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ITU-APT Foundation of India (IAFI)[1]

FURTHER UPDATES TO THE WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEWREPORT ON “CELLULAR BASED V2X FOR ITS APPLICATIONS IN APT COUNTRIES”

Background

At the 27th meetingwork on Cellular based V2X technologies, spectrum, and others in APT member countries was further progressed.

Discussions

There is continued development of 3GPP Release 17 to support new features and capabilities for V2X. This contribution provides an updated draft to capture the 3GPP Release 17 related text along with other improvements in the draft reporthighlighted in yellow.

Proposal

This contribution proposes further updates to the working document contained in AWG/TMP-22 in the attachment.

[1] ITU-APT Foundation of India (IAFI) is a new Affiliate member of APT. Details of IAFI can be seen at itu-apt.org

Contact: IAFA Email: info@itu-apt.org

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ITU-R M.2084	Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communication for intelligent transport systems applications
ITU-R M.2121	Harmonization of frequencyarrangement for Intelligent Transport System in the mobile service

ITU-R Report:

ITU-R M.2228	Advanced intelligent transport systems (ITS) radio communication
ITU-R M.2445	Intelligent transport systems (ITS) usage in ITU Member States
ITU-R .M.2444	Examples of Arrangements for Intelligent System deployment in the mobile service

ITU-R Handbook:

Land Mobile (including Wireless Access) - Volume 4: Intelligent Transport Systems

APT Report:

APT/AWG/REP-18(REV.1) The usage of ITS in APT countries

4 List of acronyms and abbreviations

5 Overview of Cellular Based V2X

V2X (Vehicle to Everything) is a new generation of information and communication technology (ICT) that connects vehicles to everything, for which V stands for vehicle and X stands for everything that interacts with the vehicle, currently including vehicles, people, roadside infrastructure, and network. The modes of V2X interactions include V2V (Vehicle to Vehicle), V2I (Vehicle to Infrastructure), V2P (Vehicle to Pedestrian), and V2N (Vehicle to Network), as shown in Figure 1

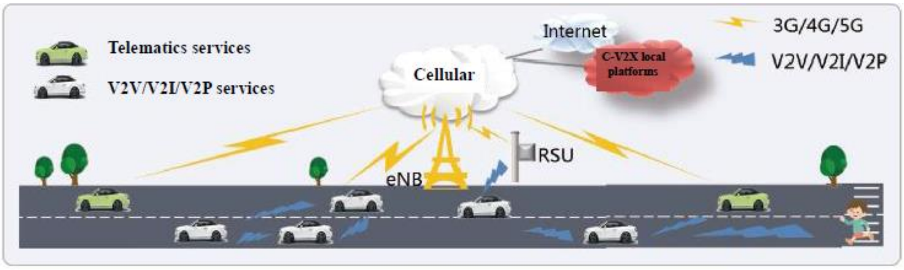

Figure 1 V2X technology

V2V refers to the communication between vehicles through an on-board device. The on-board device can obtain real-time information on nearby vehicles, such as speed, location and status of operations. Vehicles can also form an interactive platform to exchange texts, pictures, and videos in real time. V2V is mainly used to avoid or reduce traffic accidents and to perform vehicle monitoring management. V2I enables the communication between on-board devices and roadside infrastructures (such as traffic lights, traffic cameras, and road side units), in which roadside infrastructure can also obtain information on vehicles in nearby areas and publish real-time information. It is mainly applied to real-time information services, vehicle monitoring management and electronic toll collection (ETC). V2P allows on-board devices to communicate with vulnerable road users (such as pedestrians and cyclists) through user devices (such as mobile phones and laptops). It is mainly used to avoid or reduce traffic accidents, information services, etc. V2N means that the on-board devices are connected to the cloud platform through the access network / core network for data interaction, storage and processing, so as to provide various application services required by the vehicle. These services include vehicle navigation, remote vehicle monitoring, emergency rescue and information and entertainment services.

Therefore, by organizing factors involved in traffic, such as "people, vehicles, roadside infrastructure and cloud platform", V2X allows the vehicle not only to obtain more information than the unlinked vehicles, which stimulates the innovation and application of autonomous driving technology, but also to develop intelligent transportation systems (ITS) which fosters new modes and formats of automotive and transportation services. This is significant for improving traffic efficiency and management, conserving resources, reducing pollution and reducing accident incidence.

'C' in C-V2X stands for Cellular, a wireless car communication technology derived from 3G / 4G / 5G technologies. Based on the unified global standard of the Third Generation Partnership Project (3GPP), C-V2X includes LTE-V2X (Long-Term Evolution Vehicle to Everything) and 5G NR-V2X (Fifth Generation Vehicle to Everything) with technologically achievable evolution from LTE-V2X to 5G NR-V2X. The first release of C-V2X was developed in September 2016 (Release 14). Some minor enhancements were made in Release 15. These two releases are called LTE based V2X. The first release of 5G NR-V2X was developed in July 2020 (Release 16).

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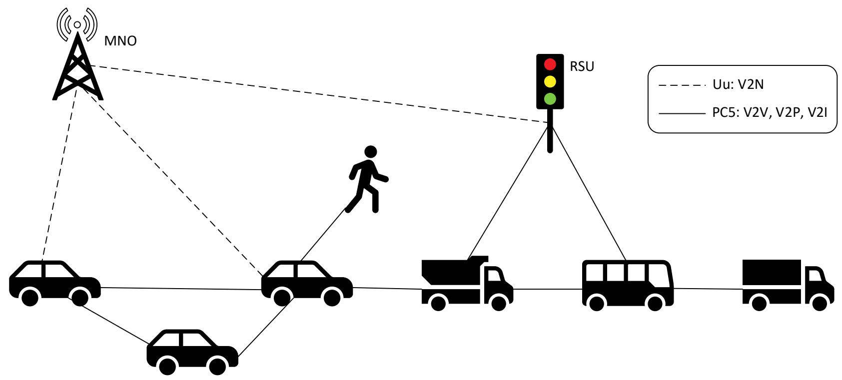

Figure A: 3GPP V2X technology (using Uu and PC5 interfaces)

5.1 LTE based V2X

There are two interfaces for LTE based V2X: the direct interface (PC5) for short-range communication among vehicles, people and roadside infrastructure and the Uu interface for reliable long-range communication between the terminal and the base station.

5.1.1 Technology of PC5 interface

The PC5 interface mechanism design, based on LTE-D2D technology defined in Release 13 to support proximity based services via direct communication, has been enhanced in many aspects, in order to support the broadcast of V2X messages (especially V2V messages), the exchanges of fast-changing dynamics (such as location, speed, and driving direction), and more superior autonomous driving applications in the future, including vehicle platooning and sensor sharing.

The physical layer is augmented to support the relative moving speed of up to 500 km/h in the high frequency band and solve the problem of high Doppler frequency spread and fast time-varying channels.

Editor Notes: To include reference to the “longer” and “higher capacity”

[It also supports longer range and higher capacity with congestion control mechanism …. than xxx.]

To ensure communication performance, C-V2X receivers and transmitters need to be synchronized with each other during communication. C-V2X enables the synchronization from different sources including GNSS, base stations, and vehicles. The terminal can obtain optimal synchronization sources through network control or retrieval of pre-configured information to achieve the possible network-wide synchronization. Moreover, C-V2X supports the dynamic maintenance of optimal synchronization sources, which allows the terminal to select the most prioritized source in a timely manner for clock synchronization.

As the core key technology of C-V2X, the PC5 interface supports the modes of scheduled resource allocation controlled by cellular network (Mode-3) and autonomous resource allocation (Mode-4). In addition, C-V2X adopts a centralized/distributed combined congestion control mechanism, which can markedly increase the number of users accessing the system in high-density scenarios.

5.1.2 Technology of Uuinterface

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Uu interface operates in traditional mobile broadband licensed spectrum. The service coverage and communication quality basically relay on mobile network operator’s implementation. Although enhancements supported in Uu interface are not dedicated to V2N services, some features such as multiple SPS, DL multicast enhancements, etc., are applicable to V2N. Those will provide better match the characteristics of V2X services.

The uplink transmission supports multi-way semi-static scheduling based on service characteristics, which significantly reduces the uplink scheduling delay under the premise of high service transmission reliability. The downlink transmission has the features of small-range broadcast, low-latency single-cell point-to-multipoint (SC-PTM) transmission, and multicast / broadcast single-frequency network (MBSFN) for local communication of V2X services. In addition, LTE-V2X supports the localized deployment of core network elements and defines the quality of service (QoS) parameters for V2X services to ensure service transmission performance.

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5.2 5G NR based V2X

3GPP Release 15 added transmit diversity (cyclic delay diversity) and improved performance, as advancements to the direct communication mode introduced in Release 14. These Release 15 additions are fully compatible with Release 14. C-V2X supported in Release 15is also defined as LTE-V2X. To support more advanced V2X services, LTE based V2X will evolve towards 5G NR based V2X (NR-V2X). As advanced V2X applications will bring stricter technical requirements on data rate, reliability and latency, 3GPP completed related work in Release 16 on PC5 interfaceenhancementsin July 2020.Release 16 NR-V2X sidelink offers major enhancements in terms of new short-range features enabling advanced applications to complement the basic safety use cases. [In the future Release 17, NR sidelink will be further enhanced on application scenarios and performance.] [Note: This sentence should be reconsidered considering Release 17 progress at the time of report publication.]

NR-V2X sidelink brings several enhancements in the form of higher throughput, lower latency, and enhanced reliability.These enhancements expand the applications of direct communication to public safety, emergency service and other direct communication related scenarios. To achieve this, the spectrum efficiency, reliability, latency and power consumption for sidelink will all be optimized.. These enhancements would be achieved by leveraging functionalities of 5G NR such as

1) Flexible OFDM-based air interface with wideband carrier support and scalable sub-carrier spacing. This efficiently addresses diverse spectrum, deployments and services.
2) a flexible slot-based framework and making demodulation reference signals (DMRS) a function of the speed. This makes it a key enabler to low-latency, and forward compatibility.
3) advanced channel coding efficiently supports large data blocks and a reliable control channel.
4) NR-V2X sidelink has optional support for time synchronization allowing robust C-V2X operation even without GPS coverage.

NR-V2X sidelink broadcast, groupcast, and unicast transmissions are supported for the in-coverage, out-of-coverage and partial-coverage scenarios in order to support different services, while LTE V2X only supports broadcast transmissionpractically.Since unicast and groupcast are supported, stability of the transmission is of great importance and HARQ mechanism is useful in enforcing the reliability of both unicast and groupcast communication. NR-V2X sidelink also introduces distance as a dimension at the physical layer. This helps in getting a uniform communication range across widely varying radio environments — for both line-of-sight and non-line-of-sight scenarios. Introducing distance as a dimension also 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.

3GPP Release 17 is working on extending the NR sidelink to realize UE power saving and support more reliable and lower latency communication. It is noted that such sidelink enhancements can be utilized for other application or use cases than V2X.

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- **UE Power saving**

  Rel-16 NR sidelink was designed based on the assumption of "always-on" when UE operates sidelink. To reduce the power consumption in the sidelink communication for such as vulnerable road users (VRUs) in V2X use cases, the enhanced resource allocation and sidelink DRX are being considered.

- **Enhanced reliability and reduced latency**

  Rel-16 NR improves reliability by introducing HARQ feedback. Rel-17 NR sidelink will further improve reliability by improving inter UE coordination. More particularly Rel-17 NR sidelink will try to address hidden node issues that is particularly relevant to urban scenarios.

5.2 3GPP Use Cases and Scenarios

In the 3GPP TR 22.885 and TR 22. 886 have recommended use cases of C-V2X. they describe C-V2X use cases, pre-conditions, service flows, post-conditions, and potential Requirements. In table xx, the use case and the description are listed for TR 22.885

Table XX: Use cases in TR 22.885

Use cases	Description
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.
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 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 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.
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.
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.
Queue Warning	In a lot of situations, a queue of vehicleson 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.
Road safety services	V2X messages are delivered from one UE supporting V2I Service to other UEs supporting V2I Service via anRSU 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.
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.
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.
V2X message transfer under MNO control	This use case describes the scenario where a given UEsupporting V2V Service sends V2X messages to other surrounding UEs and the given UE is under E-UTRAN coverage.
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.
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 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 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 ofexplicit 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.
Curve Speed Warning	Curve speed warning application alerts the driver to manage the curve at an appropriate speed.
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 usersto avoid collision with the moving vehicle.
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.
V2X by UE-type RSU	This use case describes the scenario where UE supporting V2X discovers and communicates with UE-type RSU.
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.
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.
Pedestrian Road Safety via V2P awareness messages	A pedestrian carries a UE, which is able to transmit awareness and safety related V2P broadcast messages.
Mixed Use Traffic Management	There are a number of variables to be taken into account in a scenario involving different types of vehicular traffic.
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.
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.
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.

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 TR22.886 are listed.

Table YY: Use cases in TR 22.885 Release 15

Use cases	Description
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.
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.
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.
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.
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.
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.
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.
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
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.
Information sharing for partial/ conditional	This use case is interpreted as an automated driving at the level of SAE Level 3 and Level 2 automation.

Use cases	Description
automated driving	
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.
Information sharing for high/full automated platooning	This use case is interpreted as an automated driving at the level of SAE Level 4 and Level 5 automation.
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.
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.
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.
Changing driving-mode	According to a vehicle cooperation level, driving-mode can be classified generally into three classes.
Tethering via Vehicle	This use case enables a vehicle to provide network access to occupants, pedestrians etc.
Use case out of 5G coverage	A UE supporting V2X application is equipped with a multi-RAT modem (5G, LTE).
Emergency trajectory alignment	Emergency Trajectory Alignment (EtrA) messages complement cooperative automated driving.
Teleoperated support (TeSo)	While traffic safety as well as accident-free driving is the task of each connected autonomous vehicle,
Intersection safety information provisioning for urban driving	The traffic accident occurs at the intersection where the vehicle and pedestrians are crowded.
Cooperative lane change (CLC) of automated vehicles	On a multi-lane road, a lane change manoeuvre could be initiated by a vehicle.
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;
3D video composition for V2X scenario	This use case consists of multiple UEs supporting V2X application moving in an area.

Use cases	Description

In 3GPP Rel. 16, several eV2X use cases were added and are recommended in TR. 22.886. In Table ZZ, the use cases added in Release 16 and description of TR22.886 are listed.

Table ZZ: Use cases in TR 22.885 Release 16

Use cases	Description
QoS aspects of vehicles platooning	Platooning is a coordinated mobility of group of vehicles, sharing manoeuvre and other information with each other. It increases traffic efficiency and reduces fuel consumptions.One of most critical requirements for platooning is that the information flow between platoon members should be performed in a timely and reliable way. Thus, the platooning applications installed in a vehicle will adjust the time/distance gap based on the achievable QoS of connectivity.
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
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.
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.
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

6 Scenarios and applications

6.1 Information

Information services are critical to improve the driving experience of vehicle owners, which is a major part of C-V2X applications. Typical information service scenarios include emergency call services.

In the scenario of emergency call services, in case of an emergency (such as airbag deployment or rollover), the vehicle can automatically or manually initiate emergency rescue through the network, and provide basic data information to the outside, including the type of the vehicle and the time and location of traffic accident. The services may be provided by government emergency rescue centers, operator emergency rescue centers, or third-party emergency rescue centers. The vehicle is required to have V2X communication capability that establishes communication with the network.

6.2 Traffic safety

Traffic safety is among the most important C-V2X operation scenarios, which is significant in preventing traffic accidents and reducing related losses of life and property. Typical traffic safety scenarios include intersection collision warning.

In the scenario of intersection collision warning, the driver will be alerted by an early warning sound or image to avoid collision at intersections when the vehicle detects risk of collision with other vehicles travelling on the lateral side. The vehicle needs to be able to send and receive V2X messages.

6.3 Traffic efficiency

Traffic efficiency is a major scenario for C-V2X applications and an important component of smart transportation. It has great significance for alleviating urban traffic congestion and promoting energy conservation and emissions reduction. Typical traffic efficiency scenarios include speed guidance.

In the scenario of speed guidance, the roadside unit (RSU) collects the timing information on traffic lights and signal lights, and broadcasts information such as the present state of signal lights and the time remaining in this state to nearby vehicles. Based on the information received, combined with the current vehicle speed and location, the vehicle calculates the recommended driving speed and prompts the driver in order to increase the possibility of crossing the intersection without stop. This scenario requires RSU to be able to collect traffic signal information and broadcast V2X messages to vehicles and requires the nearby vehicles to be able to send and receive V2X messages

6.4 Autonomous driving

Similar to existing video recognition on camera, millimeter wave radar, and laser radar, V2X offers another way of information interaction to obtain the motion states (speed, brake, and lane change) of other vehicles and pedestrians, which is not susceptible to the influence of such factors as weather, obstacle, and range. At the same time, V2X helps to build a comprehensive service system of time-share rental favorable for the industrialization of autonomous vehicles by integrating people, vehicles, road infrastructure, and cloud platform. Currently, typical autonomous driving scenarios include vehicle platooning and remote driving.

Vehicle platooning refers to the linking of vehicles through V2X communication. In a platoon, the leader is manned or autonomous, and followed by members that maintain stable in-vehicle distance at a certain speed based on real-time information interaction. The application supports lane keeping and tracking, cooperative adaptive cruising, cooperative emergency braking, cooperative lane change reminder, and entry and exit platooning.

Remote driving enables the driver to remotely operate the vehicle through the driver console. The camera, radar, and the like mounted to the vehicle transmit in real time the multi-channel sensing information to the remote driver console through high-bandwidth 5G network. The signals from the driver's control on steering wheel, throttle, and brake are also transmitted in real time to the vehicle through low-latency and high-reliability 5G network, which facilitates easy and accurate operations, such as driving, accelerating, braking, turning, and reversing

7 Standardization Route

Editor Note: To review if the report needs to combine Section 7.1 and 7.2 as a single section

7.1 LTE-V2X Specification

3GPP has completed the specification development of R14 LTE-V2X, mainly including service requirements, system architecture, air interface technology and security.

In terms of service requirements, the specification defines 27 use cases of V2V, V2I, V2P, V2N and service requirements for LTE-V2X services, and gives performance requirements for seven typical scenarios. In terms of system architecture, the specification identifies enhancements for support of V2X services based on the architecture of Proximity Services (ProSe) via the PC5 interface and LTE cellular communication via the Uu interface, and clearly stated that the enhancements support at least V2X services transmitted through the PC5 interface and the LTE-Uu interface. In terms of air interface technology, the specification clarifies the channel structure, synchronization process, and resource allocation on the PC5 interface, the PC5 and Uu interface's coexistence in the same carriers and adjacent carriers, radio resource control (RRC) signaling, and related radio frequency (RF) indicators and performance requirements, and explores Uu and PC5 transmission enhancements for support of LTE-V2X services. Furthermore, the study on the security aspect of the LTE architecture enhancements for support of V2X services has been completed.

7.2 LTE-eV2X Specification

LTE-eV2X represents the phase (R15) of study on enhancement technologies that supports superior V2X service scenarios, aiming to further improve the reliability, data rate, and latency performance of the Device to Device (D2D) mode and partially meet the needs of superior V2X services, while maintaining backward compatibility with R14.

The Technical Specification (TS) 22.886 has defined the service requirements for 25 use cases in five eV2X service categories, including basic requirements, vehicle platooning, semi-autonomous / autonomous driving, extended sensors, and remote driving. The ongoing study on 3GPP V2X specification Phase 2 mainly targets the feasibility and benefits of such enhancement technologies such as carrier aggregation, transmit diversity, high-order modulation, resource pool sharing, and reduced delay, and shortened transmission time interval (TTI).

7.3 5G NR-V2X Specification

5G NR-V2X represents the phase (R16and R17) to support superior V2X service scenarios based on 5G NR-based technologies. With different service capabilities from LTE-V2X, 5G NR-V2X supports more superior services and considers LTE-V2X enhancements by integrating LTE capabilities. The first version of 5G NR-V2X Specification was completed in 3GPP Release 16 in July 2020. The study covers sidelink channel model above 6 GHz. But, only 5.9 GHz is currently fully supported as operating band. 5G NR-V2X is being extended in 3GPP Release 17to support UE power saving mechanism and to achieve more reliable and lower latency sidelink communication and is expected to be completed in March 2022.

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8 Standardization Development of C-V2X

8.1 China

The Ministry of Industry and Information Technology and Standardization Administration of P.R.C jointly developed *Guideline for Developing National Internet of Vehicles Industry Standard System*, whose sub-volumes are general requirements, intelligent connected vehicle, information communication, electronic products and services. The information communication and intelligent connected vehicle sub-volume clearly defined the technical standard selection of LTE-V2X and 5G-V2X from perspectives of communication technology evolution and intelligent connected vehicle application.

Many of the domestic industry associations and standardization organizations attach high importance to the promotion of C-V2X standards in China. CCSA, TIAA, SAE-China, the Technical Committee for National on ITS (TC/ITS), China ITS Industry Alliance (C-ITS), and China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV) have actively carried out C-V2X related research and standardization work. A standard system that covers all layers and levels of the C-V2X standard protocol stack has taken the initial shape, as shown in Figure 4

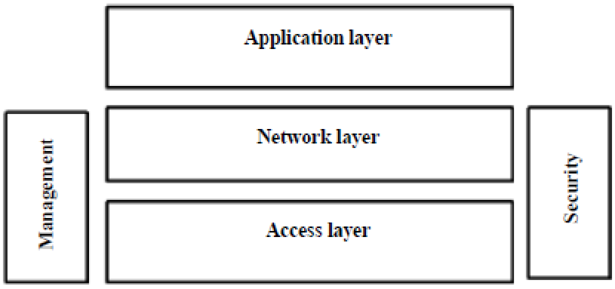

Figure 4 Overall Architecture of C-V2X Standards in China

The relevant standardization work of domestic standard organizations has supported China's system of C-V2X standards, covering application definitions and requirements, general technical requirements, key technologies, and information security. However, the majority of these standards has been studied and developed by different groups of organizations or industry standardization committees and still need coordination to accelerate the formation of full-fledged unified national standards.

Category	Title	Grade	Organization	State
General requirement	Dedicated Short-Range Communication of Cooperative Intelligence Transportation System Part 1:General Technical Requirement	National standard	TC/ITS CCSA	Released in December 2014
	General Technical Requirement for LTE-based Vehicular Communication	Industry standards	CCSA	YD/T 3400-2018 Released in 2018
	General Technical Requirement for LTE-V2X Communication	Group standard	C-ITS	Released in December 2017
	Technical Specifications for LTE-V2X based on ISO Intelligent Transportation System Framework	Group standard	C-ITS	
Access layer	Air Interface Technical Requirement for LTE-based Vehicular Communication	Industry standard	CCSA	YD/T 3340-2018 Release in 2018
	Technical Requirement for LTE-V2X AirInterface	Group standard	C-ITS	Under preparation

Network layer	Dedicated Short-Range Communication of Cooperative Intelligent Transportation System Part 3:Network Layer and Application Layer Specification	National standard	TC/ITS CCSA	Under review
Application layer	Dedicated Short-Range Communication of Cooperative Intelligent Transportation System Part 3:Network Layer and Application Layer Specification	National standard	TC/ITS CCSA	Under review
	Application Layer Specification and Data Exchange Standard for the Vehicular Communication System in Cooperative Intelligent Transportation System	Group standard	SAE-C C-ITS	Released in December 2017
	Communication Requirements of Autonomous Driving	Group standard	C-ITS	Released in December 2017
Security	Technical Requirements for LTE-based C-V2X	Industry standard	CCSA	Comments solicited

The Ministry of Industry and Information Technology and Standardization Administration of P.R.C jointly developed *Guideline for Developing National Internet of Vehicles Industry Standard System*, whose sub-volumes are general requirements, intelligent connected vehicle, information communication, electronic products and services. The information communication and intelligent connected vehicle sub-volume clearly defined the technical standard selection of LTE-V2X and NR-V2X from perspectives of communication technology evolution and intelligent connected vehicle application.

Many of the domestic industry associations and standardization organizations attach high importance to the promotion of C-V2X standards in China. China Communications Standards Association (CCSA), National Technical Committee of Auto Standardization (NTCAS), Telematics Industry Application Alliance (TIAA), SAE-China(C-SAE), the Technical Committee for National on ITS (TC/ITS), China ITS Industry Alliance (C-ITS), and China Industry Innovation Alliance for the Intelligent and Connected Vehicles (CAICV) have actively carried out C-V2X related research and standardization work. A standard system that covers all layers and levels of the C-V2X standard protocol stack has been set up, as shown in Figure 4.

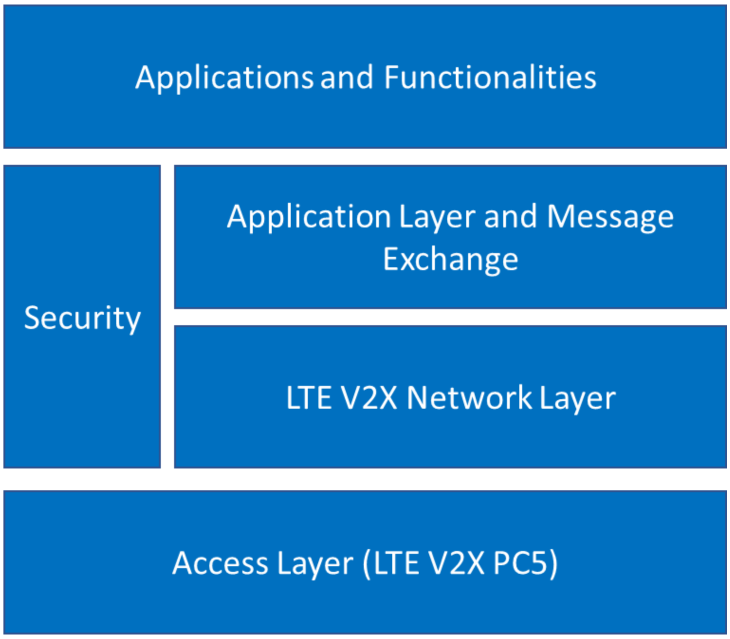

Figure 4 Overall Architecture of C-V2X Standards in China

The relevant standardization work of domestic standard organizations has supported China's system of C-V2X standards, covering application definitions and requirements, general technical requirements, key technologies, and information security. However, the majority of these standards has been studied and developed by different groups of organizations or industry standardization committees and coordination is still needed to accelerate the formation of full-fledged unified national standards.

Category	Title	Grade	Organization	State
General requirement	General technical requirements of LTE-based Vehicular Communication (YD/T 3400-2018)	Industry standards	CCSA	Released in 2018
Access layer	Technical requirements of air interface of LTE-based vehicular communication (YD/T 3340-2018)	Industry standard	CCSA	Released in 2018
	Technical requirement of vehicle terminal for LTE-based vehicular communication	Industry standard	CCSA	Ballot

	Test methods of vehicle terminal for LTE-based vehicular communication	Industry standard	CCSA	Ballot
	Technical requirement of sidelink-enabled road side unit for LTE-based vehicular communication	Industry standard	CCSA	Ballot
	Test methods of sidelink-enabled road side unit for LTE-based vehicular communication	Industry standard	CCSA	Ballot
Network layer	Technical requirements of network layer of LTE-based vehicular communication (YD/T 3707-2020)	Industry standard	CCSA	Released in 2020
	Test methods of network layer of LTE-based vehicular communication (YD/T 3708-2020)	Industry standard	CCSA	Released in 2020
Message layer	Cooperative intelligent transportation system; vehicular communication; application layer specification and data exchange standard (T/CSAE 53-2020)	Consortium standard	C-SAE C-ITS	Initial release in 2017, revision in 2020
	Technical requirements of message layer of LTE-based vehicular communication (YD/T 3709-2020)	Industry standard	CCSA	Released in 2020
	Test methods of message layer of LTE-based vehicular communication (YD/T 3710-2020)	Industry standard	CCSA	Released in 2020
Profile and Application	Technical Requirements of Vehicular Communication System based on LTE-V2X Direct Communication	National standard	NTCAS	Ballot
	Direct communication system roadside unit technical requirements of LTE-based vehicular communication (T/CSAE 159-2020, T/ITS 0110-2020)	Consortium standard	C-SAE C-ITS	Released in 2020

	Application Identity Allocation and Mapping for LTE-based Vehicular Communication	Industry standard	CCSA	Ballot
Security	General technical requirements of Security for Vehicular Communication based on LTE (YD/T 3594-2019)	Industry standard	CCSA	Released in 2019
	Technical Requirements of security certificate management system for LTE-based vehicular communication	Industry standard	CCSA	Ballot
Advanced use cases exploration	Cooperative intelligent transportation system; vehicular communication; application layer specification and data exchange standard Phase II (T/CSAE 157-2020)	Consortium standard	C-SAE C-ITS	Released in 2020

8.2 COUNTRY XYZ

9 Spectrum Considerations for C-V2X in APT Countries

9.1 Australia

9.2 China

In 2016, MIITapproved the LTE-V2X technology trial in 5 905-5 925 MHz until 2017. In 2018, MIIT approved the phase II LTE-V2X technology trial in 5 905-5 925 MHz until July, 2019.

China is now public consulting on spectrum planning about using 5 905-5 925 MHz for LTE-V2X direct link (PC5) communication.

In 2016, MIIT approved the LTE-V2X technology trial in 5 905-5 925 MHz until 2017. In 2018, MIIT approved the phase II LTE-V2X technology trial in 5 905-5 925 MHz until July, 2019.

In October 2018, the MIIT issued the radio regulation that allocated 5905-5925 MHz for LTE-V2X sidelink. OBU, RSU and the portable devices share a single 20 MHz channel. The operation of OBU and the portable devices is license-exempted, while the operation of RSU needs the frequency license and the station license. The maximum EIRP requirement for OBU and portable device is 26dBm and the maximum EIPR requirement for RSU is 29dBm.

CCSA has completed the 5G NR-V2X spectrum needs study and is working on the coexistence study between LTE-V2X and 5G NR-V2X.

9.3 Japan

In 2020, Japan issued Frequency Reorganization Action Plan (revised version of FY2020). It includes detail plans for 5.9 GHz spectrum study for ITS. The following is excerpted test from the plan:

> Based on the progress and importance of automatic driving systems (including safe driving support), a study is being carried out, which will finish by the end of FY 2021, into the technical conditions for frequency sharing with needed existing wireless systems, for example when introducing V2X communications, and with consideration for existing wireless systems on frequency bands being studied internationally (5.9 GHz band), in addition to the existing ITS frequency bands (760 MHz band, etc.).
> In addition, based on the results of these studies, a conclusion will be reached within FY 2022 regarding frequency allocation policy, such as frequency sharing and migration/reorganization when introducing V2X communications in the same frequency band, etc.

9.4 Korea

9.5 Singapore

9.6 COUNTRY XYZ

10 [Practice Cases] of C-V2X in APT Countries

10.1 Plan to Deployment

10.1.1 China

C-V2X contains LTE-V2X and 5G-V2X. Technical tests will be carried out in phases according to the progress of industry development. Before 2019, the industrial forces were pooled to the LTE-V2X technology test to promote product maturity, and in 2019, the 5G-V2X Uu technology was tested. The details are as shown in Figure 5.

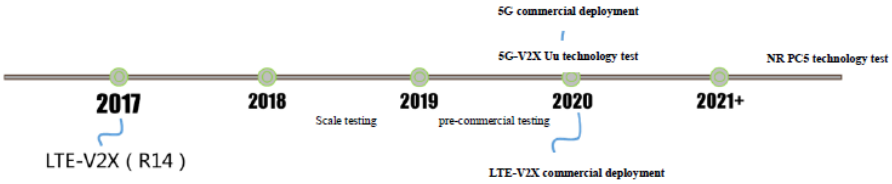

Figure XX C-V2X technology test and commercialization plan

LTE-V2X: In June 2018, the scale testing was started and roadside infrastructure upgraded, to verify the networking performance and typical V2X service performance under multi-user conditions. In 2019, some city-level infrastructure was renovated for pre-commercial testing. In 2020, the LTE-V2X commercial deployment was advanced to support the commercial applications of intelligent transportation services to increase traffic efficiency.

5G-V2X: In 2019, the Uu technology test was kicked off to validate the 5G network support of certain typical eV2X service scenarios (mainly high-bandwidth scenarios). Technical standards for low-latency and high-reliability communication will be developed. In 2021, technical tests of low-latency and high-reliability application scenarios will be conducted to validate network performance for typical applications such as autonomous driving.

10.1.2 COUNTRY XYZ

10.2 Demonstrations/Trials

10.2.1 China

In order to promote the early commercialization of C-V2X industry, the Ministry of Industry and Information Technology (MIIT) has signed the *Framework Agreement for Cooperation on Application Demonstration of Intelligent Vehicles and Smart Transportation Based on Broadband Mobile Internet* with the governments of Beijing, Baoding, Chongqing, Zhejiang, Jilin and Hubei; signed the *Cooperation Agreement on Jointly Building the Comprehensive Test Base for National Intelligent Transportation Systems* with the Ministry of Public Security (MPS) and the People's Government of Jiangsu Province; launched the Intelligent Manufacturing Pilot Project to support the construction of intelligent and connected driving demonstration zone in Shanghai; and implemented the Sino-German Pilot Project of Standards and Validation Tests for Intelligent Connected Vehicles / Internet of Vehicles to support the establishment of demonstration base in Sichuan. The Ministry of Transport (MOT) has built an intelligent driving test base based on the comprehensive road test site, where simulative urban roads, V2I communication infrastructure, traffic signal facilities, and various intelligent roadside devices are in place for testing automatic driving and V2I collaboration. Demonstration zones help to promote technological innovation and standardization, stimulate industrial integration and innovation, and foster new business formats. With the joint efforts of all shareholders, some demonstration zones have made important progress in the field of C-V2X, as described below:

National Intelligent Connected Vehicle (Shanghai) Pilot Zone

The National Intelligent Connected Vehicle (Shanghai) Pilot Zone has been built by designated Shanghai International Automobile City (Group) Co., Ltd to serve the test and demonstration of two key technologies of intelligent vehicle and V2X communication. At present, the construction has entered the second stage. Differential GPS base stations, LTE-V2X base stations, RSU, intelligent traffic lights, and various types of cameras, have been deployed. A total of 13 new LTE-V2X base stations and a platform of C-V2X Server data center have been built. These facilities can provide support for the research & development and test of C-V2X (V2P) applications by vehicle and component companies. In 2018-2019, in total 18 open roads were included into the intelligent transportation system and no less than 3,000 vehicles were organized for C-V2X application demonstration.

Wuxi Comprehensive Test Base for National Intelligent Transportation and Demonstration Zone for Internet of Vehicles

The Wuxi Demonstration Zone for Internet of Vehicles has been jointly created by the MPS Traffic Management Research Institute, China Mobile, Huawei, Wuxi Traffic Police Detachment, and CAICT. It plans three phases of construction, i.e. open road test research, city-scale demonstration application, and C-V2X industry base construction, covering multiple areas around the comprehensive test base, and deploys new business applications based on the LTE-V2X technology. The second phase will develop an IOV platform based on information exchanges of key road transportation infrastructure, intelligent traffic management system, and next generation C-V2X technology represented by LTE-V2X technology. The platform will cover 211 intersections and 5 elevated highways and be capable of serving 100,000 vehicles, thus providing strong support for large-scale IOV application.

Chongqing Intelligent Vehicle Integrated Systems Test Area (i-VISTA)

The Chongqing Intelligent Vehicle Integrated Systems Test Area, primarily constructed by CAERI, highlights the traffic and communication characteristics of the city with unique mountain and water landscape. At present, 9.6km-long open roads have been networked and V2X-enabled devices installed in vehicles, so that the test area can accommodate V2X test related monitoring and statistics services and have V2X testing capability. The second phase will complete the construction and renovation of the comprehensive test experimental area of the Chongqing Xibu Automobile Proving Ground and solve V2X related problems of systems and technical tests in highway and rural road environments. The third phase will demonstrate.

National Intelligent Vehicle and Smart Transportation (Beijing-Hebei) Demonstration Zone

The National Intelligent Vehicle and Smart Transportation (Beijing-Hebei) Demonstration Zone is primarily constructed by the Beijing Innovation Center of Mobility Intelligent. In September 2017, it officially launched the road services for tidal test of intelligent and connected vehicles. The open road, with a total length of about 12 km, has seen the transformation of various roadside infrastructure and the application of pedestrian collision warning. In February 2018, the closed test site for autonomous vehicles —Haidian Base, was officially put into use. The site covers the complex road environments of urban and rural areas in the Beijing-Tianjin-Hebei region, and supports the construction of hundreds of typical static and dynamic traffic scenarios. The site is equipped with V2X equipment and systems to support the research & development and testing of connected vehicles.

National Intelligent and Connected Vehicle (Northern) Demonstration Base

The Intelligent and Connected Vehicle (Northern) Demonstration Base is built by Qiming Information Technology Co., Ltd. The first phase, which has been completed, creates 11 large scenes and 233 small scenes for test and demonstration and enables such V2X applications as information prompts and security warnings in FAW's own intelligent and connected vehicles. Listed as a base for China-Russia joint V2X test, the northern demonstration base is expected, by the end of 2019, to add a cold-zone test and experience base for on-site test of intelligent vehicles and smart transportation in 72 major scenes and 214 sub-scenes. It will offer effective tools and means for future functionality and performance validation of intelligent vehicles and smart transportation, covering sensor, V2X, AI, and actuator.

Zhejiang Intelligent Vehicle and Smart Transportation Demonstration Zone

Zhejiang Province intends to create a test and validation demonstration zone integrating intelligent vehicles, intelligent transportation and broadband mobile Internet. As the core area, Yunqi Town of Hangzhou City will accommodate 34 LTE-V2X road sites and support a number of interaction scenarios; Wuzhen Town of Tongxiang City will mainly construct a traffic big data integration and information service model and an integrated IOV operation platform and complete a number of studies and tests of assisted driving and autonomous driving.

Hubei Intelligent Vehicle and Smart Transportation Demonstration Zone

The Hubei Intelligent Vehicle and Smart Transportation Demonstration Zone is located in the Smart Eco-City of Wuhan Economic and Technological Development Zone and was constructed by Wuhan Economic and Technological Development Zone. Aimed at a driverless smart town, it plans to gradually develop from closed test area, semi-open demonstration area to open urban traffic environment in three stages within five years, and to demonstrate multiple applications, such as intelligent vehicle test and evaluation, autonomous intelligent vehicle, smart transportation, and smart town.

10.2.2 Country XYZ

11 Co-existence study between fixed satellite service uplinks and intelligent transport system receivers

Please refer to Annex A for more information.

12 National planning options for ITS technology in the 5.9 GHz band

Please refer to Annex B for more information.

13 Future considerations

14 Summary

15 References

16 Annexes

ANNEX A

TECHNICAL OBSERVATIONS ON THE CO-EXISTENCE BETWEEN FIXED SATELLITE SERVICE UPLINKS AND INTELLIGENT TRANSPORT SYSTEM RECEIVERS

1 Introduction

At the previous meeting of the APT Wireless Group (AWG-23, May 2018, Vietnam), the draft new APT Report on *The usage of ITS in APT countries* was finalized and approved for publication by APT. This new report indicates significant regional support for the band 5850-5925 MHz (or parts thereof) to be harmonized for use by Intelligent Transport Systems (ITS) so as to encourage greater economies of scale leading to lower costs for ITS components and devices, amongst other benefits. As indicated by the draft text addressing WRC-19 Agenda Item 1.12, this same band is similarly gaining widespread support in the other regions of the world.

However, the administrations of two countries have indicated a lingering concern regarding the potential for interference to arise from Fixed Satellite Service (FSS) earth station uplinks into nearby ITS receiver devices, and prospective calls for additional mitigation measures to be fitted to FSS earth station transmitters. At least two technical studies addressing this issue have been previously undertaken[2][3], which both indicate that such significant interference is unlikely under a range of physical and technical assumptions.

This contribution presents a further technical analysis of the co-existence between FSS uplinks and nearby ITS receivers[4], to further characterize the issue and explore further possible practical mitigating measures.

2 Approach

[2] Compatibility studies between Intelligent Transport Systems (ITS) in the band 5855-5925 MHz and other systems in adjacent bands. https://www.ecodocdb.dk/download/95cf8976-fa03/ECCREP228.PDF

[3]PROPOSED MODIFICATION OF WORKING DOCUMENT TOWARD A PRELIMINARY DRAFT NEW REPORT ITU-R M.[ITS USAGE] https://www.itu.int/md/R07-WP5A-C-0783/en

[4]Note that this contribution offers no analysis of the alternative interference path comprising ITS device (vehicle or roadside) emissions incident on satellite receivers in orbit, since a number of previous studies have already clearly shown this risk to be negligible.

Following a review of the previous studies noted above, and additional investigation into the technical characteristics of ITS components and devices, a computer model was developed to simulate the practical co-existence scenario of a multi-lane roadway passing by a FSS earth station site:

The simulations were undertaken to evaluate the relationship between different levels of interference to noise ratio (I/N) and the distance between a satellite Earth Station (ES) and ITS station using LTE-V2X devices for various Earth Station elevations pointing directions (see Figure1). The particular approach adopted involved moving a ITS device throughout the area surrounding the ES - called *area analysis* - with 100m step size, while recording the I/N values experienced by the ITS receiver.

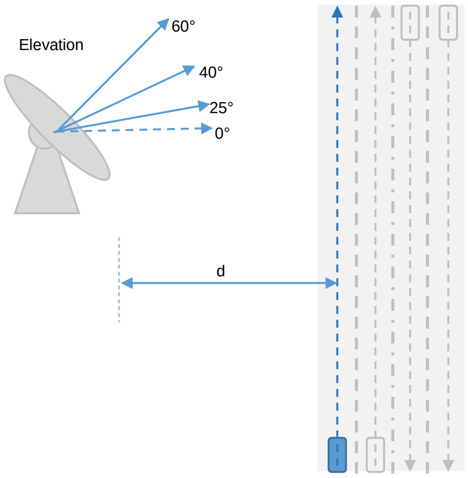

Figure 1: Generic technical co-existence scenario between FSS earth stations and ITS devices

We performed our analysis in two stages:

- First, we developed a flat terrain model and evaluated the results for a generic case.
- Then, we further evaluated the cases of two Earth Stations already operating in Australia: one with considerable natural terrain shielding in Belrose near Sydney, and another with more flat terrain located in Lockridge near Perth city.

3 Relevant Systems Characteristics

The parameters used for FSS earth station and ITS device are shown in Tables 1 and 2 below.

3. 1 FSS Earth Station

The system parameters of FSS earth station used in this study are based on reference [2]. The antenna model of FSS earth station is based on *ITU-R S.465* and the antenna pattern is shown in Figure 2.

Table1: The system parameters of FSS Earth Station transmit

Parameter	Value	Unit
Frequency	5900	MHz
Transmitter Bandwidth	2	MHz
Transmitting Power	30	dBm
Feeder Loss	0	dB
Antenna Type	ITU-R S.465	~~17~~
Height	10	m
Antenna Aperture	2.4	m
Minimum Elevation	15	°

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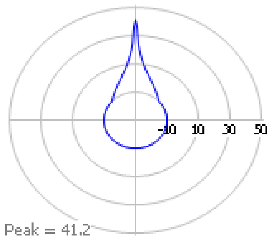

Figure 2: Earth Station Transmit Antenna Pattern, Diameter = 2.4m, Efficiency = 0.6

3.2 ITS Receiver Devices

The system parameters of ITS device used in this study are based on LTE-V2X technology. The parameters are based on reference [2] which are following 3GPP TR36.885[5] and are shown in table 1. The antenna pattern used for ITS device is also shown in Figure 3.

Table2: The System parameters of LTE- V2X ITS system receiver

Parameter		**Value**	**Unit**
Carrier		5900	MHz
Bandwidth		10/20[6]	MHz
Protection Criteria (I/N)		0	dB
Vehicular Parameters	Antenna Height	1.5	m
	Antenna Type	Omni Defined in ITU R F.1336-4 2.2	~~18~~
	Antenna Gain	3	dBi
	Transmitting Power	21	dBm
	Antenna Number	1T2R	~~19~~
	Noise Figure	9	dB

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[5] https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=2934

[6] We normalized the channel Bandwidth to 1MHz and performed per MHz analysis.

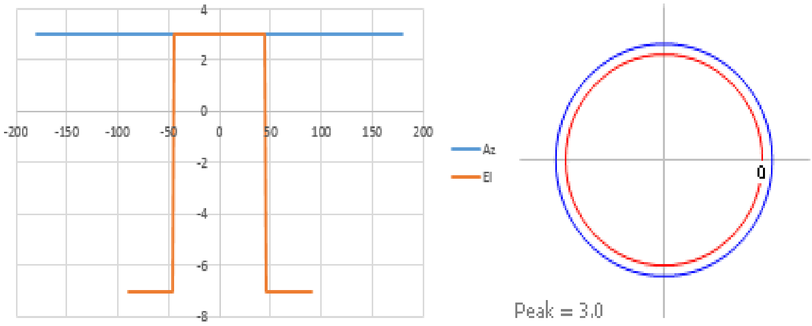


Figure 3: ITS station Receive Antenna Pattern, Omni Defined in ITU R F.1336-4 2.2

3.3 Propagation Model

For the flat terrain model ITU-R P.452-16 was used with ITS devices at a height of 1.5 m and ES antenna at 10m height, and 18.1dB clutter loss was added to the link. The value of the clutter loss was calculated from ITU-R P.452 for a village center scenario. However, for the other simulations which used actual terrain, the 18.1dB clutter loss was modified to different values. Our analysis assumed co-channel operations at 5.9GHz, and interference and noise level calculations were normalized per MHz.

4 Technical Simulations and Results

4.1 Generic Study: a flat terrain Model

After setting up the flat terrain model using the above parameters and assumptions, we ran an area analysis to calculate the minimum distance between ITS station and ES. Using this method we generated multiple circles around the ES: each one representing the 'excluded' zone for the ITS station for various I/N values (-12.2dB, -10dB, -6dB, 0dB and 2dB). Figure 4 shows a sample set of results for the case of ES elevation = 55˚.

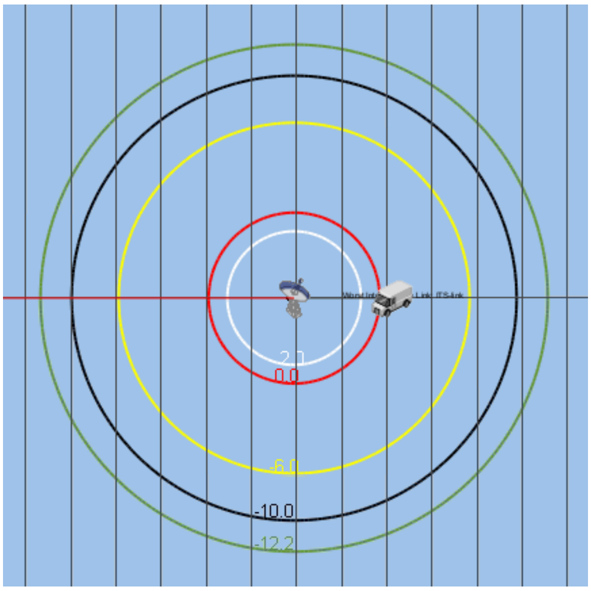


Figure 4: Area analysis (exclusion zone) for ITS station with I/N =2dB (white), 0dB (red), -6dB (yellow), -10dB (black) and -12.2dB (green) contours. ES antenna elevation = 55˚

In addition to minimum I/N values, the other parameter that affects minimum distance for co-existence of ITS station and Earth Station is the elevation angle of the Earth Station antenna. The lower the elevation angle above horizon, the higher the antenna pattern side-lobe level toward the ITS station - and hence the higher interference power received by the ITS station. To evaluate this effect we ran the simulation for multiple scenarios with varying elevation angle from 15˚ to 60˚ (above horizon) and calculated the maximum excluded distance for the ITS station (assuming a constant I/N value). Figure 5 shows how exclusion zone changes with varying elevation angle.

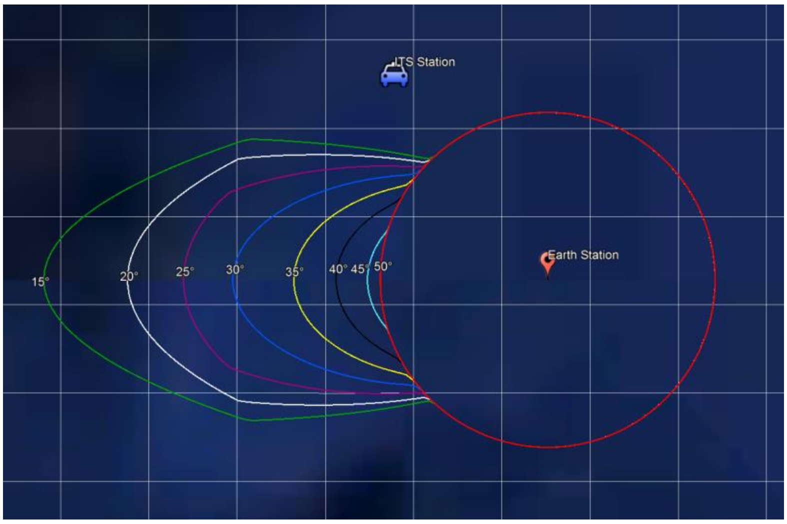


Figure 5: Area analysis (exclusion zone) for ITS station with different ES elevation angles, I/N=0dB, grid size=1km

4.1.1 Simulation Results

Using these analysis we calculated the relationship between the two parameters of elevation of ES antenna and I/N in terms of the minimum excluded distance between the two stations. A summary of this analysis (for the flat terrain case) is shown in Figure 6.

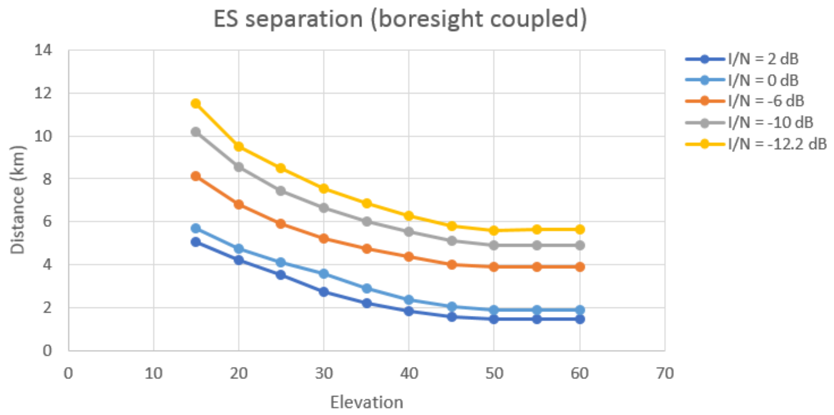


Figure 6: Minimum excluded distance based on elevation of ES antenna for varying I/N levels

Both ITS and FSS systems can co-exist if the I/N level is within tolerable level for ITS devices (protection criteria). In this study we selected I/N = 0dB as suitable protection criteria for ITS LTE-V2X systems. According to different studies on comparison of ITS technologies[7] using LTE based technologies, ITS stations can tolerate higher I/N levels. This is mainly due to the fact that LTE-V2X makes use of turbo coding which is one of the most powerful types of FEC (Forward-Error-Correcting) channel codes. This makes LTE-V2X more robust against Interference compared with other ITS technologies. Therefore, using LTE-V2X with Noise Figure = 9dB, Coding gain ≥ 0, Turbo coding and Rx Threshold ≥ Noise Level, we selected 0dB as a reasonable yet still conservative value for I/N level.

For the results, for I/N = 0dB and minimum elevation of ES antenna beam of 15°, the minimum distance between the two system at which co-existence is still possible would be around 5.7km. Notably, this distance reduces to less than 2km when elevation angle increases to 45˚.

4.1.2 Discussion

In case of flat terrain model, if there is a road deployed with ITS roadside units, or vehicles equipped with ITS devices that communicate ad-hoc with each other, crossing the excluded area, for a typical case of an ES elevation of 35˚, the excluded distance will be within a few

[7]Link level performance comparison betweenLTE V2X and DSRC.
https://link.springer.com/article/10.1007/s41650-017-0022-x

kilometres, generally around 3km. In this case if a vehicle travels at 100km/h, the ITS system will be affected for only about 2 to 3 minutes.

However, in reality the effect of the interference on ITS system from an FSS system is likely to be less harmful because of robust ITS systems. Of note, V2X systems transmissions are not occurring continuously. Instead, packets which are short in length (300 and 190 bytes) are transmitted in 1ms slots at intervals of 100ms [4]. Also, in case of unsuccessful transmission which can be due to either channel congestion or poor radio propagation environment, packets will be retransmitted. That means for the situation where a vehicle is travelling across the exclusion area, the negative impact of the FSS systems into ITS systems is expected to be minimal.

While these are the assumptions for flat terrain model case, for real scenarios were terrain shielding and obstacle/vegetation effects are included, the 'excluded' duration will be reduced considerably, and the results will improve for the cases with good terrain protection.

The flat terrain model was used as an indicative model only, to provide an overall idea about co-existence of the two systems in a generic sense. In this study we also evaluated co-existence of the two systems in real scenarios with actual terrain as below.

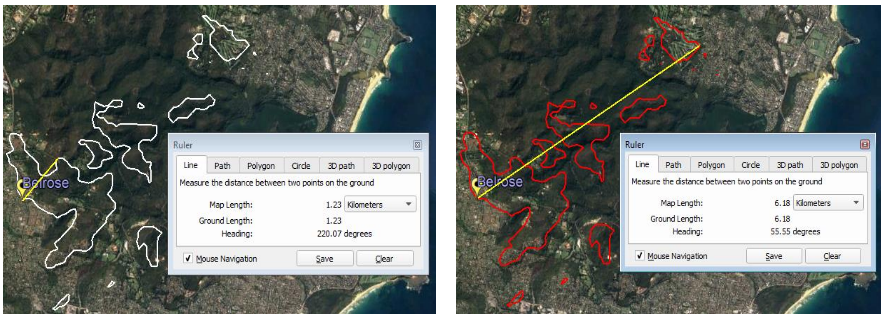
4.2 Analysis of Real Scenarios with Natural Terrain Protection

For this part of the study, we chose two C-band satellite Earth Station sites located in Australia, and with different natural terrain shielding. One a well terrain protected site in Belrose, NSW and the other one an open area site with little terrain shielding in Lockridge, WA. Figure 7 shows the location of the two selected satellite Earth Station sites in Australia.

Figure 7: Location of Belrose and Lockridge satellite sites

Unlike the flat terrain model with 18.1dB clutter loss, in these two scenarios only 10dB additional loss was included. Because of the rural nature of Belrose, 10 dB of vegetation loss was used as a reasonable level of loss caused by most tropical vegetation with solid leaves. In the case of the built-up environment surrounding Lockridge, a 10dB clutter loss was used.

Figures 8 and 9 show the results of the area analysis in Belrose and Lockridge for I/N = 0dB and ES antenna elevation = 15˚ (red) and 50˚ (white).

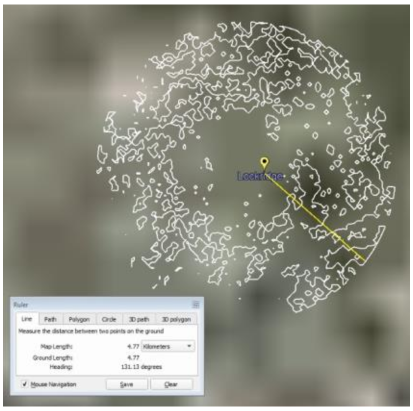


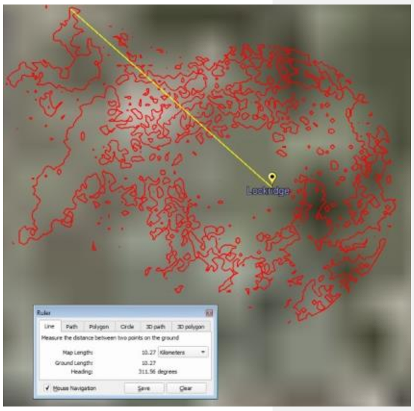
(a) (b)

Figure 8: Area analysis for Belrose, I/N =0dB, a: ES elevation=50 ˚(white), b: ES elevation=15 ˚(red)

For the Belrose case, the Earth Station is located in a natural valley which provides a large amount of terrain protection, and therefore the exclusion zones are very similar regardless of the elevation angle of ES antenna. Also, in comparison with the flat terrain model, the excluded area reduces not only in size, but also changes from a uniform circular area around the earth station, to an area determined by the terrain. Significantly, terrain shielding offers almost complete protection on west side of ES.

In the case of Lockridge, which is an open area with little terrain protection, the results are more like that of the flat terrain model. In this case, as shown in Figure 9, the change in ES antenna elevation is noticeable making about 5km difference on boresight for the two scenarios. Also the excluded area is spread rather uniformly around earth station with on average a larger excluded distance compared with flat terrain model. This difference is due to the larger clutter loss (18.1dB) considered for the flat terrain scenario to compare with 10dB clutter loss in Lockridge scenario.





(a) (b)

Figure 9: Area analysis for Lockridge, I/N =0dB, a: ES elevation=50˚ (white), b: ES elevation=15˚ (red)

5 Conclusions

In conclusion, our study shows that co-existence of ITS and FSS systems in 5.9 GHz is possible. ITS stations may be affected by FSS systems if they are within a few kilometers of an earth station. However, V2X systems, especially LTE-Based systems using turbo coding, are quite robust systems and can tolerate high levels of interference. Also natural terrain shielding, obstacles, and vegetation will add extra protection to the systems performance.

In order to ensure co-existence of the two systems in the best possible way the two suggestions can be made:

1. In the case when existing Earth Stations and roads are located close to each other, when there is no terrain shielding and protection, building a wall (earth berm) around the Earth Station can be an effective way to protect ITS systems.

2. When new Earth Stations or roads are being planned, the positive impact of the terrain, vegetation and clutter loss should also be taken into account when selecting sites or roadways.

ANNEX B

Considerations for ITS Technologies in the 5.9 GHz band

1. Background

The emergence of Intelligent Transport Systems (ITS) is largely driven by population growth and the increasing number of motor vehicles on the roads in most countries, and an associated alarming increase in the number and severity of road accidents. In addition to relatively simple toll systems and traffic routing/flow control, the escalating number of fatalities[8], and increasing economic cost of injuries, traffic disruption and other impacts, has prompted technology developments aimed at collision avoidance and safe driving capabilities, along with a variety of other driver information services. These developments are eventually likely to lead to driverless vehicles which communicate amongst each other and other surrounding entities.

In response, various road-safety related projects have been commenced around the world, notable research is underway in many countries, and several ITS technologies are starting to attract interest of roads authorities, governments and relevant industry sectors in many countries.

As shown in Figure 1, the vehicular communications portion of ITS is now envisaged to involve four distinct scenarios: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N), and Vehicle-to-Person (V2P) – and often collectively referenced as Vehicle-to-everything (V2X):

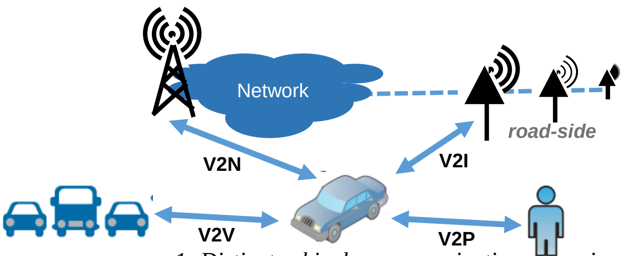


Figure 1: Distinct vehicular communication scenarios

Global consensus now appears to be emerging on the frequency band proposed to be used for wireless ITS systems, especially the crucial V2V and V2I links. Although there are some differences in actual bandwidth and frequency range, the 5850-5925 MHz band is generally seen to be attracting widespread global support for hosting the future wireless ITS systems. General agreement on this

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[8] Accident and injury/fatality rates in many countries are so significant that the World Health Organisation now considers road accidents to be a global public health issue:
[http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/]

band will enable vehicle manufacturers, road infrastructure providers and relevant national authorities to adopt a common approach to implementing wide-area ITS systems.

However, there are two main contenders for the wireless ITS communications role, and the question of efficient usage of a harmonized spectrum resource by the two main technology contenders, is now arising as administrations commence planning for initial deployments. The implementation of wide-area ITS systems may involve choosing the most suitable wireless technology for use by vehicles and infrastructure throughout the intended operations area.

2. Technology Options

The two major contenders for the wireless ITS communications role rely on differing signal waveforms and air-interface protocols:

3GPP C-V2X – see section 5 in this report.

IEEE 802.11p– also known as Digital Short Range Communications (DSRC) in some countries, commenced development about 15 years ago. Led by the global Institute of Electrical and Electronic Engineers (IEEE) technical standards body, this technology is a derivative of the popular unlicensed 802.11 (Wi-Fi) technology, and has attracted investment by a number of electronic chipset makers, equipment vendors, and automobile manufacturers. While a number of trials have been undertaken, there appear to be no commercial systems yet in operation.

Industry stakeholders are currently divided in regard to the choice of ITS technology. At least one auto-manufacturer has announced development of in-vehicle devices based on 802.11p chip-sets[9], and appears to be seeking to encourage wider adoption of that technology by peers/competitors and national administrations – possibly to avoid additional development costs associated with the C-V2X technology. On the other hand, in early-2017 the 5G Automotive Association (5GAA) was formed, including car manufacturers, and a growing number of ICT companies, and is promoting C-V2X and 5G applications to vehicle connectivity. [10].

From a national spectrum planning perspective, it is therefore prudent for administrations to take a *technology-neutral* approach to planning of the 5850-5925 MHz band which allows for either technology to demonstrate its respective benefits and market value.

[9]https://www.volkswagen-media-services.com/en/detailpage/-/detail/With-the-aim-of-increasing-safety-in-road-traffic-Volkswagen-will-enable-vehicles-to-communicate-with-each-other-as-from-2019/view/5234247/7a5bbec13158edd433c6630f5ac445da?p_p_auth=I98AdbHg
[10]http://sites.ieee.org/connected-vehicles/2017/04/26/5gaa-joins-3gpp/