc.

Depending the communication capability the VRU has, it can be divided into the following categories:

1) VRU with communication capability;

2) VRU without communication capability.

For different VRUs, there are several ways (not limited to) for recognization and warning:

1) VRU with communication capability: The VRU actively sends its own information, then Vehicle nearby and RSU receive the information to recognize the VRU and detect the VRU risk.

2) VRU without communication capability:
   - Vehicles equipped with sensors (such as cameras, radars, lidars, etc.) perform VRU recognition based on the data collected by the sensors, and send relevant VRU recognition information to surrounding vehicles and RSUs;
   - For RSU equipped with sensors, if it has the ability to analyze perceptual data, it can perform VRU recognition based on the data collected by the sensors and send relevant VRU recognization information to surrounding vehicles;
   - MEC performs VRU recognition based on the data collected by RSU sensors, and then RSU sends relevant VRU recognition information to surrounding vehicles.

4.3.15 See-through for passing

Driver of Host Vehicle that signals an intention to pass a Remote Vehicle (RV) using the oncoming traffic lane is provided a video stream showing the view in front of the RV.

HV approaches from behind or follows RV with the intention to pass using the oncoming lane. Video stream of the front view of RV is shown to the HV driver during the passing maneuver.

In this scnenario, the Host Vehicl signals an intention to pass a Remote Vehicle (RV) using the oncoming traffic lane is provided a video stream showing the view in front of the RV.

The HV approaches from behind or follows RV with the intention to pass using the oncoming lane. Video stream of the front view of RV is shown to the HV driver during the passing maneuver.

4.3.16 Obstructed view assist

This case is usually happened in the intersections, e.g., in rural and urban environments. Host Vehicle (HV) is provided an alternate when faced with an obstructed view. A video stream is provided to HV, circumventing the obstructed view from the HV perspective.

This case is usually at the intersections. A video stream is provided to HV, circumventing the obstructed view from the HV perspective.

4.3.17 High definition sensor sharing

Vehicle uses its own sensors (e.g. HD camera, lidar), and sensor information from other vehicles, to perceive its environment (e.g. come up with 3D model of world around it) and safely performs an automated driving lane change.

Vehicle uses its own sensors (e.g. HD camera, lidar), and sensor information from other vehicles to perceive its environment (e.g.3D model of world around it) and safely performs an automated driving lane change.

4.3.18 Infrastructure assisted environment perception

When an automated vehicle enters a section of the road that is covered by infrastructure sensors it enrols to receive information from the infrastructure containing environment data of dynamic and static objects on the road. This data is used to increase the trust level of the cars own sensor observations and extends its viewing range.

4.3.19 Tele-operated driving

A remote driver undertakes the control of the vehicle and drives remotely the vehicle, in an efficient and safe manner, from the current location to the destination. Based on perceived environment the remote driver provides to the vehicle that is remotely driven the appropriate trajectory and maneuver instructions for the efficient and safe navigation to the destination.

A remote driver undertakes control of the vehicle and remotely drives it. Based on the perceived environment the appropriate trajectory and maneuver instructions information is exchanged.

4.3.20 Autonomous parking

In this use case, when the vehicle arrives at the entrance of the parking lot, with IMT assistance, it can drive autonomously and drive into the right parking space. It includes functions such as the remote driving into the parking space, auto-driving into the parking space by itself, and obtaining parking space information and parking space status information, applying for parking space and parking navigation etc.

In this use case, when the vehicle arrives at the entrance of the parking lot, with IMT assistance, it can drive autonomously and drive into the right parking space. The use case includes functions such as the remote driving into the parking space, auto-driving into the parking spac, and obtaining parking space information and parking space status information, applying for parking space and parking navigation etc.

In this use case, when the vehicle arrives at the entrance of the parking lot, , it can drive in automated driving mode into the right parking space. It includes functions such as automated driving into the parking space by itself, and obtaining parking space information and parking space status information, applying for parking space and parking navigation etc.

[redacted]

5 Relationship between IMT and C-V2X

[Editor's note: This section addresses technical and operational characteristics for C-V2X by IMT systems, based on information from ITU-R members and external organizations, with making clear the relationship between them.]

The foundation of C-V2X is extensive and reliable V2X communication. The IMT system includes LTE-V2X, 5G NR, NR-V2X, can provide a reliable, flexible communication system for C-V2X services which is being developed towards vehicle-road-side-cloud collaboration.

The IMT standardization related V2X in 3GPP can be divided into 3 phases. In the first phase, i.e. 3GPP Release 14 LTE V2X standardization work was completed in March 2017, which is designed for communication requirements of basic road safety services. Sidelink, based on PC5 interface, is supported and working on frequency band 5.9GHz. The cellular network was also optimized based on Uu interface.

The second phase is in 3GPP Release 15. The standardization work was completed in June 2018. It not only includes the enhancement for LTE-V2X which mainly focused on carrier aggregation, high order modulation to improve transmission data rate and reduce transmission latency, but also includes the first 5G NR specifications with eMBB and some URLLC capabilities.

The third phase is in 3GPP Release 16. The standardization work related with C-V2X was completed in June 2020, supporting advanced C-V2X services based on multiple IMT technologies e.g. NR-V2X, 5G NR. And it is going to be further developed in future releases.

The current C-V2X commercial development is mainly based on LTE V2X and 5G NR.The current LTE V2X technology has completed all the normative work and was deeply investigated. C-V2X has 17 basic applications shown in Table 7-1-1.

6 Characteristics and capabilities of C-V2X supported by IMT

5 Required technical elements and capabilities of C-V2X supported by IMT

[Editor's note: This section summarizes service requirements, technical and operational characteristics and operation spectrum for C-V2X in several groups and organizations outside ITU-R as well as ITU-R Members.]

5.1 Service Requirements

6.1 Service Requirements

[Editor's note: This section addresses service requirements of C-V2X by IMT systems.]

[Editor notes: All of the use cases captured in C-V2X in this report should be added with quantified requirements, including but not limited as message payload size (Bytes), Tx rate (Message/Sec), Data rate (Mbps).]

[Editor notes: When the service messages delivered by different applications are the same, one message can be delivered by a UE in reality.]

5.1.1 V2X Service Requirements

6.1.1 V2X Service Requirements

{Editor's note: Service requirements for V2X Services; TS 22.185}

{Editor's note: The below paragraph is a summary of services requirements of LTE-V2X}

Some examples of V2X service requirements introduced in Rel-15 are captured below (from 22.185), referring to E-UTRAN.

General Requirements

The message transmission shall be under control of the 3GPP network when the transmitting UE is served by the E-UTRAN. A UE supporting V2X application shall be able to be pre-configured by the 3GPP network with parameters to be used for the transmission and reception of messages when not served by E-UTRAN supporting V2X communication.

An RSU shall be able to transmit/receive messages to/from a UE supporting V2X application.

The 3GPP system shall be able to support message transfer between UEs when served or not served by the same PLMN supporting V2X communications.

Latency/ Reliability Requirements

The E-UTRA(N) shall be capable of transferring messages between two UEs supporting V2V/P application, directly or via an RSU, with a maximum latency of 100ms.

For particular usage (i.e., pre-crash sensing) only, the E-UTRA(N) should be capable of transferring messages between two UEs supporting V2V application with a maximum latency of 20ms.

The E-UTRA(N) shall be capable of transferring messages between a UE supporting V2I application and an RSU with a maximum latency of 100ms.

The E-UTRAN shall be capable of transferring messages via 3GPP network entities between a UE and an application server both supporting V2N application with an end-to-end delay no longer than 1000 ms.

The E-UTRA(N) shall be able to support high reliability without requiring application-layer message retransmissions.

Message size, frequency, range and speed

The E-UTRA(N) shall be capable of transferring periodic broadcast messages between two UEs supporting V2X application with variable message payloads of 50-300 bytes, not including security-related message component.

The E-UTRA(N) shall be capable of transferring event-triggered messages between two UEs supporting V2X application with variable message payloads which can be up to 1200 bytes, not including security-related message component.

The E-UTRA(N) shall be able to support a maximum frequency of 10 messages per second per transmitting UE .

The E-UTRAN shall be capable of supporting a communication range sufficient to give the driver(s) ample response time (e.g. 4 seconds).

The 3GPP system shall be capable of transferring messages between UEs supporting V2V application, while the maximum relative velocity of the UEs is 500 km/h, regardless of whether the UE(s) are served or not served by E-UTRAN supporting V2X communication.

The 3GPP system shall be capable of transferring messages between UEs supporting V2V and V2P application, respectively, while the UE's maximum absolute velocity is 250 km/h, regardless of whether the UE(s) are served or not served by E-UTRAN supporting V2X communication.

The 3GPP system shall be capable of transferring messages between a UE and an RSU both supporting V2I application, while the UE's maximum absolute velocity is 250 km/h, regardless of whether the UE or the RSU is served or not served by E-UTRAN supporting V2X communication.

5.1.2 Enhanced V2X Service Requirements

6.1.2 Enhanced V2X Service Requirements

{Editor's note: Service requirements for enhanced V2X Services; TS 22.186}

[redacted]

3GPP Rel-16 introduced enhanced V2X service requirements in the following six areas:

- General/Common: interworking, and communication-related requirements valid for all V2X scenarios
- Vehicles Platooning
- Cooperative Driving / Maneuver Coordination
- Extended Sensors / Collective Perception Service
- Remote Driving
- Vehicle quality of service Support

[With Vehicle Platooning a group of two or more automated cooperative vehicles are in line, maintaining a close distance using wireless communication (V2V), typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional Advanced Driver Assistance Systems (ADAS)-technology based on in-vehicle perception sensors, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.

Platooning requires cooperative automation on different hierarchical levels, encompassing automation of strategic, tactical, as well as operational functionalities, based on reliable short-range vehicle-to-vehicle and vehicle-to-infrastructure communications (V2X), and long-range back-office communications.]

[redacted]

Cooperative Driving facilitates the negotiation between (semi-) automated vehicles in situations such as left turns or highway merges. Cooperative Driving can communicate the vehicle intention and future behavior to other traffic participants. By exchanging maneuver coordination messages, the intentions of the vehicles are shared and can be anticipated by other vehicles, helping to reduce accidents. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

Collective Perception provide information about detected objects (traffic participants, road objects) in the surroundings of a vehicle or road infrastructure. Vehicles capable of transmitting Collective Perception Messages can use their own sensors to detect non-communicating traffic participants and inform neighbouring V2X vehicles about those participants, participants who might be hidden from the sensors of those other vehicles, enabled through the exchange of processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.

Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.

Vehicle quality of service support enables a V2X application to be timely notified of expected or estimated change of quality of service before actual change occurs and to enable the 3GPP System to modify the quality of service in line with V2X application's quality of service needs. Based on the quality of service information, the V2X application can adapt behaviour to 3GPP System's conditions. The benefits of this use case group are offerings of smoother user experience of service.

There are requirements for General, Vehicles Platooning, Advanced Driving, Extended Sensors, Remote Driving, and Vehicle Quality of Service in {*Editor's note: it needs the reference*}.

Requirements apply to both EUTRA and NR, and cover service functionalities and KPIs. Some examples of eV2X general requirements and KPIs are provided below (from 22.186).

General Requirements

The 3GPP system shall be able to support message transfer among a group of UEs supporting V2X application.

The 3GPP system shall support relative lateral position accuracy of 0.1 m between UEs supporting V2X application.

Impact to E-UTRA(N) by UE supporting only NR based V2X communication shall be minimized.

Impact to NR by UE supporting only E-UTRA based V2X communication shall be minimized.

The 3GPP system shall enable discovery and communication between UEs supporting the same V2X application.

The 3GPP system shall be able to support the operators to select which 3GPP RAT to use for a V2X application.

The 3GPP system shall enable a UE supporting a V2X application to obtain network access via another UE supporting V2X application.

The 3GPP system shall support switching between direct 3GPP connection and indirect 3GPP connection via a UE supporting a V2X application, for a UE supporting a V2X application.

Performance requirements / KPIs

For different categories of use cases, communication requirements are characterized by a set of main performance requirements, i.e.

Payload (Bytes)	Tx rate (Message /Sec)	Max end-to-end latency (ms)	Reliability (%)	Data rate (Mbps)	Min required communication range (meters)

Different tables of KPIs are captured in TS 22.186, covering the following specific communication scenarios:

Vehicles Platooning:

Cooperative driving - Information exchange between a group of UEs

Reporting between UEs, and between a UE and RSU.

Information sharing between UE and RSU.

Advanced Driving

Cooperative collision avoidance between UEs supporting V2X applications.

Information sharing for automated driving between UEs supporting V2X application.

Information sharing for automated driving between UE supporting V2X application and RSU

Emergency trajectory alignment between UEs supporting V2X application.

Intersection safety information between an RSU and UEs supporting V2X application.

Cooperative lane change between UEs supporting V2X applications.

Video sharing between a UE supporting V2X application and a V2X application server.

Extended Sensors

Sensor information sharing between UEs supporting V2X application

Video sharing between UEs supporting V2X application

Remote Driving

Information exchange between a UE and a V2X Application Server.

6.1.3 Advanced C-V2X services requirements

[In the development process of China's C-V2X industry, through standardization research, according to the technical maturity, application value and feasibility criteria, a number of automobile companies, C-V2X suppliers, transportation departments and scientific research institutions have carried the standard of advanced C-V2X services. In this standard, considering safety of services， the actual driving environment, etc, the service requirements for each service are as follows:

{Editor's Note: Provide the reference of the table data.}

TABLE XX

Requirements of Advanced C-V2X services

Use case	Requirements
OTA	Velocity: 0～120 km/h Communication range≥300 m Rate：DL≥500 Mbps，UL≥200 Mbps Delay:100 ms
ETC	Velocity: 0～120 km/h Communication range≥300 m Tx rate≥10 Hz Delay≤100 ms Reliability≥99.99% Payload size：300 Bytes Positioning accuracy≤0.5 m

Use case	Requirements
Vehicle Inbound and outbound	Velocity: 0～70 km/h Communication range≥150 m Tx rate≥10 Hz Delay≤100 ms Reliability≥99% Positioning accuracy：lateral≤0. 5m
Intersection traffic	Communication range≥300 m Tx rate：1Hz~10 Hz Delay：RSU/Vehicle to central platform ≤100ms, others≤20 ms Reliability≥99.999% Positioning accuracy：lateral≤1 m
Dynamic Lane Management	Communication range≥500 m Tx rate≤10 Hz Delay≤100 ms Positioning accuracy≤1.5 m
Dynamic optimization of traffic signal timing	Velocity: 0～80 km/h Communication range: RSU/Vehicle to MEC≥150 m, RSU/Vehicle to central platform≥ 400 m Tx rate≥5 Hz Delay≤100 ms Positioning accuracy：lateral≤1.5 m
Flexible management of dedicated highway lanes	Velocity: 0～130 km/h Communication range≥300 m Tx rate≤10 Hz Delay: V2V≤20 ms, others≤100 ms Positioning accuracy≤1.5 m
Fleet management	Velocity: 0～120 km/h Communication range≥300 m Tx rate≥10 Hz Delay: Vehicle to Vehicle/RSU≤20 ms, Vehicle/RSU to central platform≤100 ms Positioning accuracy≤1 m
Platooning	In platoon: Payload size≤100 Bytes Delay≤30 ms Communication range:≥200 m Reliability≥90% Velocity: 30k m/h Positioning accuracy≤1 m Tx rate：10 Hz(low frequency data)/1 Hz(high frequency data) Out of platoon: Payload size≤100 Bytes Delay≤100 ms (low frequency data)/30 ms(high frequency data) Communication range:≥300 m Reliability≥90%

Use case	Requirements
	Velocity: 120 km/h Tx rate：10 Hz/1 Hz
Real-time Navigation	Velocity: 0～250 km/h Communication range≥200 m Tx rate≥10 Hz Delay≤100 ms Reliability：L0~L2 vehicle≥90%, L3~L5 vehicle≥99.9% Delay: L0~L2 vehicle≤100 ms, L3~L5 vehicle≤20 ms Positioning accuracy：L0~L2 vehicle≤1 m, L3~L5 vehicle≤0.1 m
VRU recognization	Velocity: vehicle 0～80 km/h, Vulnerable road user 0~20 km/h Communication range≥200 m Tx rate≥10 Hz Delay≤100 ms Reliability：VRU to others≥99%，Vehicle to 29ehicle/MEC/RSU, MEC to RSU≥99.9% Payload size: VRU to others 100 Byte，Vehicle to 29ehicle/MEC/RSU, MEC to RSU 300 Byte Positioning accuracy≤0.5 m
Autonomous parking	Velocity: 0～25 km/h Tx rate≤10 Hz Communication range: vehicle to RSU≥50 m, MEC/central platform to RSU/vehicle≥1 000 m Delay≤100 ms Positioning accuracy≤0.5 m

]

6.2 IMT capabilities

[Editor's note: This section addresses capabilities to meet the service, technical and operational requirements for C-V2X by IMT systems, based on information from ITU-R members and external organizations.]

6.2.1 Radio Access Network

{Editor's note: This section comes from TR 37.985}

{Editor's Note: This section needs to specify references.}

[The LTE V2X sidelink supports broadcast transmission of messages in the physical layer, since this is a suitable approach for delivery BSM, CAM, DENM and similar traffic. In the MAC layer, a broadcast address can be mapped to a single UE or a group of UEs by implementation. Such implementation techniques have no particular specification support in LTE, and are transparent to the physical layer.

Whereas LTE-V2X supports broadcast transmission in the physical layer and any finer-grained addressing is handled according to MAC layer ID implementation, NR V2X has physical layer support for broadcast, unicast, and groupcast sidelink operation. The addition of unicast and groupcast is linked with the introduction of sidelink HARQ feedback {Editor's note: TR 37.985 (clause 6.2.4), high order modulation, sidelink CSI, and PC5-RRC {Editor's note: TR 37.985} (clause 6.5.7), amongst other points.

The resource allocation, congestion control, and higher-layer protocols are described in {Editor's note: TR 37.985}]

[C-V2X (LTE V2X and NR V2X) supports the following four different types of V2X services: V2V, V2I, V2N and V2P. V2X services can be provided by PC5 interface and/or Uu interface. Support of V2X services via PC5 interface is provided by V2X sidelink communication, which is a mode of communication whereby UEs can communicate with each other directly over the PC5 interface. This communication mode is supported when the UE is served by a cellular system and when the UE is outside of the cellular system coverage. This enables reliable V2X services, e.g., coordinated driving, when inside or outside of network coverage. Only the UEs authorised to be used for V2X services can perform V2X sidelink communication.

A UE is considered in-coverage on the carrier used for C-V2X sidelink communication whenever it detects a cell on that carrier. When the UE is out of coverage on the frequency used for V2X sidelink communication, the UE use a set of transmission and reception resource pools pre-configured in the UE. When the UE is in-coverage, it may obtain the radio resources configuration from the network via broadcasted system information or dedicated signaling. Reception of V2X sidelink communication in different carriers/PLMNs can be supported by having multiple receiver chains in the UE.

C-V2X supports different types of Direct Communication: broadcast, groupcast, and unicast. In broadcast mode, it allows some finer grain control using MAC layer Layer-2 IDs. For groupcast, distanced based groupcast control, C-V2X sidelink communication enables formation of "on-the-fly" multicast groups based on distance and applications. Such multicast groups require little or no overhead for group formation and dismantling. A NR C-V2X UE can establish multiple simultaneous unicast sidelink connections with other UEs, based on application needs. These links are allowed to have different configurations, including the QoS levels, data rates, security protections, etc. Each of the link is independently managed and maintained. The unicast sidelink can be established between NR C-V2X UEs on-demand, by transmitting either broadcast or unicast a connection request to a known UE or UEs supporting a desired V2X service. This unicast link establishment procedure had already incorporated security verifications. The 3GPP design provides a generic authentication mechanism and supports various application layer security associations, e.g. certificate-based security association that is widely used in V2X ecosystem. The unicast sidelink can provide confidentiality and integrity protection for the signaling and user data, based on security requirements of the application and policies. Additionally, the NR C-V2X design also provides privacy protection for the unicast sidelink, by allowing a change of the link identifiers during the communication session, without interrupting the service. This helps the UE to meet the regulatory requirements on anti-trackability in some regions.

C-V2X supports QoS guarantee for the V2X services. For LTE V2X, it is achieved utilizing the ProSe Per Packet Priority (PPPP) and ProSe Per Packet Reliability (PPPR) of a protocol data unit provided by upper layers. The packet delay budget (PDB) of the protocol data unit can be determined from the PPPP. The low PDB is mapped to the high priority PPPP value. The Access Stratum (AS) is also provided with a transmit profile (Tx Profile) of a protocol data unit transmitted over PC5 interface by upper layers. The logical channel prioritization based on PPPP is used for V2X sidelink communication. For NR V2X, a unified QoS model based on QoS Flow managements is used for for all cast types, i.e. broadcast, groupcast, and unicast. Each of the QoS Flows is configured with a PC5 5QI (5G QoS Identifier) that represents the QoS characteristics, e.g.

delay budget, priority, reliability, etc., and additional QoS flow parameters. For example, for groupcast, the QoS flow parameters further include the maximum Range value, which can be passed to lower to perform the distance based groupcast control. For unicast, the QoS flow parameters include the link data rate, which helps lower to choose the coding and modulation mechanism.

Versatile operation parameter sets can be configured based on application needs and regulation requirements. For example, C-V2X can support channelization of 10/20/40 MHz, with subcarrier spacing of 15, 30, 60 and 120 kHz associated with CPs and frequency ranges similar to NR UL/DL, and with modulation schemes as QPSK, 16-QAM, 64-QAM, and 256-QAM. Carrier aggregation (CA) in sidelink is supported for V2X sidelink communication. For the case where multiple frequencies for V2X are supported, a mapping between V2X service types and V2X frequencies is configured by upper layers. The UE should ensure a V2X service to be transmitted on the corresponding frequency.

C-V2X enables UEs to obtain timing synchronization from a variety of sources, including GNSS, eNB/gNB and other UEs, enabling synchronization in-coverage and out-of-coverage. A UE may serve as a synchronization source by transmitting sidelink synchronization signal block (S-SSB), and may provide synchronization information to another UEs even if it does not participate in the subsequent inter-UE communication. The V2X synchronization procedure defines priorities among such synchronization sources and requires all UEs to continuously search to get to the highest-quality synchronization source they can find.

The C-V2X UEs support two modes for resource allocation: Scheduled resource allocation mode, and UE autonomous resource selection mode. The Scheduled resource allocation mode can be used when the UE is in-coverage and in CONNECTED mode. The UE autonomous resource selection mode can be used when the UE is in-coverage or out of network coverage. In UE autonomous resource selection mode, the UE selects resources from resource pools on its own and performs transport format selection to transmit sidelink control information and data. The UE performs sensing for (re)selection of sidelink resources. Based on sensing results, the UE (re)selects some specific sidelink resources and reserves multiple sidelink resources. Sidelink SPS can be supported. Simultaneous C-V2X sidelink Communication and Uu communication can be supported in both resource allocation modes.

C-V2X also supports power efficient operation mode for pedestrian UE (P-UE). Based on the configuration profile, the P-UE can be pre-configured or configured by the network to use a resources pool that does not require sensing or only partial sensing. In the Scheduled resources allocation mode, the P-UE may not be required to perform optional operations, e.g. CBR (channel busy ratio) measurements.

To support the co-existence of CEN DSRC and V2X sidelink communication, the upper layers of the UE which is performing V2X sidelink communication send an indication to lower layers when the UE is within the proximity of CEN DSRC tolling station(s).]

5.2.2 Architecture Enhancements

6.2.2 Architecture Enhancements

{Editor's note: This section comes from TS 23.285 and TS 23.287}

{Editor's Note: This section needs to specify references.}

[There are two modes of operation for V2X communication, namely V2X communication over PC5 reference point (direct communication mode) handling narrow area communication between vehicle and vehicle/road side unit (RSU)/pedestrian and V2X communication over Uu reference point.

(network communication mode) handling large area communication between vehicle and IMT base station (BS). These two operation modes may be used by a UE independently for transmission and reception.

V2X communications over PC5 reference point are supported by LTE and/or NR.

V2X communications over Uu reference point are supported by E-UTRA connected to 5GC and/or NR connected to 5GC. In EPS, V2X communication over Uu reference point can be either unicast or broadcast. In 5GS,, V2X communication over Uu reference point is only unicast.

The Architecture reference models for LTE-V2X are

1) PC5 and LTE-Uu based V2X architecture reference model

a. Non-roaming architecture for PC5 and LTE-Uu based V2X communication

b. Roaming architecture for PC5 and LTE-Uu based V2X communication

c. Inter-PLMN architecture for PC5 and LTE-Uu based V2X communication

2) MBMS for LTE-Uu based V2X architecture reference model

And further, for the 5G-V2X, the architecture reference models are

1) PC5 and Uu based V2X architecture reference model

a. Non-roaming 5G System architecture for V2X communication over PC5 and Uu reference points

b. Roaming 5G System architecture for V2X communication over PC5 and Uu reference points

c. Inter-PLMN 5G System architecture for V2X communication over PC5 reference point

2) AF-based service parameter provisioning for V2X communications

3) Interworking with EPS V2X

The functional entities, functionality and features are described in {Editor’s note: TS 23.285 and TS 23.287}]

[The 5G system is also enhanced to provide some of the NR C-V2X operation configurations to the radio network (NG-RAN), to assist the UE operation. The NG-RAN may then provide the information, e.g. in the System Information Block (SIB), or using dedicated RRC signaling if UE goes into CONNECTED mode. This helps the UE to obtain the most up-to-date operation configuration, e.g. on how to map QoS Flow to sidelink radio bearers, in case the spectrum is managed by the operators. For ITS spectrum, the UE can operate purely based on configuration.

At network side, the 5G system design is also enhanced, in order to assist the NR C-V2X operation, in case the NR C-V2X UE is in coverage. For example, 5G system has enhanced its UE Policy provisioning feature, so that the Policy Control Function (PCF) is able to update the UE authorized for NR C-V2X operation of the V2X related policies and configurations (V2XP) via the control plane signaling, when the UE comes into coverage. It also allows the NR C-V2X UE to autonomously request a policy update from the PCF when necessary. This feature also allows an V2X Application Server to provision the V2X Service operation parameters, e.g. QoS mapping, or security requirements, via the PCF to the UE reliably.

The 5G Core Network (5GC) has also introduced some enhancements, to facilitate better V2N services when Uu connection is used. These includes the notification on QoS Sustainability Analytics, and the Alternative QoS Profiles. The notification on QoS Sustainability Analytics allows the 5GC to provide an estimation of the QoS level support along the path indicated by a V2X

Application Server. The V2X Application Sever could adjust its QoS requirements if 5GC informs it ahead of time that some QoS level cannot be met. On the other hand, the Alternative QoS Profile allows the V2X Application Server to request multiple QoS levels to the 5GC. In case there is a congestion in the network, the NG-RAN will automatically adjust the QoS level to one of the provided Alternative QoS Profiles. This ensures that the mission critical V2X application can continue at the minimum operational level, instead of being cut off.]

5.2.3 Application Layer Support

6.2.3 Application Layer Support

{Editor's Note: This section needs to specify references.}

[Figure x illustrates the simplified 3GPP architectural model for the V2X application layer {Editor's note: TS 23.286}. The V2X UE1 communicates with V2X application server over V1 reference point. The V2X UE1 and V2X UE2 communicate over V5 reference point. V2X UE1 can also act as a UE-to-network relay, to enable V2X UE2 to access the V2X application server over V1 reference point.

FIGURE X

Simplified architectural model for the V2X application layer

The V2X application layer functional entities for the V2X UE and the V2X application server are grouped into the V2X application specific layer and the V2X application enabler (VAE) layer. The VAE layer offers the VAE capabilities and support functions to the V2X application specific layer.

The interactions related to V2X application layer support functions between VAE client and VAE server, or between two VAE clients, are supported by V1-AE reference point, or V5-AE reference point, which is an instance of the reference points shown above.

In order to ensure efficient use and deployment interoperability of V2X applications on 3GPP networks, 3GPP has defined a set of VAE layer procedures and information flows.

The VAE client provides the client side V2X application layer support functions, e.g.:

registration of VAE clients for receiving V2X messages;

receiving V2X messages from the VAE server and the delivery to V2X application specific client(s) according to the V2X service ID;

receiving network monitoring reports from the VAE server;

supports switching the modes of operations for V2V communications (e.g. between direct and in-direct V2V communications);

providing application level locations to the VAE server (e.g. tile, geo-fence);

receiving 3GPP system configuration information (e.g. V2X USD, PC5 parameters) from the VAE server; and

supporting dynamic group management.

The VAE client supports interactions with the V2X application specific client(s).

The VAE server provides the server side V2X application layer support functions, e.g.:

communicating with the underlying 3GPP network systems (EPS, 5GS) for unicast and multicast network resource management;

receiving monitoring reports/events from the underlying 3GPP network systems (EPS, 5GS) regarding network situation corresponding to RAN and core network;

supporting registration of V2X UEs;

tracking the application level geographic location of the V2X UEs;

supporting V2X message distribution for the V2X applications;

supporting provisioning of 3GPP system configuration information (e.g. V2X USD, PC5 parameters);

providing network monitoring reports to the V2X UEs;

communicating V2X service requirements to the underlying 3GPP network systems (EPS, 5GS);

maintaining the mapping between the V2X user ID and the V2X UE ID;

providing V2X service discovery;

supporting V2X service continuity; and

supporting V2X application resource adaptation.]

[In order to ensure efficient use and deployment of V2X applications on 3GPP networks an architecture for V2X application layer consisting of V2X application enabler should be specified {Editor's note: TS 23.286}.

The V2X application enabler capabilities takes into consideration for

1) Specifies the functional architecture, procedures and information flows for V2X application enabler layer

2) Capabilities of the application layer support for V2X services that are necessary to ensure efficient use and deployment of V2X services over 3GPP systems

3) The VAE capabilities applies to EPS.]

6.3 Operational Spectrum

[Editor's note: This section summarizes information on operational spectrum for C-V2X, based on input contributions.]

6.3.1 Uu interface

C-V2X allows the use of any Uu connection for the V2X services. Therefore, all the bands defined in 3GPP TS 36.101 and TS 38.101 for E-UTRA and NR are valid operational spectrum.

6.3.2 PC5 interface

{Editor's Note: This section needs description of the spectrum.}

{Editor's Note: The tables below need explanation and need to be modified.}

TABLE KKK

LTE V2X operating band

E-UTRA Operating Band	E-UTRA V2X Operating Band	V2X UE transmit		V2X UE receive		Duplex Mode	Interface
		FUL_low – FUL_high		FDL_low – FDL_high			
47	47	5 855 MHz	5 925 MHz	5 855 MHz	5 925 MHz	HD	PC5

NR V2X communication is designed to operate in the operating bands in FR1 defined in Table ZZZ.

TABLE ZZZ

NR V2X operating bands in FR1

V2X Operating Band	Sidelink (SL) Transmission operating band			Sidelink (SL) Reception operating band			Duplex Mode	Interface
	FUL_low – FUL_high			FDL_low – FDL_high				
n381	2 570 MHz	-	2 620 MHz	2 570 MHz	-	2 620 MHz	HD	PC5
n47	5 855 MHz	-	5 925 MHz	5 855 MHz	-	5 925 MHz	HD	PC5
Note 1: When this band is used for V2X SL service, the band is exclusively used for NR V2X in particular regions.								

For E-UTRA based V2X (LTE V2X): Band 47 (5 855 MHz - 5 925 MHz) is defined for PC5 operation, with 10 or 20 Mhz channel bandwidth. The detailed band definition is in 3GPP TS 36.101 clause 5.5G and 5.6G.

For NR based V2X (NR V2X): Band 38 (2 570 MHz – 2 620 MHz) and Band 47 (5 855 MHz – 5 925 MHz) are defined for PC5 operation, with 10, 20, 30, or 40 MHz channel bandwidth. The detailed band definition is in 3GPP TS 38.101 clause 5.2E and 5.3E.

7 Case Study

7.1 Case Studies from [Various Other] Countries in Annex 1

8 Summary

[Editor’s note: To be described.]

ANNEX XXX-1

7 Case Study

7.1 Country China

7.1.1 Typical C-V2X Service Scenarios

In the development of China's C-V2X industry, through standard research, according to the technical maturity, application value and feasibility criteria, a number of automotive companies, C-V2X suppliers, transportation departments, scientific research institutions in the industry, 17 C-V2X basic service scenarios has been defined, as shown in Table 7-1-1, as well as five basic interaction messages, as BSM, RSM, MAP, SPAT and RSI, supporting these service scenarios, and a trusted template has been provided for the current application of C-V2X technology.

During the underlying service scenario phase, most applications are implemented based on real-time state sharing between vehicles, road facilities, and other participants. On the basis of realizing state sharing by using C-V2X information interaction, decision-making or assistance is made independently.

TABLE 7-1-1

C-V2X basic service scenario

No.	**Applications**
1	Forward collision warning
2	Collision warning for intersections
3	Turn left aid
4	Blind spot alert/change aid
5	Reverse overtaking warning
6	Emergency braking warning
7	Unusual vehicle alerts
8	Vehicle out-of-control warning
9	Warnings of road hazards
10	Speed limit warning
11	Traffic lights violation warning
12	Collision warning for vulnerable traffic participants
13	Green wave speed guide
14	Signs in the car
15	Alert of congestion ahead
16	Emergency vehicle alert
17	Car near-field payment

Beyond the basic C-V2X service, advanced C-V2X services as showed in Table 7-1-2 also have been identified and specified by automotive, ITS, communication industries. These advanced C-V2X services are supported by IMT system not only LTE-V2X, but also 5G system. MEC is also another technical enabler.

Table 7-1-2

Advanced C-V2X services in China

No.	Applications
1	Over the Air
2	High definition map collecting & sharing
3	ETC(Electronic Toll Collection)
4	Vehicle inbound and outbound
5	Intersection traffic
6	Dynamic Lane Management
7	Dynamic optimization of traffic signal timing
8	Flexible management for dedicated highway lanes
9	Fleet management
10	Platooning
11	Real-time Navigation
12	VRU recognization
13	See-through for passing
14	Obstructed view assist
15	High definition sensor sharing
16	Infrastructure assisted environment perception
17	Tele-operated driving
18	Autonomous parking

7.1.2 C-V2X Spectrum

In terms of frequency resource allocation, in order to promote the maturity and industrialization of LTE-V2X technology, in December 2016, the Chinese government allocated 5 905-5 925 MHz as the research and experimental working band of LTE-V2X. In June 2018, the Ministry of Industry and Information Technology of China publicly sought comment on "Regulations of the use of the 5 905-5 925 MHz band for direct-connected communications (Intelligent Networked Vehicles) (draft for comments)". In November 2018, the Radio Administration of the Ministry of Industry and Information Technology of China officially released the on "Regulations of the use of the 5 905-5 925 MHz band for direct-connected communications (Intelligent Networked Vehicles) (temporary)" and planned the 5 905-5 925 MHz band as the working band for direct-connected communications based on LTE-V2X technology, marking the official entry of LTE-V2X into industrialization in China.

7.1.3 C-V2X Standards

In November 2018, in China, the National Technical Committee for Automotive Standardization, the National Technical Committee for Standardization of Intelligent Transportation Systems, the National Technical Committee for Communication Standardization and the National Technical Committee for Standardization of Road Traffic Management jointly signed the framework agreement to strengthen cooperation on C-V2X standards for automotive, intelligent transportation, communications and traffic management, and promote C-V2X standard-setting and industrial landing.

In terms of information and communication standards system of China, access layer, network layer, message layer and security and other core technical standards of LTE-V2X have been developed, at the same time, equipment specifications, test methods and other standards have been developed too, the technical standard system is basically formed, as shown in Figure 7-1-1. There is summary of the standard content and progress of the LTE-V2X series in China in Table 7-1-2.

FIGURE 7-1-1

China LTE-V2X standard system

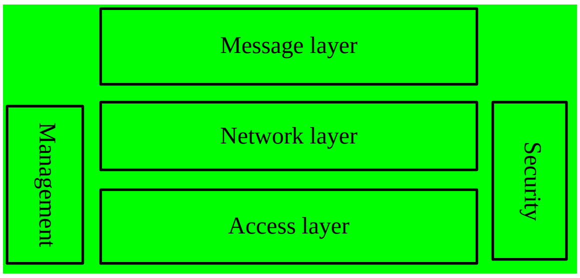


TABLE 7-1-2

China LTE-V2X standard content and progress

Category	**Name**	**Level**	**Organization**	**State**
General technical requirements	General technical requirements of LTE-based Vehicular Communication	Industry Standard	CCSA	Published
Access layer	Technical requirements of air interface of LTE-based vehicular communication	Industry Standard	CCSA	Published
	Technical requirements and test Method of equipment for LTE-based vehicular communication	Industry Standard	CCSA	Draft
	Technical requirements and test Method of network layer for LTE-based vehicular communication	Industry Standard	CCSA	Published
	Technical requirements and test Method of message layer for LTE-based vehicular communication	Industry Standard	CCSA	Published
Security	General technical requirements of Security for Vehicular Communication based on LTE	Industry Standard	CCSA	Published
	Technical requirements of security certificate management system for LTE-based vehicular communication	Industry Standard	CCSA	Draft
Profile	Technical Requirements of Vehicular Communication System based on LTE-V2X Direct Communication	National Standard	NTCAS	Draft
	Direct Communication System Roadside Unit Technical Requirements of LTE-based Vehicular Communication	Industry Standard	C-SAE & C-ITS	Draft
Application identity	Application Identity Allocation and Mapping for LTE-based Vehicular Communication	Industry Standard	CCSA	Draft

7.1.4 Industrial activities

In terms of industry, China's LTE-V2X industry is at the forefront of the world, and the three large-scale ICV interconnection testing activities in 2018, 2019 and 2020 show that China has the foundation to commercialize LTE-V2X-related technologies.

In November 2018, the V2X "Three Cross" Connectivity Application Demonstration Event was held by China Intelligent Network Alliance Automotive Innovation Alliance, IMT-2020 (5G) Propulsion Group C-V2X Working Group and Shanghai International Automobile City (Group) Co., Ltd., realizing the world's first cross-communication module, cross-terminal and cross-vehicle connectivity.

In October 2019, C-V2X "four cross" interconnection application demonstration event was held in Shanghai, it was the first time to achieve the "cross-chip module, cross-terminal, cross-vehicle, cross-security platform" C-V2X application display, which focused on the addition of a communication security scenario. As information security is a vital part of vehicle network communication, "four cross" activities verified the interoperability between a number of security chip enterprises, security solution providers, CA certificate management service providers, based on China's completed LTE-V2X security standards.

On October 27-29, 2020, the 2020 ICV C-V2X "New Four Cross" and large-scale pilot application demonstration activity was held in Shanghai, which deployed a more realistic and commercial-oriented continuous scenario, adopted a new digital certificate format, and increased high-precision maps and high-precision positioning. The activity focused on verifying the large-scale operation capability of the C-V2X, fully verifying the communication performance of C-V2X technology in the real environment, and at the same time, it explored the safety mechanism and the use of geographical coordinates in the vehicle networking application, and carried out comprehensive testing by many manufacturers, which provided an important technical basis for the subsequent scale commercialization.

7.1.5 Demonstration zone and pilot zone construction

In order to promote the C-V2X industry to land as soon as possible, China's Ministry of Industry and Information Technology, Ministry of Transport, Ministry of Public Security and other departments actively cooperate with local governments to promote the construction of China's demonstration zones. By the end of 2019, the number of national ICV test demonstration zone supported by the Ministry of Industry and Information Technology has reached 10, the number of self-driving test site licensed by the Ministry of Transport is three. There are also 3 ICV self-driving closed site test base jointly licensed by the Ministry of Industry and Information Technology and the Ministry of Transport. In addition, there are a number of urban and enterprise-level test demonstration points, ICV demonstration area has covered all the first-line and second-tier cities in the central and eastern regions after four years of development, the radiation effect has been formed.

In May 2019, Jiangsu (Wuxi) became the first pilot zone approved by the Ministry of Industry and Information Technology to further scale the deployment of C-V2X networks and equipment. In June 2020, at the 4th World Intelligent Congress held in Tianjin, Tianjin (Xiqing) National ICV Pilot Zone was unveiled. In October 2020, the Ministry of Industry and Information Technology approved Hunan (Changsha) to create another ICV pilot zone. At present, there are a number of demonstration zones in the active application for upgrading to pilot zones, which will further drive the C-V2X industry development.

Based on the pilot zones, not only the basic C-V2X services but also some advanced C-V2X services also have been tested. For example, in Xiongan pilot zone, with the integrated system including LTE-V2X, 5G NR, MEC, high precision positioning technology etc. advanced C-V2X services e.g. remote driving, Intersection traffic, autonomous parking, OTA, etc. are being tested. Further, in limited driving condition, e.g.TianJin harbor, based on IMT-2020 system, the intelligent quay crane and unmanned truck can be remote controlled to improve the working safety and efficiency.

7.1 Country AAA

7.2 Country BBB

ANNEX XXX-2

Applications (Use cases) indicated in Report ITU-R M.2445 "ITS usage"

These applications are extracted and copied hereunder from the Report ITU-R M.2445 which was developed by WP 5A. The reason why contents of this Annex were picked up from Report ITU-R M.2445 is that it is easy to understand that applications are classified in accordance with their purposes.

(Section 1 to 7.5 were omitted.)

7.6 Applications

7.6.1 V2V, V2P Safety-Related Applications

– Blind Spot Warning + Lane Change Warning
– Control Loss Warning
– Do Not Pass Warning
– Emergency Electronic Brake Light
– Emergency Vehicle Alert
– Forward Collision Warning
– Intersection Movement Assist
– Motorcycle Approaching Indication
– Situational Awareness
– Wrong way driving warning
– V2V Emergency Stop
– Vulnerable Road User (VRU) Safety
– Queue Warning

7.6.2 V2I Safety-Related Applications

– Curve Speed Warning
– Emergency Communications and Evacuation Information
– Emergency Vehicle Preemption
– End of Ramp Deceleration Warning
– Enhanced Maintenance Decision Support System
– Incident Scene Work Zone Alerts for Drivers and Workers
– In-Vehicle Signage
– Oversize Vehicle Warning
– Pedestrian in Signalized Crosswalk Warning
– Railroad Crossing Violation Warning
– Red Light Violation Warning
– Reduced Speed Zone Warning / Lane Closure

– Restricted Lane Warnings
– Roadside Lighting
– Stop Sign Gap Assist
– Stop Sign Violation Warning
– Transit Vehicle at Station/Stop Warnings
– Vehicle Turning Right in Front of a Transit Vehicle
– V2I Emergency Stop

7.6.3 Transportation System Efficiency and Operations Applications

– Cooperative Adaptive Cruise Control
– Intelligent Traffic Signal System
– Intermittent Bus Lanes
– Pedestrian Mobility
– Performance Monitoring and Planning
– Speed Harmonization
– Traffic Flow Optimisation
– Transit Signal Priority
– Variable Speed Limits for Weather-Responsive Traffic Management
– Vehicle Data for Traffic Operations

7.6.4 Environment Applications

– Eco-Approach and Departure at Signalized Intersections
– Eco-Speed Harmonization
– Low Emissions Zone Management
– Spot Weather Impact Warning ,

7.6.5 Core Services

– Core Authorization
– Location and Time
– Security and Credentials Management

7.6.6 Non-Priority Communications , such as E-Commerce and Infotainment

– Wireless Advertising
– Vehicle to Infrastructure Internet Connection
– Drive-Thru Payments
– Vehicle to Vehicle Messaging

7.6.7 Other Applications

– Border Management Systems

- Electric Charging Stations Management
- Road Weather Information for Maintenance and Fleet Management Systems
- Smart Roadside Initiative
- Automated Parking System

(Section 7.7 to section 8 were also omitted.)