

MCMC MTSFB TC G049:2025

# TECHNICAL CODE

## CELLULAR VEHICLE-TO-EVERYTHING (C-V2X) - SYSTEM ARCHITECTURE AND SPECIFICATIONS

Developed by



Registered by



Registered date: 27 February 2025

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### **Committee representation**

This technical code was developed by the Vehicle-to-Everything (V2X) Sub Working Group under the International Mobile Telecommunications and Future Networks (IFN) Working Group of the Malaysian Technical Standards Forum Bhd (MTSFB), which consists of representatives from the following organisations:

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Cyberview Sdn Bhd

Maxis Broadband Sdn Bhd

Orbitage Sdn Bhd

TM Technology Services Sdn Bhd

UCSI Education Sdn Bhd

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## **Foreword**

This technical code for Cellular Vehicle-to-Everything (C-V2X) System Architecture and Specifications (‘this Technical Code’) was developed pursuant to Section 185 of the Communications and Multimedia Act 1998 (Laws of Malaysia Act 588) by the International Mobile Telecommunications and Future Networks Working Group of the Malaysian Technical Standards Forum Bhd (MTSFB).

This Technical Code shall continue to be valid and effective from the date of its registration until it is replaced or revoked.

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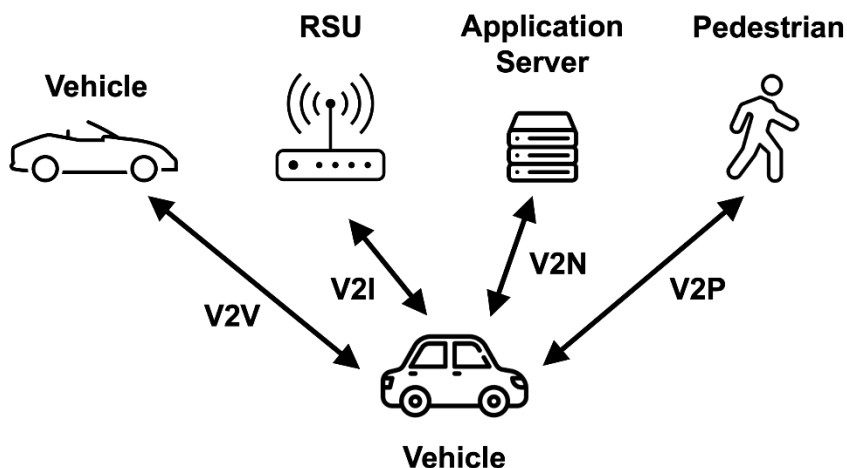
## CELLULAR VEHICLE-TO-EVERYTHING (C-V2X) - SYSTEM ARCHITECTURE AND SPECIFICATIONS

### 0. Introduction

In anticipation of introduction of Vehicle-to-Everything (V2X) technologies in Malaysia, there is a need to develop the technical code relevant to specify the underlying system architecture and technologies for the Vehicle-to-Everything (V2X) covering cellular technologies as specified in the scope.

The V2X applications in the present specification, referred to as Vehicle-to-Everything (V2X), contain the following four different types as specified in 3GPP TS 22.185:

- a) Vehicle-to-Vehicle (V2V);
- b) Vehicle-to-Infrastructure (V2I);
- c) Vehicle-to-Network (V2N); and
- d) Vehicle-to-Pedestrian (V2P).



**Figure 1. Types of V2X applications**

Figure 1 shows the four types of V2X applications that can collaborate through 'co-operative awareness' to provide smarter services for end users. This allows vehicles, road infrastructure, application servers, and pedestrians to collect local environmental data from sensors in the vicinity or from other vehicles. This enables more advanced services such as autonomous driving, vehicle warnings, and enhanced traffic management.

The impact on economic is anticipated with the establishment of the technology requirements and specification in realising the V2X in Malaysia. The V2X can help in optimising routes to avoid delay in supply chain and high cost of transportation.

This Technical Code can increase confidence level particularly to drivers, passengers and pedestrians as Malaysia can facilitate the required V2X ecosystem that can improve traffic safety and reduce traffic congestion.

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In addition to that, this Technical Code is useful as a reference to the car manufacturers, network operators, government agencies, private companies and universities on the V2X specification and network environment.

## **1. Scope**

This Technical Code specifies system architecture and specifications for Cellular-V2X (C-V2X) based on terrestrial radio for IMT-2020.

## **2. Normative references**

The following normative references are indispensable for the application of this Technical Code. For dated references, only the edition cited applies. For undated references, the latest edition of the normative references (including any amendments) applies.

Refer to Annex A.

## **3. Abbreviations**

For the purpose of this Technical Code, the following abbreviations apply:

See Annex B.

## **4. Terms and definitions**

For the purposes of this Technical Code, the following terms and definitions apply.

### **4.1 5G NR (New Radio)**

A new radio access technology developed by the 3rd Generation Partnership Project for the 5G mobile network.

### **4.2 Cellular Vehicle-to-Everything (C-V2X)**

A specific implementation of V2X using cellular technology.

### **4.3 Evolved Universal Terrestrial Radio Access (E-UTRA)**

Air interface of Long Term Evolution (LTE) for communications.

### **4.4 Evolved Universal Terrestrial Radio Access Network (E-UTRAN)**

LTE communication from UE to radio access network infrastructure.

### **4.5 Next Generation Radio Access Network (NG-RAN)**

A radio access technology is designed to work with 5G core network that enhanced capabilities of the network.

#### **4.6 PC5**

LTE Sidelink for a direct communication interface that connects vehicles to other vehicles, smart infrastructure and pedestrians without the need for a base station.

#### **4.7 On-Board Unit (OBU)**

A C-V2X transceiver that is normally mounted in or on a vehicle, a mobile unit, or is integrated in a portable unit. An OBU can be operational while the vehicle or the portable unit is either in motion or stationary. The OBUs receive and transmit on one or more Radio-Frequency (RF) channels.

#### **4.8 Relay**

A function in the 5G new radio or Roadside Unit (RSU) that passes on the communication information/data from one vehicle to traffic vehicle at the network edge without needing to send it back to the network. This also reduces the latency on the transferal of data between vehicles.

#### **4.9 Roadside Unit (RSU)**

A stationary infrastructure entity supporting V2X applications that can exchange messages with other entities supporting V2X applications. RSU is a term frequently used in existing ITS specifications. RSU is a logical entity that supports V2X application logic using the functionality provided by either a 3GPP network or an UE.

#### **4.10 Uu Interface**

Air interface communication that connects a UE to cellular base stations and mobile core networks

#### **4.11 Vehicle-to-Devices (V2D)**

Vehicle connected to mobile devices, host computers and navigation units in the vehicle.

#### **4.12 Vehicle-to-Infrastructure (V2I)**

Vehicles interact with infrastructure components such as traffic lights, through RSU.

#### **4.13 Vehicle-to-Network (V2N)**

Vehicles connect to network systems including cloud platform and smart grid for expansive data exchange.

#### **4.14 Vehicle-to-Pedestrian (V2P)**

Specific case of V2D communication when the vehicle communicates with a nomadic device associated with a pedestrian.

#### **4.15 Vehicle-to-Vehicle (V2V)**

Vehicles in proximity to each other exchanging vital information, such as location, speed and warning derived from on-board units.

#### **4.16 Vehicle-to-Everything (V2X)**

A general communication technology that enables vehicles to exchange information with each other, with infrastructure, with pedestrians, and with networks.

## 5. V2X Applications

### 5.1 Vehicle-to-Vehicle (V2V) applications

V2V communication involves the wireless transmission of data between vehicles. The primary aim of V2V communication is to enable surrounding vehicles to exchange useful information through broadcasting. These applications allow vehicles to transmit messages containing critical data such as traffic dynamics, location, and vehicle attributes as depicted in 3GPP TS 22.185.

One example of a V2V application, as highlighted in ITU-T X.1372, is the transmission of warnings to alert vehicles of potential risks. For instance, Figure 2 illustrates a scenario where a forward accident alert is broadcast from one vehicle to others, spreading the warning rearward to notify vehicles behind of potential hazards. Similarly, Figure 3 shows a situation where an emergency vehicle, such as an ambulance, approaches from behind. A warning message is sent forward to nearby and ahead vehicles, prompting them to take proactive measures such as adjusting their speed or moving aside to ensure a safe and clear passage for the emergency vehicle. Both scenarios demonstrate how V2V communication helps manage traffic and enhance safety by sharing critical information in real-time. More examples of V2V applications can be referred in ITU-T X.1372.

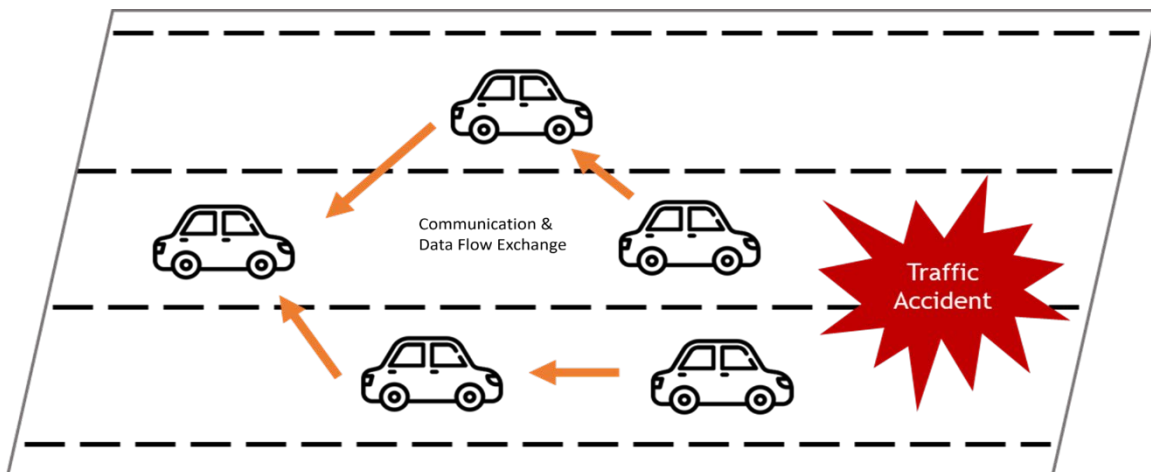


Figure 2. V2V warning propagation - rearward propagation

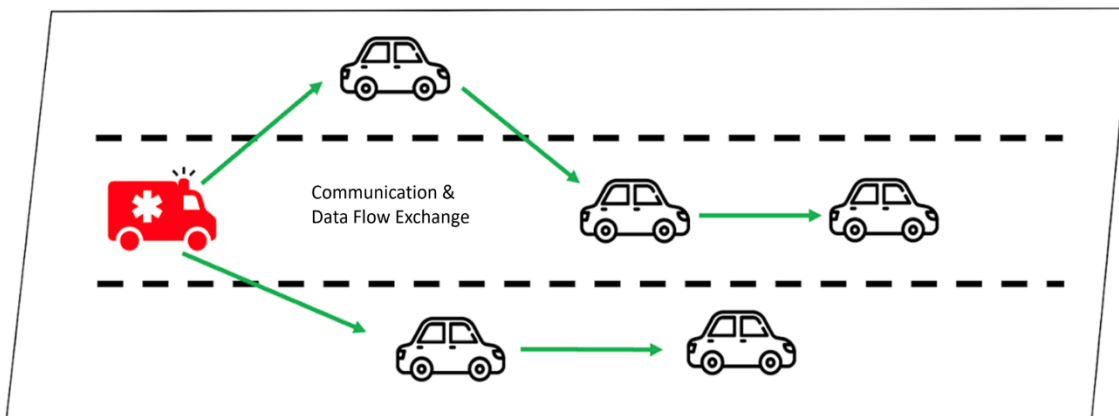


Figure 3. V2V warning propagation - forward propagation

## 5.2 Vehicle-to-Infrastructure (V2I) application

Vehicle-to-Infrastructure (V2I) communication refers to the wireless exchange of data between vehicles and infrastructure, such as a roadside unit (RSU). The primary aim of V2I is to enhance road safety, improve traffic efficiency, and enable smarter transportation systems.

One of the V2I applications, as highlighted in ITU-T X.1372, is the warning scenario that facilitates communication between a vehicle and infrastructure, such as RSUs. For example, in Figure 4, if a traffic accident occurs at an intersection, an RSU can send a warning message to vehicles approaching the intersection. Additionally, V2I warnings can notify vehicles about proximity issues when negotiating lane entries, such as right or left turns, and confluent points. More examples of V2I applications can be referred in ITU-T X.1372.

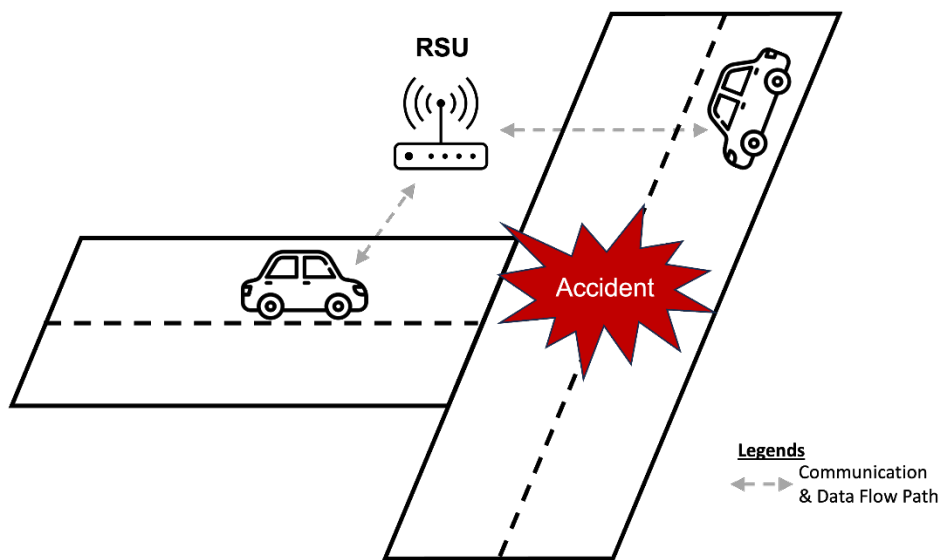


Figure 4. V2I warning

## 5.3 Vehicle-to-Network (V2N) application

Vehicle-to-Network (V2N) communication refers to the connection between vehicles and network systems, enabling vehicles to exchange information with application server. The primary aim of V2N is to enhance the efficiency and safety of transportation by allowing vehicles to access real-time data and services that improve their operation and the overall driving experience.

One of the V2N applications is the ability to enhance safety in critical situations through real-time communication between vehicles and emergency services. For example, in Figure 5, during an accident, the vehicle can automatically transmit its location and status to emergency services. This rapid interaction enables a swift response from first responders, significantly improving road safety.

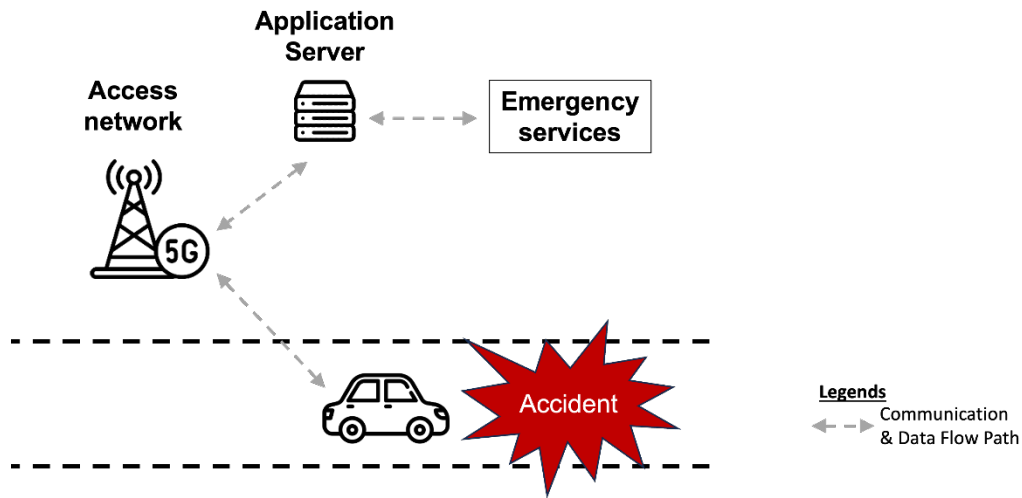


Figure 5. V2N emergency call scenario

#### 5.4 Vehicle-to-Pedestrian (V2P) application

Vehicle-to-Pedestrian (V2P) communication focuses on exchanging information between vehicles and nomadic devices used by pedestrians in close proximity. V2P applications facilitate the exchange of messages containing relevant information between vehicles and pedestrians' devices, either directly or with the support of an RSU or an application server, depending on the scenario [3GPP TS 22.185]. The primary aim of V2P is to improve safety by increasing awareness between vehicles and nearby pedestrians.

Figure 6 illustrates how V2P communication enables vehicles to alert pedestrians about their presence and potential hazards, while pedestrians can receive notifications about approaching vehicles, enhancing safety for both parties.

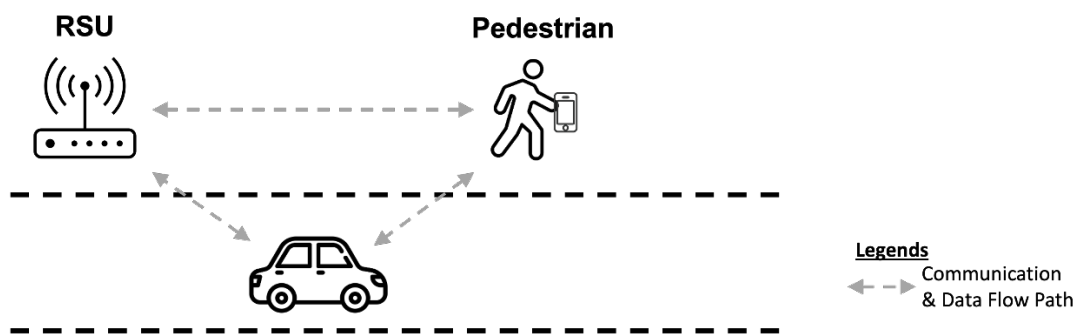


Figure 6. V2P scenario example

V2P is a specific case of V2D, which V2D communication refers to the exchange of data between a vehicle and external devices such as smartphones, wearables, or laptops. The details of V2D can be found in ITU-T X.1372.

## 6. V2X requirements

V2X works in 5G Standalone (SA) and Non-Standalone (NSA) networks as seen in Figure 7. In NSA mode, devices are attached to 5G-NR at gNB and send the signal to EPC directly or through 4G eNB. In 5G NSA, Dual Connectivity (DC) refers to a UE connected to two different cellular networks for data transmission, namely the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) for LTE network and Next Generation Radio Access Network (NG-RAN) for 5G network. While in SA mode, signals are sent directly to the 5G core (5GC). The NG-RAN is the radio access network that provides wireless connectivity between UE and the core 5G network. In the context of V2X, the UE can be an on-board unit (OBU) in the vehicle. Typically, the SA network is for critical applications, whereas the NSA network is for non-critical applications. More details on V2X architecture will be presented in Clause 6 of this Technical Code.

For managing delay-sensitive V2X applications, mobile edge computing, now denominated as Multi-Access Edge Computing (MEC), was brought to light. With cloud resources brought closer to the edge of the network, MEC greatly reduces task offloading delay, thereby striving to satisfy the constraints of real-time applications. As highly demanding mobile applications, vehicular networks are a target to be addressed in terms of performance, especially communication and computation delay. The latest V2X architectures unveil the mechanisms behind the improved performance, network availability and coverage, reliability and loss of network connectivity, large data handling and task offloading.

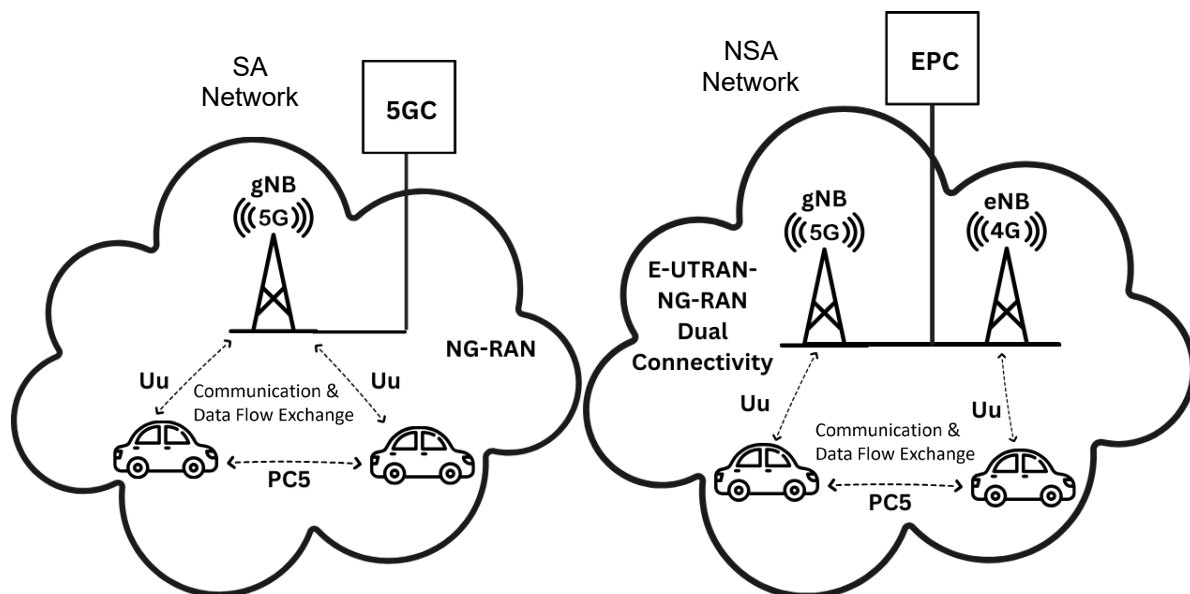


Figure 7. Overview of V2X in 5G networks

### 6.1 Overall requirements

The overall requirements for network elements supporting V2X applications are specified in Table 1. It covers the requirements identified for different network elements, which are UE, RSU, LTE transport and EPS/5G.

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**Table 1. Requirements for network elements in supporting V2X applications**

Network elements	Requirements
UE	<ul style="list-style-type: none"> <li>a) Shall be able to be pre-configured by the 3GPP network with parameters to be used for the transmission and reception of messages when V2X communication is not served by E-UTRAN/NG-RAN.</li> <li>b) Shall be able to transmit and receive messages when V2X communication is served or not served by E-UTRAN.</li> <li>c) Shall be able to identify the support of V2X communication by E-UTRAN.</li> <li>d) Should minimise the impact on resources (e.g., battery consumption) due to message transfer when resources (e.g. battery) are limited.</li> </ul>
RSU	<ul style="list-style-type: none"> <li>a) Shall be able to transmit or receive messages to or from a UE supporting V2X application.</li> <li>b) Should be able to communicate with up to 200 UEs supporting a V2X application when served by NG-RAN.</li> </ul>
LTE Transport	<ul style="list-style-type: none"> <li>a) Message transmission shall be under control of the 3GPP network when the transmitting UE is served by the E-UTRAN/NG-RAN.</li> <li>b) Shall support message transfer between UEs when served or not served by the same Public Land Mobile Network (PLMN) supporting V2X communications.</li> <li>c) Shall be able to provide means to prioritise message transmission among UEs supporting V2X application.</li> <li>d) Shall be able to provide means to prioritise message transmission according to the type (e.g., safety vs. non-safety).</li> <li>e) Shall be able to vary the transmission rate and range of the V2X communication based on service conditions (e.g., UE speed, UE density).</li> <li>f) Shall be able to provide resource-efficient information distribution to large numbers of UEs supporting V2X application.</li> <li>g) Shall be able to provide means for an application server and the RSU to control the area and the size of the area message distribution.</li> <li>h) Shall be able to provide message distribution from a UE supporting V2X application to locally relevant application servers.</li> <li>i) Shall be able to support a high density of UEs supporting V2X application.</li> <li>j) Shall be able to charge for network resource usage when messages are transferred by a UE supporting V2X application (i.e., HPLMN and VPLMN operators).</li> <li>k) Should make available any supported positional accuracy improvement techniques (e.g., DGPS and/or OTDOA) in a resource-efficient way to a subscribed UE supporting V2X application.</li> </ul>
EPS/5G	<ul style="list-style-type: none"> <li>a) Shall be able to control the communication range for a message based on the characteristics of the messages transmitted by a UE supporting V2X application.</li> <li>b) Shall be able to optimise the communication between UEs supporting V2X application belonging to the same group and in proximity.</li> <li>c) Shall be able to support the message transfer for group management operations as requested by the application layer.</li> <li>d) Shall be able to support message transfer among a group of UEs supporting V2X application.</li> <li>e) Shall be able to support message transfer between two UEs belonging to the same group of UEs supporting V2X application.</li> <li>f) Shall be able to support confidentiality and integrity of message transfer among a group of UEs supporting V2X application.</li> <li>g) Shall support relative lateral position accuracy of 0.1 m between UEs supporting V2X application.</li> <li>h) Shall support high connection density for congested traffic.</li> </ul>

Table 1. Requirements for network elements in supporting V2X applications (continued)

Network elements	Requirements
EPS/5G	<ul style="list-style-type: none"> <li>i) Shall support efficient coordination of radio resources used for message transport to maximise the utilisation of the available spectrum and to ensure the required reliability.</li> <li>j) Shall be able to control the Uplink (UL) and Downlink (DL) reliability of transport of V2X communications, depending on the requirement of V2X application.</li> <li>k) Shall be minimal impact to E-UTRAN by UE supporting only NR-based V2X communication.</li> <li>l) Shall be minimal impact to NR by UE supporting only E-UTRA-based V2X communication.</li> <li>m) Shall be able to support message transfer between UEs or between a UE and a UE-type RSU, regardless of whether or not they are subscribers of the same PLMN supporting V2X communications. In case they are subscribers to different PLMNs, there shall be no service degradation of the message transfer.</li> <li>n) Shall enable discovery and communication between UEs supporting the same V2X application.</li> <li>o) Shall be able to support the operators in the selection of 3GPP Radio Access Technology (RAT) to use for a V2X application.</li> <li>p) Shall enable a UE supporting a V2X application to obtain network access via another UE supporting V2X application.</li> <li>q) Shall enable a UE supporting a V2X application to discover another UE supporting V2X application that can offer access to the network.</li> <li>r) 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.</li> <li>s) Shall be able to support confidentiality and integrity of message transfer between a UE supporting a V2X application and network, when the UE is using an indirect 3GPP connection.</li> <li>t) Shall allow UEs supporting V2X application to use NR for direct communication when the UEs are not served by a RAN using NR.</li> <li>u) Shall be allow UEs supporting V2X application to use E-UTRA for direct communication when the UEs are not served by a RAN using E-UTRA.</li> <li>v) Should be able to support confidentiality and integrity of message transfer between a UE supporting V2X application and a V2X application server.</li> <li>w) Shall provide addressing information mechanism (e.g., IP address or FQDN) of V2X application server(s) to the UEs supporting V2X applications.</li> <li>x) Shall allow the UE to use simultaneous multiple 3GPP RATs (i.e., NR &amp; E-UTRA) for direct communication.</li> </ul>

## 6.2 Specific service V2X requirements

This clause covers specific service requirements as specified in 3GPP TS 22.185 applicable to 5G NSA and SA architecture with reference to MCMC MTSFB G027.

### 6.2.1 Latency and reliability requirements

Latency requirements refer to the maximum tolerable elapsed time from the instant a data packet is generated at the source application to the instant it is received by the destination application. Low latency values are provided to support services in the case of mutual awareness of the vehicle or to send warning messages as defined in some use cases in 3GPP TR 22.885.

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Reliability requirements refer to the maximum tolerable packet loss rate at the application layer and a packet is considered lost if it is not received by the destination application within the maximum tolerable end-to-end latency for that application.

Table 2 lists the maximum latency and reliability of E-UTRA(N) message transfer for different communication category.

**Table 2. E-UTRA(N) message transfer maximum latency and reliability**

Communication Category	Definition	Maximum latency	Reliability
V2V or V2P	Shall be capable of transferring messages between two UEs supporting V2V or V2P application, directly or via an RSU	100 ms (source to destination)	Shall be able to support high reliability without requiring application-layer message retransmissions.
V2V or V2P (critical safety)	Should be capable of transferring messages between two UEs supporting V2V for particular usage (e.g., pre-crash sensing) only	20 ms (source to destination)	
V2I	Shall be capable of transferring messages between a UE supporting V2I application and an RSU	100 ms (source to destination)	
V2N	Shall be capable of transferring messages via 3GPP network entities between a UE and an application server both supporting V2N application	1000 ms (end-to-end delay)	

### 6.2.2 Message size requirements

The requirements of message size for both periodic broadcast and event-triggered messages are listed in Table 3.

**Table 3. E-UTRA(N) variable payload size**

Message type	Message size (not including security-related message component)
Periodic broadcast messages	Shall be capable of transferring variable message payloads of 50-300 bytes
Event-triggered messages	Shall be capable of transferring variable message payloads of up to 1200 bytes

### 6.2.3 Message transfer frequency requirements

Frequency requirements refer to the minimum required bit rate for the application to function correctly. The maximum frequency for all message types is shown in Table 4.

**Table 4. E-UTRA(N) message transfer frequency**

Message type	Maximum frequency
All	Shall be able to support 10 messages per second per transmitting UE

### 6.2.4 Range requirements

Range requirements refer to the maximum distance between source and destination(s) of a radio transmission within which the application should achieve the specified reliability.

Due to the limitation of 4G network, the E-UTRAN shall be capable of supporting a communication range sufficient to give the driver(s) ample response time (e.g., 4 seconds for non-critical V2X applications).

**6.2.5 Speed requirements**

Absolute velocity refers to the actual speed of the vehicle in relation to a stationary point of reference. Meanwhile, the relative velocity refers to the speed of the vehicle compared to the speed of another vehicle, applicable in the V2V communication category. For example, if two vehicles are travelling at 250 km/h but in opposite directions, the relative speed between the vehicles is 500 km/h. The speed requirements in Table 5 should be supported regardless of whether the UE(s) are served or not served by E-UTRAN supporting V2X communication.

**Table 5. Support of UE speed for V2X communication**

Communication Category	Maximum velocity
V2V	Should be capable of transferring messages while the maximum relative velocity of the UEs is 500 km/h
V2V and V2P	Should be capable of transferring messages while the maximum absolute velocity is 250 km/h
V2I	Should be capable of transferring messages while the maximum absolute velocity is 250 km/h

**6.2.6 Security requirements**

To ensure the ecosystem security, the trustworthiness and resilience of the V2X information need to be protected against all form of threats and risks. Prevention measure needs to be in place to anticipate any unauthorised access, disruption, modification, or destruction of any data. Table 6 below shows the types of security requirements for V2X specified by 3GPP TS 33.185 and 3GPP TS 33.356.

**Table 6. Types of security services supported by 3GPP V2X system**

Security service	Details
Authorisation	<ul style="list-style-type: none"> <li>a) Mobile Network Operator (MNO) shall authorise a UE supporting V2X application to perform V2X communication when served by E-UTRAN supporting V2X communication.</li> <li>b) MNO shall authorise UEs supporting V2X application separately to perform V2N communication.</li> <li>c) A clearly define access control should be in place.</li> </ul>
Pre-authorisation	<ul style="list-style-type: none"> <li>a) MNO shall authorise a UE supporting V2X application to perform V2X communication when not served by E-UTRAN supporting V2X communication.</li> </ul>
Integrity	<ul style="list-style-type: none"> <li>a) Shall support integrity protection of the transmission for a V2X application. Messages should be free from any unauthorized modification.</li> </ul>

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**Table 6. Types of security services supported by 3GPP V2X system (continued)**

Security service	Details
Confidentiality	a) Unauthorised entity should not be able to interpret messages between vehicles, infrastructures, pedestrians and other nomadic devices. A cryptographic algorithm such as AES, SHA-256, should be in place. b) Should support pseudonymity and privacy of a UE using the V2X application, by ensuring that a UE identity cannot be tracked or identified by any other UE beyond a certain short time-period required by the V2X application, subject to regional regulatory requirements and/or operator policy for a V2X application. c) Should support pseudonymity and privacy of a UE in the use of a V2V/V2I application, such that no single party (operator or third party) can track a UE identity in that region, subject to regional regulatory requirements and/or operator policy for a V2V/V2I application.
Availability	a) Access by authorised entity to the information should be accessible when required.
Non-repudiation	a) An entity should be able to deny it's previous messages.

In addition, the recommendation ITU-T X.1372 also provides security guidelines for V2X's security requirements (e.g., confidentiality, integrity, availability, non-repudiation, authenticity, accountability, and authorisation), threats identification, and implementation strategies (e.g., encryption, digital signature, platoon registration, and vehicular public-key infrastructure's certificates and revocation).

### 6.3 Categories of requirements to support V2X scenarios using EPS/5G transport

This section covers V2X scenarios service requirements as specified in 3GPP TS 22.186 related to EPS/5G transport, applicable to 5G SA architecture.

#### 6.3.1 Requirements to support vehicles platooning

Vehicles platooning enables a group of vehicles to travel together in a dynamic manner. The platoon operation requires all the following vehicles to receive periodic data from the leading vehicle to ensure that the gap distance between vehicles is extremely small. The following vehicles can be autonomously driven in platooning applications. Vehicle platooning shall support up to 5 UEs for a group of UEs supporting V2X application. However, the number of UEs in a platoon can be smaller for group of heavy goods vehicle platooning due to limitations related to the communication range, the length of truck, inter-truck distance. The performance requirements for vehicles platooning are listed in Table 7, referenced from the 3GPP TS 22.186 (version 16.2.0 Release 16) or ETSI TS 122 186 V16.2.0 (2020-11).

Table 7. Performance requirements for vehicles platooning

Degree of automation	Payload (B)	Tx rate (Message/s)	Max end-to-end latency (ms)	Reliability <sup>4</sup> (%)	Data rate (Mbps)	Min required communication range <sup>5</sup> (m)
<b>Communication scenario description:</b> Cooperative driving for vehicle platooning information exchange between a group of UEs supporting V2X application.						
Lowest	300-400 <sup>1</sup>	30	25	90	N/A	N/A
Low	6 500 <sup>2</sup>	50	20	N/A	N/A	350
Highest	50-1200 <sup>3</sup>	30	10	99.99	N/A	80
High	N/A	N/A	20	N/A	65 <sup>2</sup>	180
<b>Communication scenario description:</b> Reporting needed for platooning between UEs supporting V2X application and between a UE supporting V2X application and RSU.						
N/A	50-1200	2	500	N/A	N/A	N/A
<b>Communication scenario description:</b> Information sharing for platooning between UE supporting V2X application and RSU.						
Lower	6 000 <sup>3</sup>	50	20	N/A	N/A	350
Higher	N/A	N/A	20	N/A	50 <sup>3</sup>	180
Notes.						
1 This value is applicable for both triggered and periodic transmission of data packets.						
2 The data that is considered in this V2X scenario includes both cooperative manoeuvres and cooperative perception data that could be exchanged using two separate messages within the same period of time (e.g., required latency 20 ms).						
3 This value does not include security related messages component.						
4 Sufficient reliability should be provided even for cells having no value in this table.						
5 This is obtained considering UE speed of 130km/h. All vehicles in a platoon are driving in the same direction.						

### 6.3.2 Requirements to support advanced driving

Advanced driving involves longer inter-vehicle distance compared to platooning application to enable semi-automated or fully automated driving. The vehicles coordination of trajectories or manoeuvres is dependent on sharing of data obtained from each vehicle and/or RSU with vehicles in proximity. Each vehicle also needs to share its driving intention with other vehicles in proximity. This group of use case, shown in Table 8, will offer safer traveling, collision avoidance, and improved traffic efficiency benefits. The performance requirements are referenced from the 3GPP TS 22.186 document (version 16.2.0 Release 16).

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Table 8. Performance requirements for advanced driving

Degree of automation	Payload (B)	Tx rate (Message/s)	Max end-to-end latency (ms)	Reliability <sup>4</sup> (%)	Data rate (Mbps)	Min required communication range <sup>5</sup> (m)
<b>Communication scenario description:</b> Cooperative collision avoidance between UEs supporting V2X applications.						
N/A	2 000 <sup>5</sup>	100 <sup>5</sup>	10	99.99	10 <sup>1</sup>	N/A
<b>Communication scenario description:</b> Information sharing for automated driving between UEs supporting V2X application.						
Lower	6 500 <sup>1</sup>	10	100	N/A	N/A	700
Higher	N/A	N/A	100	N/A	53 <sup>1</sup>	360
<b>Communication scenario description:</b> Information sharing for automated driving between UE supporting V2X application and RSU						
Lower	6 000 <sup>1</sup>	10	100	N/A	N/A	700
Higher	N/A	N/A	100	N/A	50 <sup>1</sup>	360
<b>Communication scenario description:</b> Emergency trajectory alignment between UEs supporting V2X application.						
N/A	2 000 <sup>5</sup>	N/A	3	99.999	30	500
<b>Communication scenario description:</b> Intersection safety information between an RSU and UEs supporting V2X application.						
N/A	UL: 450	UL: 50	N/A	N/A	UL: 0.25 <sup>2</sup> DL: 50 <sup>2</sup>	N/A
<b>Communication scenario description:</b> Cooperative lane change between UEs supporting V2X applications.						
Lower	300-400	N/A	25	90	N/A	N/A
Higher	12 000	N/A	10	99.99	N/A	N/A
<b>Communication scenario description:</b> Video sharing between a UE supporting V2X application and a V2X application server.						
N/A	N/A	N/A	N/A	N/A	UL: 10	N/A
Notes.						
1 This includes both cooperative manoeuvres and cooperative perception data that could be exchanged using two separate messages within the same period of time (e.g., required latency 100 ms).						
2 This value is referring to a maximum number of 200 UEs. The value of 50 Mbps DL is applicable to broadcast or is the maximum aggregated bitrate of all UEs for unicast.						
3 Sufficient reliability should be provided even for cells having no value in this table.						
4 This is obtained considering UE speed of 130 km/h. All vehicles in a platoon are driving in the same direction.						
5 These values are based on calculations for cooperative manoeuvres only.						

### 6.3.3 Requirements to support extended sensors

Local sensors are physically mounted on the vehicle itself, to provide the vehicle with a direct view of its immediate surroundings. However, to enhance vehicle's perception of its environment beyond what its own sensors can detect for a more comprehensive view of the local situation, extended sensors facilitate the exchange of raw or processed data gathered through local sensors or real-time video data among listed below (as depicted in Figure 8):

- a) Vehicles.

- b) RSUs.
- c) Devices of pedestrians.
- d) V2X application servers.

The performance requirements for extended sensors are presented in Table 9.

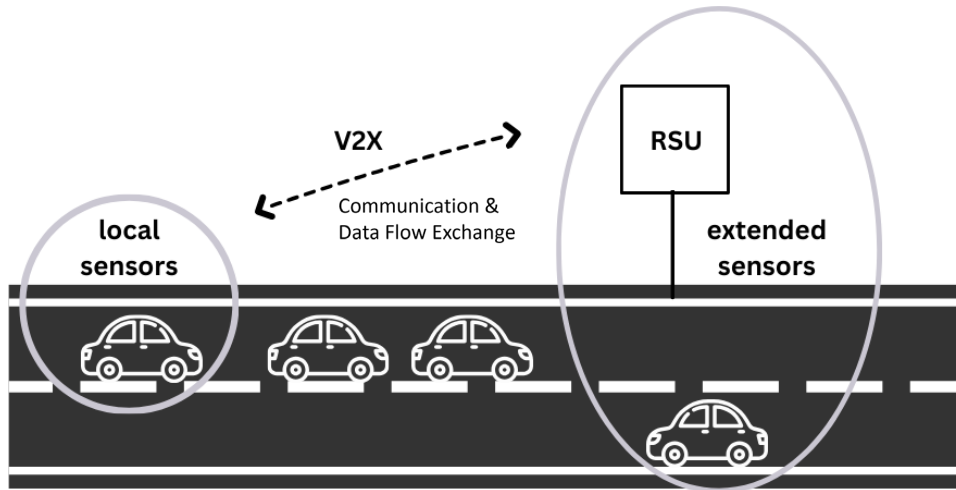


Figure 8. V2X perception based on local and extended sensors

Table 9. Performance requirements for extended sensors

Degree of automation	Payload (B)	Tx rate (Message/s)	Max end-to-end latency (ms)	Reliability (%)	Data rate (Mbps)	Min required communication range (m)
<b>Communication scenario description:</b> Sensor information sharing between UEs supporting V2X application						
Lower	1 600	10	100	99	N/A	1000
Higher	N/A	N/A	10	95	25 <sup>1</sup>	N/A
	N/A	N/A	3	99.999	50	200
	N/A	N/A	10	99.99	25	500
	N/A	N/A	50	99	10	1000
	N/A	N/A	10	99.99	1000	50
<b>Communication scenario description:</b> Video sharing between UEs supporting V2X application						
Lower	N/A	N/A	50	90	10	100
Higher	N/A	N/A	10	99.99	700	200
Notes.						
1 This is peak data rate.						

### 6.3.4 Requirements to support remote driving

Remote driving enables a remote vehicle to be operated by a remote driver or a V2X application for passengers who cannot drive themselves or for a remote vehicle located in dangerous environments. Cloud computing-based driving can be used when variation is limited and routes are predictable, such as public transportation. Access to cloud-based back-end service platform can also be considered for this use case group. The performance requirements for remote driving is presented in Table 10.

Table 10. Performance requirements for remote driving

Communication scenario description	Max end-to-end latency (ms)	Reliability (%)	Data rate (Mbps)
Information exchange between a UE supporting V2X application and a V2X Application Server	5	99.999	UL: 25 DL: 1

## 7. V2X communication architecture

3GPP has identified V2X concept with enhancements over radio access, protocols, core network to support the categories of vehicular communications, such as V2V, V2D, V2I and V2N. 3GPP Rel-14 introduces 4G enhancements for V2X communications with the enhancement on the EPS. 3GPP Rel-16 extends 5G architecture by offering support for new specific service functionalities for V2X, advancing V2X services and vehicle QoS support, as well as coexisting NR and LTE SL.

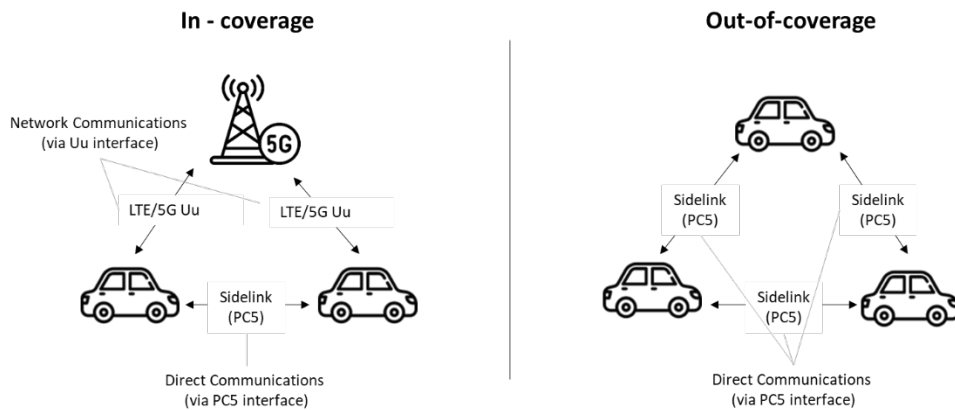


Figure 9. In-coverage and out-of-coverage for V2X communication over PC5 interface

As depicted in 3GPP TS 23.287, there are two modes of operation for single cellular technologies of V2X communication as illustrated in the Figure 9 such as follows:

- a) PC5 interface between UE-to-UE connection.
- b) Uu interface between UE to 5G NR gNB or 4G LTE eNB.

There are 2 modes of operation for V2X communication as listed below:

- a) V2X communication over PC5 Reference Point (RP)

This mode of operation is supported by LTE as depicted from TS 23.285 and/or NR. This direct communications between vehicles (V2V), between vehicles and infrastructure (V2I), and vehicles and other road users, such as cyclists and pedestrians (V2P).

- b) V2X communication over Uu RP

This mode of operation is supported by E-UTRA connected to 5GC and/or NR connected to 5GC (only unicast). This network communications, in which C-V2X employs the conventional mobile network to enable the vehicle to receive information about road conditions and traffic in the area.

These two operation modes may be used by a UE independently for transmission and reception.

7.1 System architecture for V2X communication

There are two types of architecture for V2X communication over PC5 and Uu RP, non-roaming as illustrated in Figure 10 and roaming illustrated in Figures 11 and 12. In the case of roaming, there are two types of 5G architecture for V2X communication scenarios known as local breakout illustrated in Figure 11 and home routed illustrated in Figure 12. Roaming architecture is mainly to support V2X application that required services covering by more than one operator. Local breakout allows the latency sensitive V2X application to able to use edge connectivity towards its application server. This may require agreement between two involved operators. In the case of inter-PLMN V2X communication over PC5 RP, the PC5 parameters need to be configured in a consistent way among the UEs within a certain region. The architecture for the Inter-PLMN PC5 case is similar to the one defined in Figure 11.

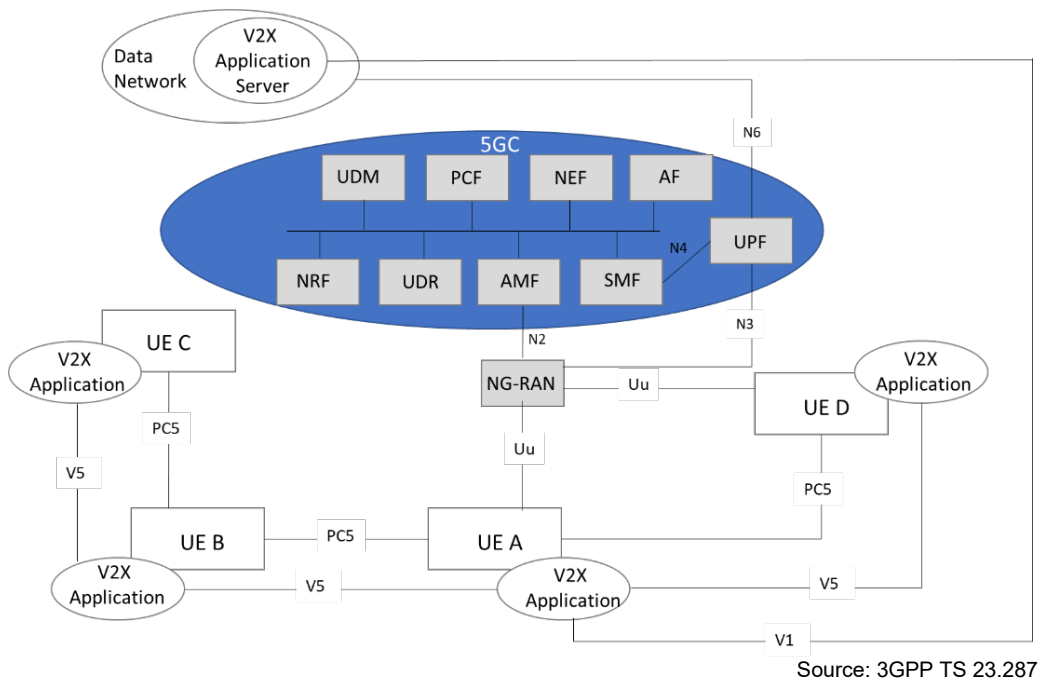
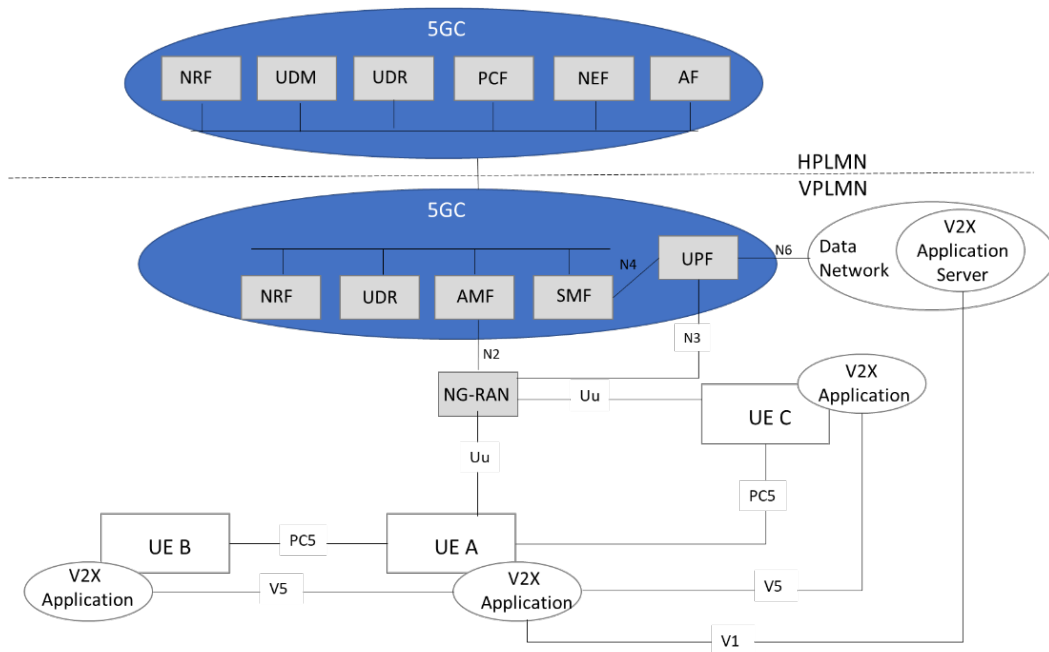


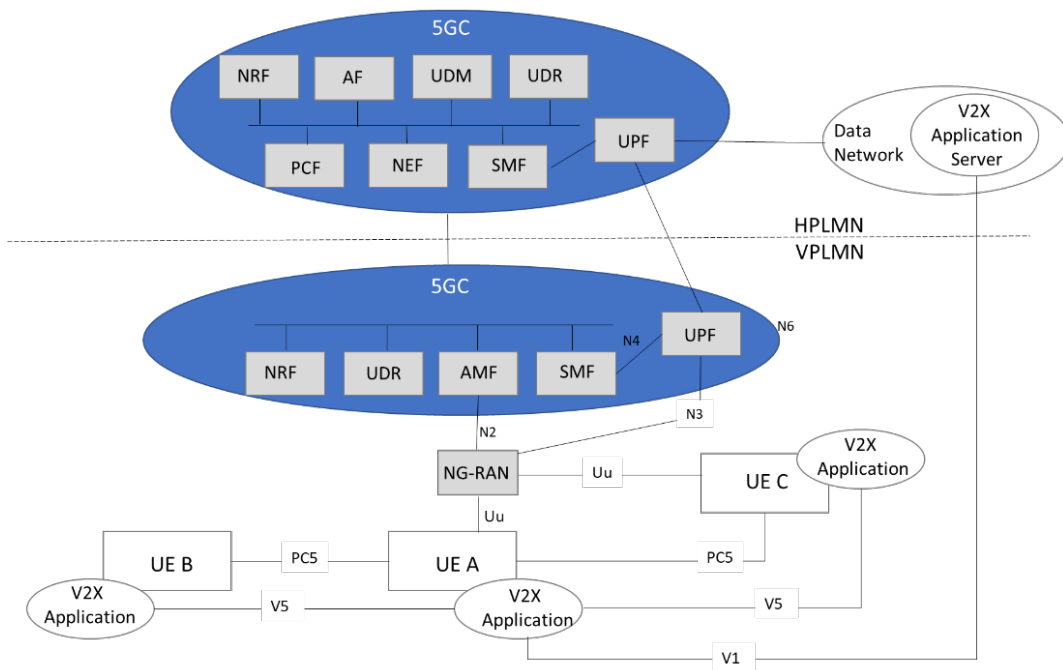
Figure 10. Non-roaming 5G system architecture for V2X communication over PC5 and Uu RP

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Source: 3GPP TS 23.287

Figure 11. Roaming 5G system architecture for V2X communication over PC5 and Uu RP (local breakout scenario)



Source: 3GPP TS 23.287

Figure 12. Roaming 5G system architecture for V2X communication over PC5 and Uu RP (home routed scenario)

7.1.1 AF-based service parameter provisioning for V2X communications

The 5G System provides NEF services to enable communication between NFs in the PLMN and V2X Application Server as illustrated in Figure 13. The V2X Application Server may provide V2X service parameters to the PLMN via NEF. The NEF stores the V2X service parameters in the UDR. The overall network functions of the 5GC can be referred to MCMC MTSFB G027:2023.

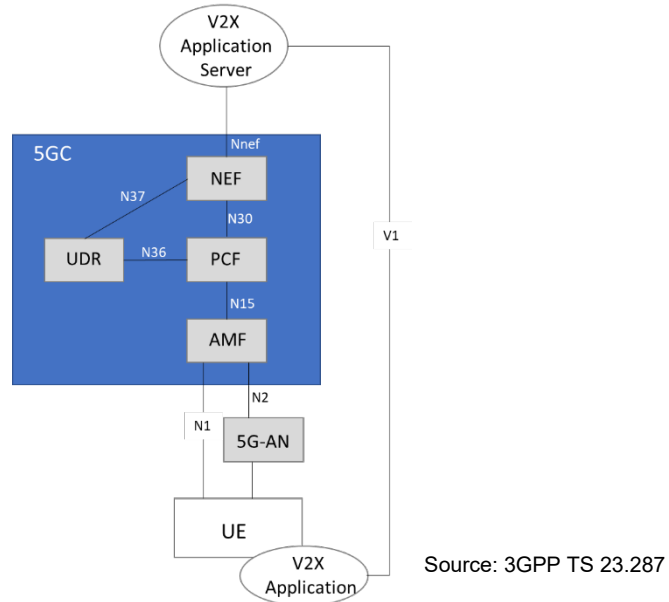


Figure 13. 5G System architecture for AF-based service parameter provisioning for V2X communications

7.1.2 System Architecture Interworking with EPS and 5GS V2X

The interworking between 5GS V2X and EPS V2X does not require any new interface between 5GS V2X and EPS V2X architectures and does not impact existing network function entities in EPC and 5GC.

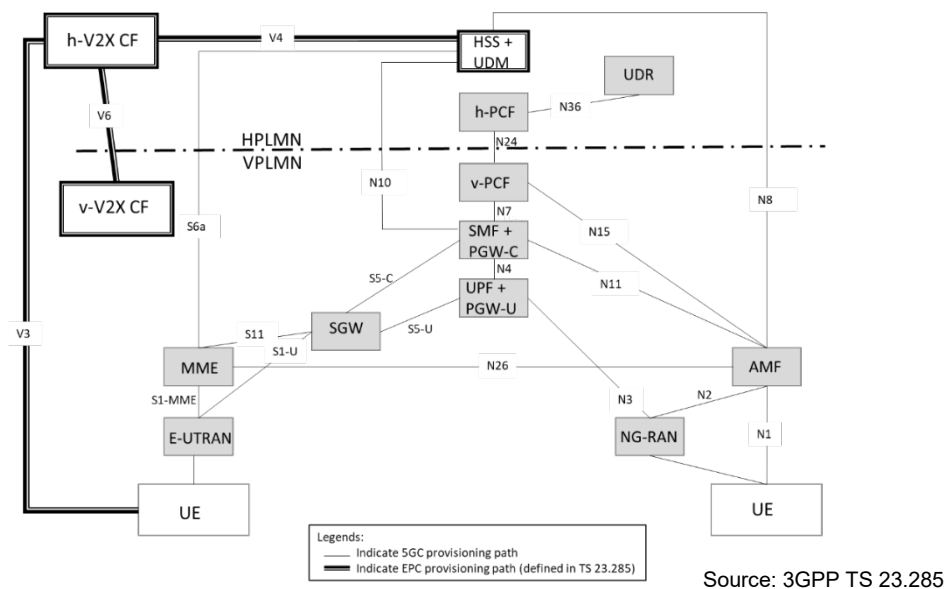
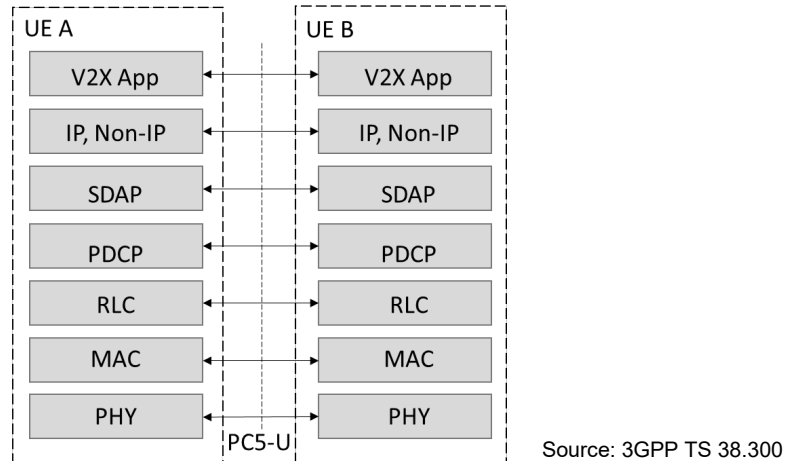


Figure 14. Architecture for interworking with 5GS V2X and EPS V2X (local breakout roaming)

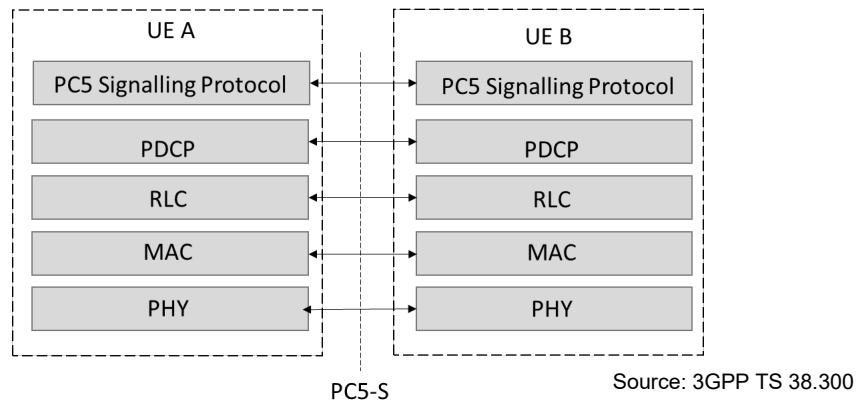
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### 7.2 Protocol stacks for V2X communication over PC5 Reference Point (RP)

Protocol stacks are a layered collection of protocols that work together to provide communication services. The user plane and the control plane protocol stack depicted in 3GPP TS 23.287 are both illustrated in Figure 15 and Figure 16 respectively. The SDAP/PDCP/RLC/MAC/PHY functionality of user plane and the PDCP/RLC/MAC/PHY functionality are both specified in 3GPP TS 38.300.



**Figure 15. PC5 user plane protocol stacks**



**Figure 16. PC5 control plane protocol stacks or PC5 signalling protocol stack**

The details information of Uu RP is referenced to MCMC MTSFB G027:2023.

### 7.3 V2X communication service provisioning

The authorisation and provisioning functions are controlled by PCF on QoS, radio parameters, and configuration parameters supported by the PLMN.

In 5GS, the parameters for V2X communications over PC5 and Uu RPs may be made available to the UE in following ways:

- a) Pre-configured in the ME.
- b) Configured in the UICC.
- c) Preconfigured in the ME and configured in the UICC.

- d) Provided or updated by the V2X application server via PCF and/or V1 RP.
- e) Provided or updated by the PCF to the UE.

If the same parameters described above are provided by different sources, the UE shall consider them in the following priority order:

- a) Provided or updated by the PCF.
- b) Provided or updated by the V2X application server via V1 RP.
- c) Configured in the UICC.
- d) Pre-configured in the ME.

The further details can be obtained from 3GPP TS 23.287, 3GPP TS 24.587, and 3GPP TS 24.588.

#### **7.4 V2X communication operating frequency**

V2X employs 2 complementary transmission modes to enable a very broad range of driving safety features. These modes are:

- a) Direct communications or PC5 interfaces

Operate in the 5.9 GHz frequency band – the Intelligent Transport System (ITS) spectrum that has been identified internationally for safety purposes as depicted in 3GPP TS 38.101. In this mode, V2X works independently from the cellular networks.

- b) Network communications or Uu interfaces

Operates in the spectrum that has been licensed to mobile operators to provide connectivity to their respective users as per 6.4 of MCMC MTSFB TC G027 contains the spectrum identified by ITU for IMT-2020 and 3GPP NR bands for Uu interfaces. Besides, V2X designed to operate concurrent with E-UTRA uplink or downlink on the operating bands combinations as depicted in 3GPP TS 36.101.

Notwithstanding the frequency bands by listed in the relevant 3GPP specifications, the use of the frequency bands for IMT in Malaysia are subject to the relevant instruments issued under the Communications and Multimedia Act 1998 ("Act") and the subsidiary legislations made under the Act including the Communications and Multimedia (Spectrum) Regulations 2000 as well as or other instruments or references, guidelines and regulatory policies, including any revision(s) made to the same thereafter.

#### **7.5 V2X communication over PC5 RP**

The V2X communication over PC5 RP is connectionless with no signalling over PC5 for connection establishment. V2X service communication and V2X message exchange are both carried out between UE over PC5 user plane.

There are three (3) communication modes for V2X communication over PC5 RP:

- a) Broadcast mode V2X communication over PC5 RP is supported over both LTE based PC5 RP and NR based PC5 RP. The broadcast transmission, characterized by transmission and reception of user traffic among UEs in SL.

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- b) Groupcast mode V2X communication over PC5 RP is only supported over NR based PC5 RP and applies to all types of groups, i.e. Application Layer connection-less group and Application Layer managed group. The groupcast transmission, characterised by transmission and reception of user traffic among UEs belonging to a group in SL and support of SL HARQ feedback.
- c) Unicast mode V2X communication over PC5 RP is only supported over NR based PC5 RP. The unicast transmission, characterised by:
  - i) Support of one PC5-RRC connection between peer UEs for the pair.
  - ii) Transmission and reception of control information and user traffic between peer UEs in sidelink.
  - iii) Support of SL HARQ feedback.
  - iv) Support of SL transmit power control.
  - v) Support of RLC AM.
  - vi) Detection of radio link failure for the PC5-RRC connection.

### 7.5.1 Operating mode

V2X communication over PC5 RF is designed for both in-coverage and out-of-coverage as shown in Figure 11.

As depicted in 3GPP TS 36.213, two modes of operation are introduced for LTE:

- a) Mode 3 (managed mode)

The UE requests resources for the V2X service from the eNB. Thus, the LTE-Uu interface is used to communicate the UEs with the eNBs, and the PC5 interface for V2V.

- b) Mode 4 (unmanaged mode)

An autonomous mode in which no communication from the UEs to the network is required, ie, communication is independent and is performed through the PC5 interface, also known as SL.

Similarly, for NR V2X, two transmission modes are defined: SL Mode 1 and SL Mode 2 as mentioned in 3GPP TS 38.300. Such communication modes are known as SL, since it allows establishing a communication link between two devices, without having to carry traffic through a gNB.

- a) SL Mode 1

Similar to LTE V2X Mode 3, the SL resource allocation is provided by the network.

- b) SL Mode 2

Similar to LTE V2X Mode 4, UE decides the SL transmission resources in the resource pool(s) and the UEs can establish a communication link outside the coverage area of gNB.

The summary of V2X for LTE and NR are shown in Table 15.

**Table 15. Summary of V2X for LTE and NR operating modes**

Networks	In-coverage	Out-of- coverage
LTE-V2X	Uu and PC5 (Mode 3)	PC5 (Mode 4)

**Table 15. Summary of V2X for LTE and NR operating modes (continued)**

Networks	In-coverage	Out-of- coverage
NR-V2X	Uu and PC5 (SL Mode 1)	PC5 (SL Mode 2)

**7.5.2 PC5 QoS identifier**

QoS handling for V2X communication over PC5 is based upon the 5QI (5G QoS Indicator) format, with an additional parameter covering range being added. 6.3 of MCMC MTSFB G027:2023 contains 5G QoS Class Identifier (QCI) of Uu interfaces.

Table 16 shows the one-to-one mapping of standardised PC5 QoS Identifier (PQI) values to PC5 QoS characteristics is specified in 3GPP TS 23.287.

**Table 16. One-to-one mapping of standardised PC5 QoS Identifier (PQI) values to PC5 QoS characteristics**

PQI value	Resource type	Default priority level	Packet delay budget (ms)	Packet error rate	Default maximum data burst volume (B)	Default averaging window (ms)	Example services
21	GBR (Note 1)	3	20	10 <sup>-4</sup>	N/A	2 000	a) Platooning between UEs (higher degree of automation) b) Platooning between UE and RSU (higher degree of automation)
22		4	50	10 <sup>-2</sup>	N/A	2 000	Sensor sharing (higher degree of automation)
23		3	100	10 <sup>-4</sup>	N/A	2 000	Information sharing for automated driving – between UEs or UE and RSU (higher degree of automation)
55	Non-GBR	3	10	10 <sup>-4</sup>	N/A	N/A	Cooperative lane change (higher degree of automation)
56		6	20	10 <sup>-1</sup>	N/A	N/A	a) Platooning informative exchange (low degree of automation) b) Platooning (information sharing with RSU)
57		5	25	10 <sup>-1</sup>	N/A	N/A	Cooperative lane change (lower degree of automation)
58		4	100	10 <sup>-2</sup>	N/A	N/A	Sensor information sharing (lower degree of automation)
59		6	500	10 <sup>-1</sup>	N/A	N/A	Platooning (reporting to an RSU)
90	Delay Critical GBR (Note 1)	3	10	10 <sup>-4</sup>	2 000	2 000	a) Cooperative collision avoidance; Sensor sharing (higher degree of automation) b) Video sharing (higher degree of automation)
91		2	3	10 <sup>-5</sup>	2 000	2 000	Emergency trajectory alignment; Sensor sharing (higher degree of automation)

Note 1: GBR and Delay Critical GBR PQIs can only be used for unicast PC5 communications.

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Meanwhile, for QoS handling for V2X communication over Uu RP, the V2X service data can be delivered via non-GBR QoS flow as well as GBR QoS flow (i.e. using the GBR resource type or the delay-critical GBR resource type) as specified in 3GPP TS 23.501.

### **8. V2X use cases in Malaysia**

V2X is an innovative communication system that enables vehicles to exchange real-time information with other vehicles, infrastructure, pedestrians, and the overall transportation ecosystem. The integration of V2X into the nation transportation system will provide significant benefits, including enhanced safety, improved traffic efficiency, reduced congestion, and increased connectivity.

The 5G Automotive Association (5GAA) has produced three volumes of Use Case descriptions, the Use Case Service Level Requirements (SLRs), and corresponding frameworks. The first volume (Volume 1) was also referred as Wireless Access in Vehicular Environment (WAVE1) Use Cases (UCs), which is specified in 5GAA T-200111. The second volume (Volume II) describes use cases and includes advanced UCs that require complex interactions among vehicles as well as between vehicles and infrastructure in relation to self-driving (autonomous) vehicles. Seven identified areas of UCs: Safety, Vehicle Operations Management, Convenience, Autonomous Driving, Platooning, Traffic Efficiency and Environmental Friendliness, Society and Community. Meanwhile, the third volume (Volume III) of use case descriptions are written from the vehicle perspective and strive to be solution agnostic and applicable to both driven and autonomous vehicles.

With the growing number of vehicles on Malaysian roads, V2X technology has the potential to transform the way people commute, reducing accidents, and creating a more efficient transportation system. There are many potential key scenarios where V2X technology can bring substantial advantages. Examples of the scenarios are as listed below.

#### **a) Intersection safety**

Intersections often pose significant risks due to potential collisions and conflicting traffic flows. V2X-enabled vehicles can communicate with traffic lights, road signs, and other vehicles to share their positions, intentions, and speed, allowing for coordinated manoeuvres and reducing the risk of accidents.

#### **b) Pedestrian safety**

V2X technology can greatly enhance pedestrian safety by enabling vehicles to detect and communicate with pedestrians equipped with compatible devices, such as smartphones or wearables. This exchange of information can alert drivers to the presence of pedestrians, even when they are not in the direct line of sight, significantly reducing accidents involving pedestrians.

#### **c) Emergency vehicle prioritisation**

By integrating V2X technology, emergency vehicles can transmit their location, route, and priority status to surrounding vehicles and traffic infrastructure. This enables the optimisation of traffic signal timings, creating clear pathways for emergency vehicles and reducing response times in critical situations.

#### **d) Traffic management and congestion reduction**

V2X technology can provide real-time data on traffic flow, congestion, and road conditions. This information can be utilised to optimize traffic management systems, dynamically adjust signal timings, suggest alternate routes to drivers, and improve overall traffic flow, leading to reduced congestion and smoother journeys.

e) Infrastructure efficiency and maintenance

V2X technology allows infrastructure to communicate with vehicles, enabling early detection of road hazards, construction zones, and maintenance activities. By providing timely notifications to drivers, congestion and potential accidents caused by unexpected disruptions can be minimized, enhancing overall road safety and efficiency.

f) Autonomous vehicle integration

As autonomous vehicles become more prevalent, V2X technology will play a critical role in enabling effective communication between autonomous and traditional vehicles, pedestrians, and infrastructure. This collaboration will be essential to ensure the safe integration of autonomous vehicles into the existing transportation ecosystem.

Table 11 lists some V2X use cases that can be implemented in Malaysia by using the IMT-2020 technology.

**Table 11. Example of V2X use cases potentially be implemented in Malaysia**

Type of V2X	Functionality	Description	Use case or application
V2V	Collision avoidance	<ul style="list-style-type: none"> <li>a) V2X enables vehicles to share real-time data, such as speed, position, and direction with nearby vehicles.</li> <li>b) V2X data provide warnings and alert the vehicle and/or driver to take autonomous actions to avoid collisions, such as emergency braking or steering assistance.</li> </ul>	<ul style="list-style-type: none"> <li>a) Advanced Driver Assistance Systems (ADAS)</li> <li>b) Cooperative adaptive cruise control</li> <li>c) Blind spot warning</li> <li>d) Forward collision warning</li> <li>e) Emergency stop</li> <li>f) Pre-crash sensing warning</li> </ul>
	Emergency vehicle alert	<ul style="list-style-type: none"> <li>a) V2X allow emergency vehicle to transmit the location and driving speed to nearby vehicles.</li> <li>b) Nearby vehicles receiving the alerts and make way for the emergency vehicle to pass safely.</li> </ul>	<ul style="list-style-type: none"> <li>a) Traffic flow optimisation</li> <li>b) Emergency vehicle journey planning</li> </ul>
	Intersection safety	<ul style="list-style-type: none"> <li>a) V2X enhances safety at intersections by allowing vehicles to communicate with traffic signals and other infrastructure.</li> <li>b) Critical information about traffic signals at an intersection is exchanged through mechanism called Signal Phase and Timing (SpaT) in between the vehicles and infrastructures.</li> <li>c) The information specified on the particular phase and timing that enable vehicle and infrastructure to make informed decisions (e.g., dynamic driving operations).</li> </ul>	<ul style="list-style-type: none"> <li>a) Intersection collision avoidance</li> <li>b) Emergency Stop</li> <li>c) Road Safety Services</li> <li>d) Forward Collision Avoidance</li> </ul>

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**Table 11. Example of V2X use cases can be implemented in Malaysia (continued)**

Type of V2X	Functionality	Description	Use case or application
V2V	Improved visibility	<ul style="list-style-type: none"> <li>a) V2X allows for co-operative perception, where vehicles share sensor input data (e.g., radar, LiDAR) with each other to enhance the collective vehicle data inputs environment.</li> <li>b) The data inputs enhance vehicle visibility system which significantly enable vehicle to visualise the environment beyond obstacles for improving safety in complex scenarios.</li> </ul>	<ul style="list-style-type: none"> <li>a) Vehicle sensing</li> <li>b) Path planning and navigation</li> <li>c) Routing and perception</li> <li>d) HD mapping</li> </ul>
V2P	Pedestrian safety	<ul style="list-style-type: none"> <li>a) V2X extends the communication to pedestrians (V2P communication).</li> <li>b) Information is shared using V2X-enabled devices or smartphones that communicate with nearby vehicles and/or RSU.</li> <li>c) Vehicles can then provide alerts and warnings to drivers when pedestrians are in close proximity, even if they are not within the driver's line of sight.</li> </ul>	<ul style="list-style-type: none"> <li>a) Pedestrian collision warning</li> <li>b) Crosswalk safety alerts</li> <li>c) Pedestrian assist at intersections</li> <li>d) Pedestrian road safety (awareness message and alert)</li> </ul>
	Vulnerable Road User (VRU)	<ul style="list-style-type: none"> <li>a) V2X detect the VRU (pedestrian, cyclist, etc.) via V2X-enabled devices.</li> <li>b) Alerts and warning are triggered for any potential hazard/threat to VRU.</li> <li>c) Vehicle system is alerted with potential hazard/threat and responses to the hazard/threat.</li> </ul>	<ul style="list-style-type: none"> <li>a) Vulnerable road user safety.</li> <li>b) Smart crosswalk safety alerts.</li> <li>c) Overview to road traffic participants and parties.</li> </ul>
	Point of interest	<ul style="list-style-type: none"> <li>a) In tourist areas, V2X provides pedestrian with information about nearby points of interest, historical sites, and cultural attractions.</li> </ul>	Tourism information
V2I	Traffic signal optimisation	<ul style="list-style-type: none"> <li>a) V2X configure the traffic signal for optimisation and efficiency based on real-time traffic data received from nearby vehicles.</li> <li>b) The optimisation reduces congestion, decreases travel times, improves fuel efficiency, etc.</li> </ul>	<ul style="list-style-type: none"> <li>a) Journey planning</li> <li>b) Fleet management</li> <li>c) Road congestion update</li> <li>d) Vehicle counting</li> </ul>
	Toll collection and payment	<ul style="list-style-type: none"> <li>e) V2X enable electronic and seamless toll collection through centralised platform, allowing vehicle to pass through toll booth without stopping.</li> </ul>	Electronic toll collection

Table 11. Example of V2X use cases can be implemented in Malaysia (continued)

Type of V2X	Functionality	Description	Use case or application
V2I	Speed limits	<ul style="list-style-type: none"> <li>a) V2X enable speed limit signs to be adjusted based on road conditions, traffic congestion, and weather.</li> <li>b) Variable speed limits help improve safety by encouraging driver to not violate speed limit and to match with the prevailing conditions.</li> <li>c) The mechanism greatly aids for improving authority in term of enforcing speed limit on the road.</li> </ul>	Variable speed limit
	Parking management	<ul style="list-style-type: none"> <li>a) V2X communication system helps driver to find available parking spaces more efficiently.</li> <li>b) Parking facilities are equipped with V2X to relay real-time occupancy data to drivers, enabling vehicle to locate and reserve parking spaces in advance.</li> </ul>	Smart parking system
	Electric Vehicle (EV) charging	<ul style="list-style-type: none"> <li>a) V2X helps to optimise the charging operation of EV by coordinating charging schedules based on electricity demand and grid capacity.</li> </ul>	<ul style="list-style-type: none"> <li>a) EV smart charging</li> <li>b) Smart grid integration</li> </ul>
V2N	Traffic updates	<ul style="list-style-type: none"> <li>a) V2X allows vehicle to receive real-time traffic information from network-connected sources, such as traffic management centre, RSU or other vehicles.</li> <li>b) Information such as live traffic data, including congestion, accidents, road closures, and alternative routes, helping vehicle and driver to make informed decisions to avoid traffic jams and reduce travel time.</li> </ul>	<ul style="list-style-type: none"> <li>a) Real-time traffic update</li> <li>b) Journey planning</li> <li>c) Emergency response</li> <li>d) eCall</li> </ul>
	Firmware and software updates	<ul style="list-style-type: none"> <li>a) Vehicle manufacturers leverage on V2X communication to remotely deliver firmware updates and software upgrades to vehicles.</li> <li>b) It is to ensure that vehicle is equipped with the latest version of firmware and software, covering the features, security patches and others.</li> </ul>	<ul style="list-style-type: none"> <li>a) Firmware over the air (FOTA) updates</li> <li>b) Software over the air (OTA) updates</li> <li>c) Vehicle cybersecurity</li> </ul>
	Real-time vehicle diagnostic	<ul style="list-style-type: none"> <li>a) V2X allows vehicle to transmit diagnostic data to manufacturers and service centre in real-time.</li> <li>b) The real-time diagnostic data enables manufacturer to remotely monitor the health of vehicles, identify potential issues, and proactively schedule maintenance, reducing breakdowns and improving vehicle reliability.</li> </ul>	<ul style="list-style-type: none"> <li>a) Firmware over the air (FOTA) updates</li> <li>b) Software over the air (OTA) updates</li> <li>c) Vehicle cybersecurity</li> </ul>
	Infotainment services	<ul style="list-style-type: none"> <li>a) V2X enables vehicle to access streaming media, internet radio, and cloud-based infotainment services.</li> <li>b) Passengers can enjoy a variety of entertainment options during their journeys.</li> </ul>	On-demand infotainment and streaming services

**Table 11. Example of V2X use cases can be implemented in Malaysia** *(continued)*

Type of V2X	Functionality	Description	Use case or application
	Intelligent Transportation System (ITS)	<ul style="list-style-type: none"> <li>a) ITS leverage V2X communications to create smarter, safer, and more efficient transportation networks. V2X technology enhances ITS capabilities by enabling vehicles to communicate with each other, infrastructure, and traffic management systems.</li> <li>b) ITS requires extensive and reliable data inputs to exchange information for developing informed decision making.</li> <li>c) Data sharing is crucial with no tampering of data inputs (with full credentials and data source responsibilities)</li> </ul>	<ul style="list-style-type: none"> <li>a) Traffic management and signal coordination</li> <li>b) Public transport integration</li> <li>c) Emergency alerts and notifications</li> <li>d) Real-time traffic updates</li> <li>e) Freight and logistics optimisation</li> <li>f) Enforcement purposes (e.g., variable speed limit, anti-theft, permit Issuance, etc.)</li> </ul>

**Annex A**  
(informative)

**Normative references**

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## Annex B (informative)

### Abbreviations

For the purpose of this Technical Code, the following abbreviations apply:

3GPP	3 <sup>rd</sup> Generation Partnership Project
5G	Fifth Generation
5GC	Fifth Generation Core
5GS	Fifth Generation Systems
AF	Application Function
AM	Acknowledge Mode
AMF	Access and Mobility Management Function
C-V2X	Cellular Vehicle-to-Everything
EPS	Evolved Packet System
GBR	Guaranteed Bit Rate
HARQ	Hybrid Automatic Repeat Request
IoT	Internet-of-Things
LTE	Long Term Evolution
MAC	Medium Access Control
MEC	Multi-Access Edge Computing
ME	Mobile Equipment
NEF	Network Exposure Function
NFs	Network Functions
NRF	Network Repository Function
NSA	Non-Standalone
gNB	NR Node B
NR	New Radio
PCF	Policy Control Function
PDCP	Packet Data Convergence Protocol
PHY	Physical
PLMN	Public Land Mobile Network
RLC	Radio Link Control
RP	Reference Point
RRC	Radio Resource Control
SDAP	Service Data Adaptation Protocol
SL	Sidelink
SMF	Session Management Function
SLR	Service Level Requirement
SA	Standalone
UCs	Use Cases
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UICC	Universal Integrated Circuit Card

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UPF	User Plane Function
USIM	Universal Subscriber Identity Module
V2D	Vehicle-to-Device
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
WAVE	Wireless Access in Vehicular Environment

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