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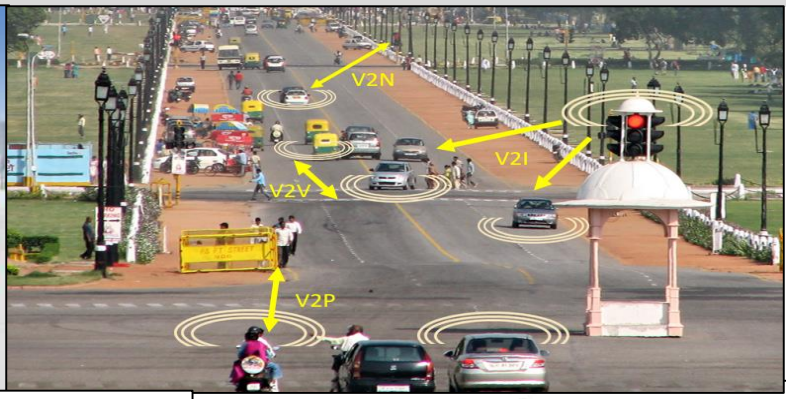
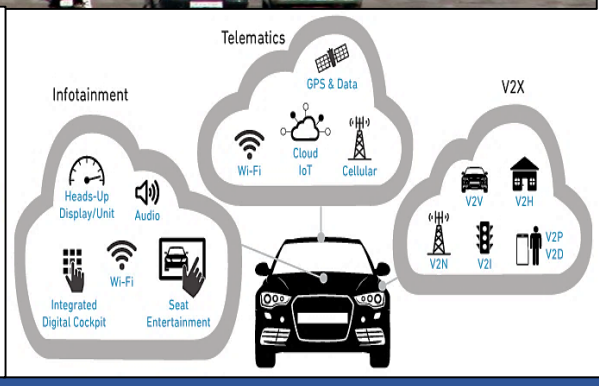
TECHNICAL REPORT

Technologies and Standards for Intelligent Transport System

TEC 31218:2023

WORKING GROUP: TECHNOLOGIES AND STANDARDS FOR INTELLIGENT TRANSPORT SYSTEM





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DEPARTMENT OF TELECOMMUNICATIONS
MINISTRY OF COMMUNICATIONS
GOVERNMENT OF INDIA

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GOVERNMENT OF INDIA
MINISTRY OF COMMUNICATIONS
DEPARTMENT OF TELECOMMUNICATIONS

Message

I am happy to note that Telecommunication Engineering Centre (TEC) has prepared a Technical Report on ***Technologies and Standards for Intelligent Transport System,*** which is being released as a guiding document for the related stakeholders.

IoT division, TEC has already released twenty Technical Reports covering various verticals viz. Automotive, Power, Health, Safety & Surveillance, Smart Homes, Smart Cities, Smart Village & Agriculture and in the horizontal layer - M2M Gateway & Architecture, Communication Technologies in IoT domain, EMF radiation from IoT/ M2M devices and IoT Security etc. This document is an addition to the series of expert reports.

Importance of these technical reports can be envisaged from the fact that International Telecommunication Union (ITU) has posted the TEC Technical Reports on its website in IoT sections (2023, 2022 and 2021), recognizing as insightful technical resource for the benefit of global community.

In view of massive urbanization, smart infrastructure is required to be created in various verticals including intelligent transport system, to address the challenges of daily life and also to improve the quality of life of the citizens.

This Report covers technologies and standards for the development of Intelligent transport system including C-V2X and also elaborates the use cases and trials in India and abroad.

I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out this report. I wish them success in all their future endeavours.

Date: 06.10.2023

(Neeraj Mittal)

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Message

I am happy to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on ***Technologies and Standards for Intelligent Transport Systems.***

I acknowledge the excellent work by TEC in releasing twenty Technical Reports in M2M/ IoT domain in the last 6-8 years, covering various verticals as well as horizontal layers viz. Automotive, Power, Remote Health Management, Smart Homes, Smart cities, Smart Village & Agriculture etc.; M2M Gateway & Architecture, communication technologies in IoT domain, EMF radiation from IoT devices and IoT Security.

A number of recommendations emerged from these reports such as 13-digit numbering scheme for SIM based devices/ gateways, adoption of e-SIM, spectrum for PLC and Low Power Wireless Communication technologies, spectrum for V2X communication, common service layer (adoption of oneM2M specifications), Guidelines for securing consumer IoT are the part of policies and standards.

I am delighted to share that this technical report has elaborated the technologies and standards for the development of Intelligent transport system based on the study of national / international standards and guidelines released by ITU, 3GPP, APT, IEEE, ETSI, ISO-SAE, 5GAA etc and the use cases. This technical report of TEC is a good reference for the related stakeholders in developing the eco-system for the automotive sector.

I appreciate the efforts put in by Telecommunication Engineering Centre in bringing out this report. I congratulate IoT division for all their hard work and best wishes for the future.

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MESSAGE

I am pleased to note that Telecommunication Engineering Centre (TEC) is bringing out a Technical Report on ***Technologies and Standards for Intelligent Transport System***. This report is in continuation to the series of twenty technical reports already released in various verticals, Communication technologies, EMF exposure from IoT devices and IoT security.

Some of the recommendations provided in these reports are being used in the policies and standards for the development of M2M/ IoT ecosystem.

This Technical Report covers the V2X based on 3GPP standards and ITU-R recommendations related to Intelligent transport system. This report also covers detailed use cases and trails in India and abroad.

TEC has also adopted oneM2M Release 2 as well as Release 3 specifications as National Standards; an important step towards developing standards based IoT ecosystem especially for Smart cities. oneM2M release 3 provides interworking specifications with 3GPP and the interworking with 3GPP V2X is expected in release 4.

I am pleased to note that the International Telecommunication Union (ITU) has made available six TEC reports on its website within the IoT section, acknowledging them as valuable technical resources for the global community's benefit.

This technical report of TEC is a good reference for the related stakeholders as it provides the recommendations related to spectrum, security aspects and standards for the development of eco system for Intelligent Transport system in the country.

I appreciate the efforts of Telecommunication Engineering Centre specially its IoT Division and the members of the Working Group for bringing out this technical report in a very timely manner. I wish them success in all their endeavours.

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Foreword

TEC is the National Standardization Body (NSB) for telecommunication in India and the national enquiry point for WTO-TBT (Technical Barrier to Trade) for telecom sector. TEC has also been mandated to interact with various international standardization bodies like ITU, APT, ETSI, IEEE, oneM2M, 3GPP etc. for standardization works.

TEC takes up development of standards based on study, continuous participation/ submitting contributions in the meetings of standardization bodies and interaction with stakeholders.

M2M/ IoT is one of the most emerging technologies being used to create smart infrastructure in various verticals and also in Smart cities. As per NDCP 2018, ddeveloping framework for accelerated deployment of M2M services while safeguarding security and interception for M2M devices has to be ensured.

TEC has already released twenty Technical Reports covering various verticals, Communication technologies, EMF radiation from IoT devices and IoT Security. Some of the technical reports are namely M2M Enablement in Remote Health management, Safety & Surveillance, Smart Homes, Smart Cities, Smart Village & Agriculture, V2V/V2I Radio communication & Embedded SIM, Communication Technologies in M2M/ IoT domain, M2M Gateway & Architecture, National Trust Centre for M2M devices and applications, Security by design for IoT device manufacturers etc. Important actionable points emerged from these reports are being used in the development of standards / policies; enabling the proliferation of IoT ecosystem in the country. Work carried out by TEC in M2M/ IoT domain has been listed n brief in the report ***TEC initiatives in M2M/ IoT domain: An overview***. All the technical reports are available on TEC website (***https://tec.gov.in/M2M-IoT-technical-reports***).

Envisaging the importance of TEC Technical Reports, International Telecommunication Union (ITU) has posted the following six reports on its website (***https://www.itu.int/cities/dt-resource-hub/iot/***) in IoT sections (2023, 2022 and 2021), recognizing as insightful technical resource for the benefit of global community:

1. Security by design for IoT device manufacturers

2. Framework of National Trust Centre for M2M/IoT Devices and Applications,
3. IoT/ ICT Standards for Smart Cities
4. Code of practice for Securing Consumer IoT
5. Emerging Communication Technologies & Use Cases in IoT Domain
6. IoT/ICT Enablement in Smart Village and Agriculture

TEC has adopted oneM2M Release 2 as well as Release 3 standards (transposed by TSDSI) as National standards (***https://tec.gov.in/onem2m***). oneM2M Release 3 is having interworking with 3GPP.

DoT has issued the Office Memorandum (OM) to all the ministries of Government of India and telecom service providers with the request for wider circulation of TEC technical report on ***Code of practice for Securing Consumer IoT*** to all related stakeholders (IoT device manufacturers, IoT Service Providers System Integrators, Application Developers etc.) for voluntary adoption of the guidelines and provide feedback. Recently, DoT has also issued an advisory to M2M service providers for following first three guidelines available in this report.

Guidelines available in the Technical Report ***Security by design for IoT device manufacturers*** are quite important from the policy and Standards perspective, which will help in securing IoT eco system.

The TEC Working group/ committee on *Technologies and Standards for Intelligent Transport System* is having members from Government, industry, academia, R&D organisations and start-ups. Around 10 virtual meetings and a number of short meetings / discussions have already been held in drafting and finalizing the content of the Technical Report titled ***Technologies and Standards for Intelligent Transport System***. This technical report is based on the study of national / international standards and guidelines released by ITU, 3GPP, APT, IEEE, ETSI, ISO-SAE, 5GAA etc and the use cases carried out by the working group having the related stakeholders. Working group discussed iThis technical report is a good reference for the related stakeholders in developing the eco-system for the automotive sector.

This report is expected to provide guidance to all concerned stakeholders.

I appreciate the efforts put in by officers of IoT division and working group members in bringing out this report. I wish them success in all their future endeavors.

(R. R. Mittar)

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Executive Summary

Intelligent Transport Systems (ITS) may be defined as a suite of public transport planning, operations management and customer service applications that are enabled by advanced **information and communications technologies**. They act to enhance the effectiveness, efficiency, and usability of the public transport service to the benefit of public transport authorities, operators, and passengers.

International Telecommunication Union (ITU) has defined Intelligent transport system (ITS) as systems utilizing the combination of computers, communications, positioning and automation technologies to improve the safety, management and efficiency of terrestrial transport systems [ITU-T Y.4407].

Every year there is a large number of casualties in road accidents. Even after the accident, it is difficult to provide ambulance assistance to the victims to carry them quickly to the hospitals so that the life of victims can be saved. It is required to make our roads safer by using the IoT and ICT.

Safer road infrastructure, safer vehicles, and safety of vulnerable road users (pedestrians, bicyclist etc.) using ITS is a part of **National Road Safety Policy**[1] of Ministry of Road Transport & Highways, Government of India. This policy states that the Government will take measures to review standards pertaining to safety in the design of rural and urban roads and bring them in consonance with international best practices keeping in view Indian traffic conditions. Continuing application of Intelligent Transport Systems (ITS) under a national framework to establish a safe and efficient transport system will be encouraged.

Use of M2M / IoT technology along with ICT infrastructure can help / solve the jams occurring to a large extent. With limitation for growth infrastructure there is a strong need to depend on technology (IoT/M2M) to address challenges, currently faced by the industry. M2M enabled transportation system include telematics and all types of communications in vehicles, between vehicle and citizens/Authorities (car to application), between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure).

National Digital Communication Policy (NDCP) 2018 released by Department of Telecommunications, has mentioned about developing the market for IoT/ M2M connectivity services in sectors including **Intelligent Transport Networks, Multimodal Logistics, Smart Cities,** Agriculture, Smart Electricity Meter, Consumer Durables etc. incorporating international best practices.

There may be a large no. of use cases in automotive sector depending upon the local requirements. Important use cases are such as Vehicle tracking, e-call (911 in USA and 112 in Europe, 112 has been adopted in India), V2V and V2I applications, Traffic control, Navigation, Infotainment, Fleet management, Asset tracking, Manufacturing and logistics, Intelligent transport System, Smart Parking etc.

Government of India has already mandated to install GPS/GRPS devices with video camera and panic button in all public transport with cellular connectivity to police stations for woman safety in public transports under AIS140/ IS16833.

RFID based Electronic Toll Collection devices are being deployed in India on various National Highways / Expressways, in the sub-GHz band 865 MHz – 867 MHz band.

[1] https://morth.nic.in/national-road-safety-policy-1

M2M communication / IoT will make the verticals smart by providing the data in real time and will enable to take the decision for planning, operation and other related activities.

Connected vehicle provides a feeling of safety to the user. Extending connectivity on the roads for managing traffic, surveillance cameras, safety for the pedestrian may create a smart infrastructure for the automotive sector.

IoT/ ICT technologies are playing a key role in the development of Intelligent Transport System.

Automotive connectivity or "connected car" applications have found themselves into designs and can be represented as addressing one of the three applications: connect the car to the environment (V2X), the cloud (telematics), and infotainment for passengers and drivers.

TEC has released the technical reports covering in brief the related technologies such as Dedicated short range communication (DSRC) based on IEEE 802.11p specifications and also the C-V2x based on 3GPP specifications (Please refer Section 1.2 for more details).

The objective of this report is to focus on a Survey of existing Intelligent Transport Systems (ITS) techniques and towards developing India's ITS stack / architecture based on global best practices and interoperable standards. This report covers the Communication / Radio interface layer, Information exchanges for ITS applications, Architectural aspects for ITS applications, Security aspects, Spectrum, Testing & certification and its relevance to enable the ITS implementation and adoption in India.

1 Introduction & background

Intelligent Transport Systems (ITS) are an important aspect of India's National Road Safety Policy[2] for ensuring safer road infrastructure. The policy notes that in addition to design of roads, continuing application of ITS under a national framework to establish a safe and efficient transport system will be encouraged.

Globally, ITS has been central to the discussions on improving safety and traffic efficiency by leveraging applications such as vehicle-to-infrastructure, vehicle-to-vehicle, vehicle-to-pedestrian communications[3].

1.1 National Digital Communication Policy (NDCP) 2018

NDCP 2018 was released by Department of Telecommunications in 2018. It covers many points related to IoT, Artificial Intelligence and 5G.

Extract related to IoT, 5G and other emerging technologies in NDCP is as given below:

1. **Propel India:** Enabling Next Generation Technologies and Services through Investments, Innovation, Indigenous Manufacturing and IPR Generation
   2022 Goals:
   a) Expand IoT ecosystem to 5 Billion connected devices by 2022
   b) Creation of innovation led Start-ups in Digital Communications sector
   c) Train/ Re-skill 1 Million manpower for building New Age Skills

2. **Accelerating Industry 4.0**
   a) Create a roadmap for transition to Industry 4.0 by 2020 by closely working with sector specific Industry Councils
   b) Establish a multi-stakeholder led collaborative mechanism for coordinating transition to Industry 4.0
   c) Developing market for IoT/ M2M connectivity services in sectors including Agriculture, Smart Cities, Intelligent Transport Networks, Multimodal Logistics, Smart Electricity Meter, Consumer Durables etc. Incorporating international best practices

3. **Ensuring a holistic and harmonized approach for harnessing Emerging Technologies**
   a) Creating a roadmap for emerging technologies and its use in the communications sector, such as **5G, Artificial Intelligence, Robotics, Internet of Things, Cloud Computing and M2M**
   b) Synergising deployment and adoption of new and emerging technologies by:
   Simplifying licensing and regulatory framework whilst ensuring appropriate security framework for IoT/ M2M/ future services and network elements incorporating international best practices
   c) Earmarking adequate licensed and unlicensed spectrum for IoT/ M2M services
   d) Encourage use of Open APIs for emerging technologies
   e) Ensuring the Transition to IPv6 for all existing communications systems, equipment, networks and devices
   f) Enabling Hi-speed internet, Internet of Things and M2M for rollout of 5G technologies and services

[2] https://morth.nic.in/national-road-safety-policy-1

[3] ITU-R Handbook on "Land Mobile (including Wireless Access) - Volume 4: Intelligent Transport Systems" https://www.itu.int/pub/R-HDB-49

- Implementing an action plan for rollout of 5G applications and services
- Enhancing the backhaul capacity to support the development of next-generation networks like 5G
- Ensuring availability of spectrum for 5G in < 1 GHz, 1-6 GHz and > 6 GHz bands
- Reviewing industry practices with respect to traffic prioritization to provide 5G enabled applications and services
- Developing framework for accelerated deployment of M2M services while safeguarding security and interception for M2M devices
- Defining policy for EMF radiation for M2M devices, with accompanying institutional framework to coordinate government-funded and India-specific research in this regard

g) Facilitating and supporting deployment of innovative solutions in identified Smart Cities

4. **Ensuring adequate numbering resources, by:**
   Allocating 13-digit numbers for all M2M mobile connections

5. **Recognizing Digital Communications as the core of Smart Cities by:**
   a) Developing, in collaboration with Ministry of Urban Development, a Common Service Framework and Standards for Smart Cities
   b) Facilitating and supporting deployment of innovative solutions in identified Smart Cities

6. **Promoting research & development in Digital Communication Technologies by:**
   a) Creating a framework for testing and certification of new products and services

1.2 TEC Technical Reports in M2M/ IoT domain

TEC is working in M2M/ IoT domain since 2014 and created a framework for finalizing specifications in sync with global bodies. TEC formed various multi-stakeholders working groups time to time to study the M2M/ IoT domain, with the outcome to be used in policies / standards. These working groups are having members from the related stakeholders i.e. industry, academia, R&D organisations, Standards developing organisations (SDOs), Government etc.

Twenty Technical Reports have been released so far covering various verticals such as Power sector, Automotive (Intelligent transport system), Remote Health Management, Safety & Surveillance, Smart homes, Smart cities, Smart Village & Agriculture, and also in the horizontal layer (requirements common to all the verticals) such as M2M Gateway & Architecture, Communication Technologies, EMF Exposure from IoT/ M2M devices and Security aspects in M2M/ IoT domain.

Out of these, five Technical Reports related with the automotive sector are listed below:

i. IoT/ ICT Standards for Smart Cities (released in March 2022)
ii. Emerging Communication Technologies & Use Cases in IoT Domain (released in 2021)
iii. Communication Technologies in M2M / IoT Domain (released in 2017)
iv. V2V / V2I Radio communication and Embedded SIM (released in 2015)
v. M2M Enablement in Automotive (Intelligent Transport System) Sector (released in 2015)

Technical Report on ***Emerging Communication Technologies & Use Cases in IoT Domain*** (TEC 31168:2021), has elaborated 5G (3GPP Release 15 / 16), Wi-Fi 6 / Wi-Fi HaLow, and Bluetooth Mesh technologies. This report has also covered the use cases related to Intelligent Transport System (Connected vehicles, C-V2X etc.), Industry 4.0, Smart Homes, Smart Cities etc. and the recommendations

related to spectrum and regulatory aspects, maybe useful for the development of ecosystem in the country.

Brief of the work done by TEC in M2M/ IoT domain is available in the report **TEC Initiatives in M2M / IoT domain- An overview** (TEC 31198:2022). All these Technical Reports are available on TEC website[4].

Adoption of oneM2M and 3GPP specifications as National Standards:

TEC has adopted oneM2M Release 2 and Release 3 as well as 3GPP specifications transposed by TSDSI time to time as National Standards for the development of standards based smart infrastructure in the country. These are available on TEC website[5]. oneM2M Release 3 is having interworking with 3GPP and Release 4 (expected to be published in near future) with V2X.

International recognition of TEC Technical Reports:

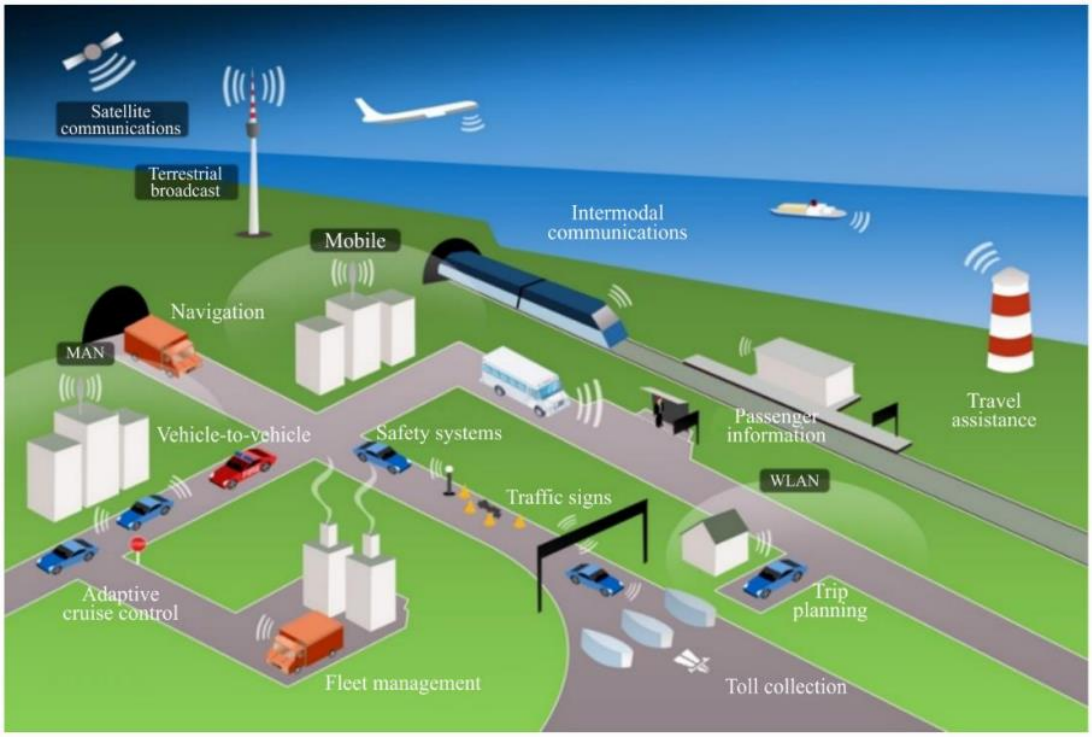
International Telecommunication Union (ITU) has posted the following six TEC Technical Reports on its website[6] in IoT sections (2023, 2022 and 2021), recognizing as insightful technical resource for the benefit of global community-

i. Security by design for IoT Device Manufacturers
ii. Framework of National Trust Centre for M2M/IoT Devices and Applications
iii. IoT/ ICT Standards for Smart Cities
iv. Emerging Communication Technologies & Use Cases in IoT Domain
v. Code of Practice for Securing Consumer Internet of Things (IoT)
vi. IoT/ ICT Enablement in Smart Village and Agriculture

1.3 ITS Landscape and Future of Transport

As per ITU-R Report M.2445 on “Intelligent Transport Systems (ITS) usage”, ITS is system to support transportation of goods and humans with information and communication technologies in order to efficiently and safely use the transport infrastructure and transport means (cars, motorcycles, bicycles, trains, planes, ships, and other) as visualized in Figure 1 below.

[4] https://tec.gov.in/M2M-IoT-technical-reports
[5] https://tec.gov.in/standards-adoption-policy
[6] https://www.itu.int/cities/dt-resource-hub/iot/



[Source: ITU-R Land Mobile Handbook, Vol.4-01]

Figure 1: Intelligent Transportation Systems (ITS)

ITS for the future of transport includes the following services:

- Transport Surveillance
- Visible Operation & Dispatch
- Efficient Emergency Control
- Efficient Traffic Management
- Door to Door Traffic Information Service
- Efficient Decision Making
- Integrated Public Transport
- Internet of Vehicles

1.4 V2X for India

Standard bodies like 3GPP are leading the C-V2X development and the V2X technology is evolving with constant improvement. India can benefit with the standardization and implementation in other parts of the world.

Considerations for V2X in India

One of the crucial elements in ITS is beyond the Line-of-Sight (LoS) in blind intersections, bad weather conditions. These situations are where wireless communication proves to be useful.

- Most traffic issues occur because of non-line of sight scenarios.
- Most sensors do not work well in these scenarios and V2X fills the gap.

V2X has the potential to be extended with other technologies like 5G and can evolve as an important sensor for various applications running on the cloud or edge.

Currently, the intelligent transport system (ITS) deployment is in the third generation which revolves around enabling connectivity to cars/ vehicles and fully automated driving systems[7]. The applications ranging from infotainment, pedestrian safety and collision avoidance are part of a typical ITS. These are achieved through integration of various automotive IoT peripherals in the vehicles. The onboard line-of-sight (LOS) sensors such as cameras, radar, LiDAR (Light Detection and Ranging), and others enables vehicles to see, hear, and anticipate potential driving hazards, even at blind intersections or in poor weather conditions. A short-range direct-communication among nearby vehicles also provides 360° non-line-of-sight (NLOS) awareness that complements the onboard sensors to improve safety and efficiency. V2X applications can share and coordinate information to extend the effective range of ADAS up to several kilometers.

V2X in various regions have evolved to encompass use-cases for safety, efficiency, and convenience. A few use-cases of relevance to India are listed below:

- **Day-1 applications:** These would include the early set of applications with immediate benefit for the road and traffic ecosystem (e.g., red light violation warning, road works warning, road hazard warning, curve speed warning, time to green, tolling, etc.)
- **Advanced applications:** These would include applications that have progressively greater benefit (e.g., forward collision warning, left / right turn assist, do not Pass Warning, etc.)

Further details about some use-cases are also provided in Annex A.6.

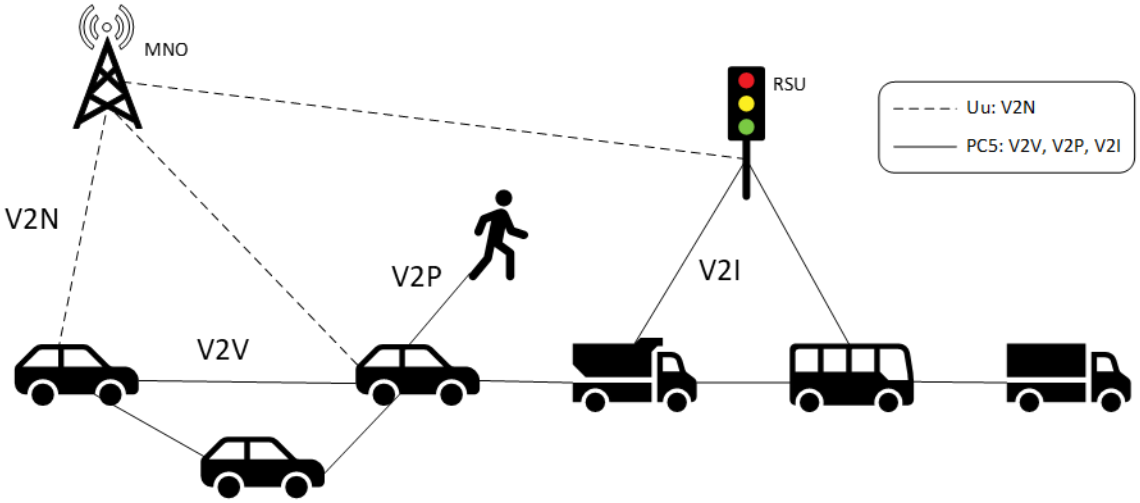
[7] Intelligent transport systems towards automated vehicles, https://news.itu.int/intelligent-transport-systems-towards-automated-vehicles/

2 Global Standards

Wireless communication technologies for connected and automated (SAE level 0 to 5)[8] vehicles are at an advanced stage of standardization and commercial operation. The overall set of standards can be classified into two groups, a) access layer and b) the non-access layer.

2.1 Access layer standards

The access layer technologies including the communication with the network (V2N) and the direct communication (V2V, V2P, V2I)[9] are collectively called V2X. The direct communication links can operate independently even in the absence of a cellular network. Having access to V2N is complimentary and adds additional functionality to the V2X applications.



[Source: APT Report[10] on cellular based V2X for ITS applications in APT countries, 09/2022]

Figure 2: Different modes of communication in V2X (APT/AWG/Rep-12)

The direct V2X communication technologies are:

- **IEEE based:** IEEE technology is based on the amendment to IEEE 802.11 called IEEE 802.11p (2010), now part of IEEE 802.11-2016. This access technology is deployed in Europe under the name of ITS-G5 and dedicated short range communication (DSRC) in the US, as well as ITS Connect in Japan. A successor to IEEE 802.11p is currently being developed in IEEE under the working name IEEE 802.11bd.

- **3GPP based (C-V2X):** 3GPP based access layer technology is an enhancement on the initial work on D2D communications defined as part of ProSe services (in Release 12 and Release 13 specifications) for supporting ad hoc communication are LTE V2X (from Release 14 to Release 15) and NR V2X (from Release 16 to the current Release 18). Further, 3GPP Release 18 is currently working on standardizing aspects related to sidelink based positioning, improved co-channel co-

[8] https://www.sae.org/blog/sae-j3016-update
[9] Explanation: *Direct communication is also referred to as side-link communication in 3GPP terminology*
[10]https://www.apt.int/sites/default/files/2022/09/APT-AWG-REP-121_-_APT_Report_on_cellular_based_V2X_for_ITS_applications_in_APT_countries.docx

existence between LTE & NR V2X, etc. The 3GPP based access layer technologies are in advanced stages of commercialization in several countries across the world.

The access technologies used for V2N are usually public 4G and 5G networks mobile network operators. The 4G and 5G can also be used by the vehicles or by the RSU.

- The RSU connected by a cellular network (for backhaul) can connect to the digital / cloud-based platforms for sharing the V2I information.
- The vehicles with V2N connectivity can get information (e.g., maps, weather, etc.) to augment the V2V information (e.g., connecting to virtual RSU[11]).

2.2 Non-access layer standards

In addition to the access layer connectivity standards, there are set of non-access layer standards required to support all the ITS and V2X functionality. Globally some of the non-access layer set of standards like ETSI ITS[12], IEEE 1609[13], SAE[14], that are utilized for message sets, security and enabling the use-cases[15] (Refer section 3.2 for further details).

2.3 End-to-end communication

The complete use-case definition for V2X includes all the protocol layers involving an end-to-end communication between the multiple entities involved. This includes both the access layer and the non-access layer communication. The relationship between the two layers is important to understand the technical performance and capabilities required to satisfy the V2X use-case.

At a conceptual level, the vehicles may desire to exchange certain information (that includes some amount of message size, reliably within a certain timeframe). The use-case itself imposes the desired performance metrics to be achieved to support the safety / utility function. The higher layer standards provide the information to be exchanges and the common language. And finally, the access layers enable to actual transfer of messages between the entities.

The relationship between the different levels / layers can be visualized in the Figure 3 below:

[11] https://5gaa.org/wp-content/uploads/2019/05/06.Virtual_RSU_Architecture.pdf
[12] ETSI Technical Committee (TC) Intelligent Transport Systems (ITS) https://www.etsi.org/committee/its
[13] IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Identifiers https://standards.ieee.org/ieee/1609.12/7446/
[14] LTE Vehicle-to-Everything (LTE-V2X) Deployment Profiles and Radio Parameters https://www.sae.org/standards/content/j3161_202204/
[15] Explanation: *There may be national / regional variants of these international standards in some cases.*

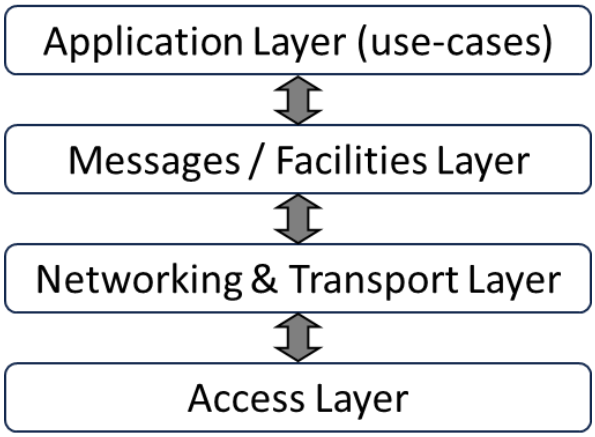


Figure 3: Framework for V2X communications and relationship between different layers

As seen in the Figure 3 above, the relationship may be better explained with an example of a dummy example of a demanding application or use-case.

For example, in the case of lookahead information for emergency vehicle use-case, the driving assistance information in the form of ETSI DENM / SAE BSM message will be sent in a V2V connection mode, typically with a transmission interval of 10 messages per second, with size of 1000 bytes and latency requirement in the order of 100ms.

- The situation description will have to be encoded to machine readable format utilizing a common unified language understood by all the vehicles on the road and the adjoining infrastructure.
- This message and facilities layer will add some overhead of its own in terms of message size.
- Further, the use-case imposes communication semantics on the network and transport layer to support either a unicast (peer to peer communication) or a broadcast (all recipients in the vicinity).
- And finally, accounting for all overheads, the access layer may have to attempt and deliver the messages encoded in a unified format, with the appropriate communication group in the desired latency.

2.4 C-V2X Standards from 3GPP

3GPP C-V2X standards capture the technology development and enhancements to support the advancements in the use-cases and the corresponding technical capabilities.

The support for 3GPP C-V2X was developed by introducing enhancements with evolving 3GPP Releases. LTE V2X is from Release 14 to Release 15, and NR V2X is from Release 16 to the current Release 18 and the future Releases.

LTE V2X supports several advanced ITS use cases. The technology has been tested extensively with trials in several countries in the world for satisfying crucial safety-of-life use-cases and advanced convenience use-cases.

3GPP Release 14, LTE V2X specification, work was completed in March 2017, which was designed to support the communications needs of use cases in ITU-R M.2445. The sidelink, based on the PC5 interface, was supported, and working on frequency band 5.9 GHz.

3GPP Release 15 specification work was completed in June 2018. It not only included the enhancement for LTE V2X which mainly focused on carrier aggregation, high order modulation to improve transmission data rate and reduce transmission latency. With the addition of NR, more advanced and comprehensive V2X use cases may be supported.

3GPP Release 16 specification work was completed in June 2020, supporting advanced V2X use cases based on multiple technologies, e.g., NR V2X complements LTE V2X for advanced V2X use cases, including connected and automated driving, and is capable of supporting advanced ITS. The 3GPP Release 16 specifications are designed to support three categories of advanced V2X use cases, including fully automated driving vehicle scenarios. Some of these use cases may require network connectivity. These categories of use-cases are:

- Platooning Vehicles – enables the vehicles to dynamically form a group travelling together.
- Extended Sensors – enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of vulnerable road users and V2X application servers.
- Advanced Driving – enables semi-automated or fully automated driving.
- Remote driving - enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. In certain use-cases, the remote operation of a vehicle may be for short durations of time.

All the advanced use case categories described above require ubiquitous, highly reliable, low-latency wireless communications. Key performance indicators for these use cases were developed and used to guide the design of the 3GPP Release 16 capabilities.

In Release 17, completed in Q2-2022, 3GPP extends the flexibility of the cellular technologies into an expanding number of vertical industries. 3GPP Release 17 has added further V2X enhancements, e.g., power, efficiency, better latency, enhanced reliability, and improved ranging and positioning. Further evolution currently underway in Release 18 will introduce other features important to connected and automated vehicles, e.g., sidelink based positioning, improved co-channel co-existence between LTE and NR V2X, as well as other improvements.

Annex A.1 provides further details about 3GPP standardization work of C-V2X.

3GPP Release 15, Release 16 and Release 17 have also been adopted as National Standards in India by TEC[16].

2.5 Consideration of enabler technologies

2.5.1 Cellular Communication Technologies

The cellular network provides a means for the mobile network operator to authorize a UE supporting the C-V2X application of IMT systems to perform V2X communication when served by a cellular network. The cellular network also supports integrity protection of the transmission for a V2X use case. Subject to regional regulations and/or operator policy for a V2V/V2I use case, the cellular network should support pseudonymity and privacy of a UE in the use of a V2V/V2I use case, such that no single party (operator or third party) can track a UE identity in that region.

[16] National Standards by TEC, https://www.tec.gov.in/standards-adoption-policy

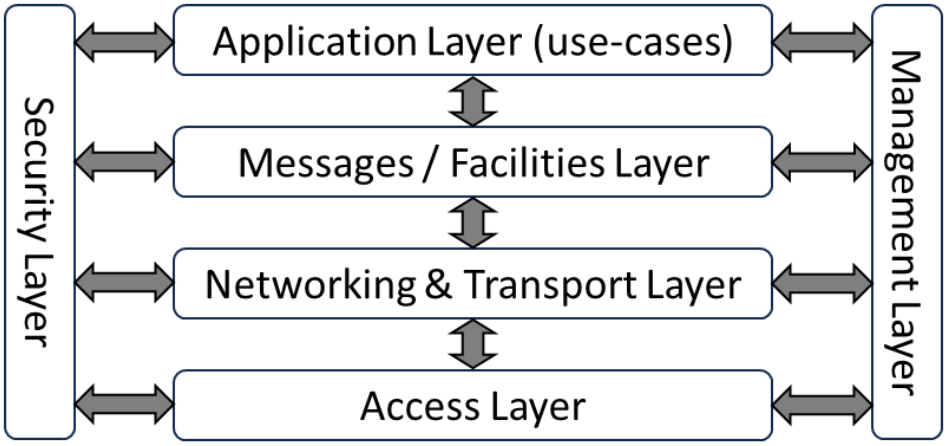
V2N links may also be utilized as a range extension for Uu communication for vehicles with LTE Uu but without PC5. One such example is provided in Annex A.3.

2.5.2 Automotive Radars

The onboard line-of-sight (LOS) sensors such as cameras, radar, LiDAR (Light Detection and Ranging), and others enables vehicles to see, hear, and anticipate potential driving hazards. Automotive radars could also be considered as sensors using radar equipment for ITS. Typically, these radars may use various mm Wave bands (e.g., see ITU-R Recommendation M.1452).

3 ITS Stack

ITS (Intelligent Transport Systems) access technologies layer covers various communication media and related protocols for the physical and data link layers. A Reference Architecture for ITS stack is provided in the Figure 4 below:



[Source: Qualcomm]

Figure 4: ITS Stack - Reference Architecture

The **ITS access layer** technologies are not restricted to specific type of media, though most of the access technologies are based on wireless communication. The access technologies are used for communication inside of an ITS station (among its internal components) and for external communication (for example with other ITS stations). For external communication, some of the ITS access technologies represent complete, non-ITS specific communication systems (such as 4G/5G) that are regarded as 'logical links' over which ITS data is transparently transported.

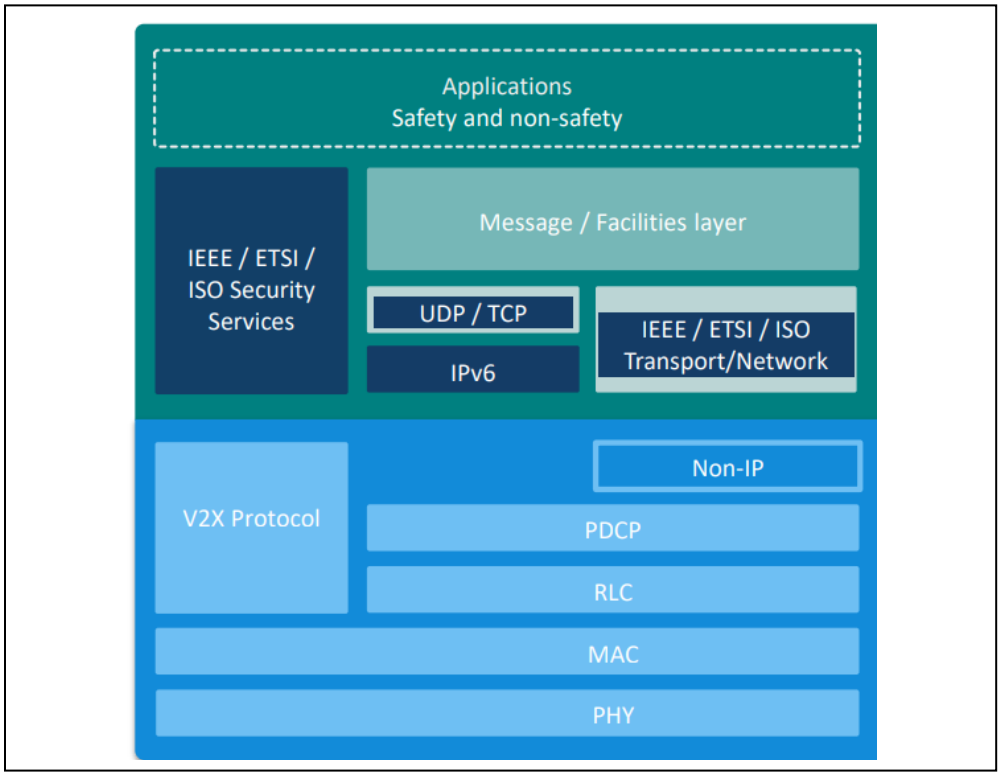
The **ITS network & transport layer** comprises protocols for data delivery among ITS stations and from ITS stations to other nodes, such as nodes in the core network (e.g. the Internet). **ITS network protocols** particularly include the routing of data from source to destination through intermediate nodes and the efficient dissemination of data in geographical areas. **ITS transport protocols** provide the end-to-end delivery of data and, depending on requirements of ITS facilities and applications, additional services, such as reliable data transfer, flow control and congestion avoidance. A particular protocol in the ITS network & transport layer is the Internet protocol IP version 6 (IPv6). The usage of IPv6 includes the transmission of IPv6 packets over ITS network protocols, dynamic selection of ITS access technologies and handover between them, as well as interoperability issues of IPv6 and IPv4.

The **ITS facilities layer** provides a collection of functions to support ITS applications. The facilities provide data structures to store, aggregate and maintain data of different type and source (such as from vehicle sensors and from data received by means of communication). As for communication, ITS facilities enable various types of addressing to applications, provide ITS-specific message handling and support establishment and maintenance of communication sessions. An important facility is the management of services, including discovery and download of services as software modules and their management in the ITS station.

The **ITS applications layer** refers to ITS applications and use cases for road safety, traffic efficiency, infotainment and business. The two vertical protocol entities are:

- ITS management entity is responsible for configuration of an ITS station, cross-layer information exchange among the different layers and others tasks.
- ITS security entity provides security and privacy services, including secure messages at different layers of the communication stack, management of identities and security credentials, and aspects for secure platforms (firewalls, security gateway, tamper-proof hardware).

The automotive industry, through SAE International, ETSI, and IEEE, have done considerable work in defining the Applications, the message/facilities later, security services and the Transport/networking layers. C-V2X leverages all of the existing standards in these layers, and just replaces the PHY and the MAC (commonly called the Access layers) from 3GPP to provide the end-to-end solution. A reference for 3GPP C-V2X standards is shown in the Figure 5.

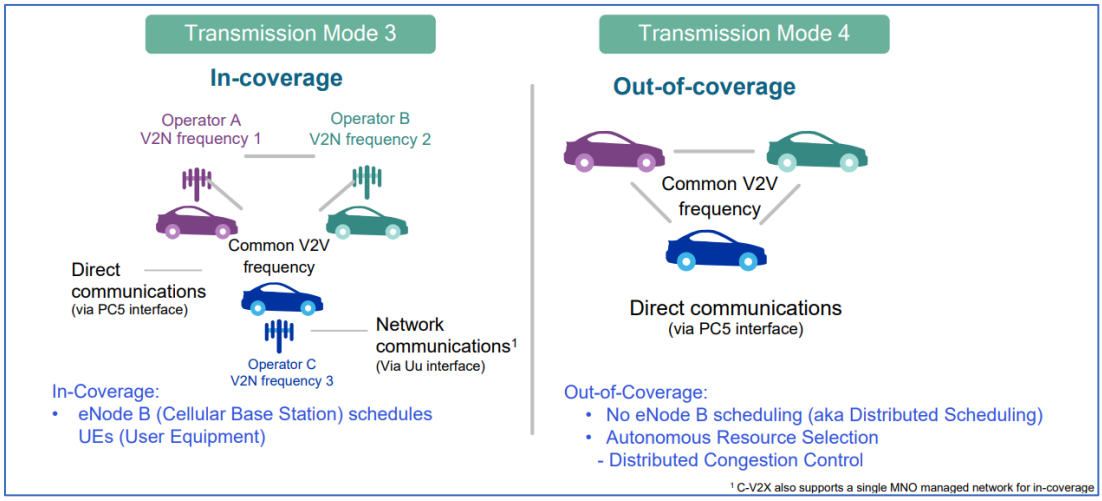


[Source: Qualcomm]

Figure 5: C-V2X Protocol Stack

3.1 End-to-End Architecture

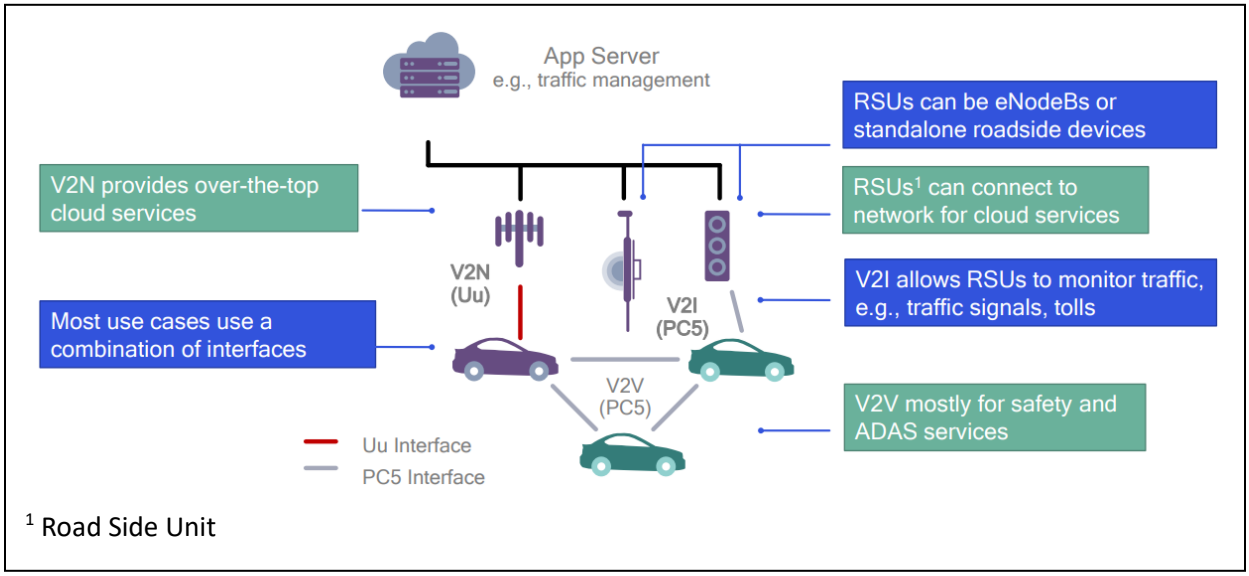
Cellular-V2X defines a new air interface called PC5 for V2V, V2I communication. V2N is still over the legacy LTE Uu air interface and provides over the top cloud services.



[Source: TEC Report on Emerging Communication Technologies & Use Cases in IoT Domain, Release 2.0, Nov 2021[17]]

Figure 6: PC5 Interface Modes supported by LTE V2X

The system level aspects for the communication modes are covered in 3GPP TS 23.285 and TS 23.287. The overall end-to-end architecture for C-V2X is shown in Figure 7.



[Source: adapted from Qualcomm]

Figure 7: C-V2X Architecture

[17] TEC Report on "Emerging Communication Technologies & Use Cases in IoT Domain", Release 2.0, Nov 2021, https://tec.gov.in/pdf/M2M/Emerging%20Communication%20Technologies%20&%20Use%20Cases%20in%20IoT%20domain.pdf

4 Spectrum Considerations

A white paper[18] by an automotive and mobile industry association reports on the results of its studies relating to the evolution of automotive connectivity for the purposes of enhanced road safety, improved traffic efficiency, greener environmental impact, and more comfortable driving.

Effectively, 70-75 MHz of ITS spectrum in the 5.9 GHz band is needed to support the basic safety and advanced use cases under consideration today. The 5GAA report also highlights the need for additional spectrum for cellular network-based communications for use by mobile operators in delivering advanced driving capabilities in rural and urban environments.

Identification of suitable spectrum ensuring global harmonized frequencies is essential for earlier adoption of C-V2X with global economies of scale. A global snapshot of spectrum[19] targeted or allocated to ITS is depicted in the Table 4-1 below:

Table 4-1: Examples of frequency usage for evolving ITS within Regions

Region 1	
Country or Group	**Frequency bands**
CEPT	5 855-5 925 MHz
United Arab Emirates	5 855-5 925 MHz
Region 2	
Country or Group	**Frequency bands**
Brazil	5 855-5 925 MHz
Canada	5 895-5 925 MHz
United States	5 895-5 925 MHz
Region 3	
Country or Group	**Frequency bands**
Australia	5 855-5 925 MHz
China	5 905-5 925 MHz
India	5 875-5 925 MHz
Japan	755.5-764.5 MHz 5 770-5 850 MHz
Korea	5 855-5 925 MHz
Singapore	5 855-5 925 MHz

In India, the revised National Frequency Allocation Plan (NFAP-2022[20]) released in October 2022 has taken care of the future plans of C-V2X. The following IND Footnote may be referred from NFAP-2022:

> *"**IND 29** Subject to not constraining the use of the frequency band 5 875 to 5 925 MHz by the services to which it has been allocated in the RR, the band may also be considered for V2X technologies/Intelligent Transport Systems."*

[18] 5GAA White Paper, "A visionary roadmap for advanced driving use cases, connectivity technologies, and radio spectrum needs", https://5gaa.org/wp-content/uploads/2020/09/A-Visionary-Roadmap-for-Advanced-Driving-Use-Cases-Connectivity-Technologies-and-Radio-Spectrum-Needs.pdf.

[19] From ITU-R Recommendation ITU-R M.2121-0 – Harmonization of frequency bands for Intelligent Transport Systems in the mobile service, including proposed edits in ITU-R WP5A for the next revision

[20] https://dot.gov.in/whatsnew/national-frequency-allocation-plan-2022

In USA, the Federal Communication Commission (FCC) issued a directive in November 2020 to allocate the upper 30 MHz of the 5.9 GHz (5.895 –5.925) ITS band to C-V2X technology that gives the C-V2X industry the green light to deploy C-V2X Roadside Units (RSU) and Onboard Units (OBU). This decision was affirmed in August 2022. In April 2023, FCC granted waiver[21] for initial C-V2X deployments to several Vehicle OEM vendors and state Department of Transportation.

The Innovation, Science and Economic Development (ISED) Canada[22] also made a similar decision to allocate the upper 30 MHz of the 5.9 GHz (5.895 –5.925) ITS band to C-V2X technology.

In China, the Ministry of Industry and Information Technology (MIIT) issued the administrative regulations on the use of 5.905-5.925 GHz Spectrum for Direct Connected Communication on the Internet of Vehicles, providing dedicated C-V2X spectrum with a total bandwidth of 20 MHz. Some of the use-cases related to V2X in China have been listed in Annex A.7.

ITU-R published a report on "The use of the terrestrial component of International Mobile Telecommunications for the Cellular-Vehicle-to-Everything"[23]. Further, APT published a "Report on cellular based V2X for ITS applications in APT countries"[24]. For the spectrum related aspects, the reports indicates the operations spectrum for both Uu and PC5 interface.

4.1 Uu interface

IMT mobile network capabilities allow the use of any Uu connection for the V2X use cases. Therefore, all the bands defined in 3GPP TS 36.101[25] and TS 38.101-1[26] for LTE and NR are valid for operation where regulations permit.

4.2 PC5/sidelink interface

LTE V2X communication is designed to operate in the operating bands in FR1 defined in the table below:

Table 4-2: Operating bands of LTE V2X

E-UTRA operating band	E-UTRA V2X operating band	V2X UE transmit	V2X UE receive	Duplex mode	Interface
		FUL_low – FUL_high	FDL_low – FDL_high		
47	47	5 855 MHz – 5 925 MHz	5 855 MHz – 5 925 MHz	HD	PC5

NR V2X communication is designed to operate in the operating bands in FR1 defined in the table below.

[21] https://5gaa.org/5gaa-applauds-fcc-action-to-permit-initial-c-v2x-deployments/

[22] https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/learn-more/key-documents/decision-technical-and-policy-framework-radio-local-area-networks-devices-5850-5895-mhz-band-and

[23] ITU-R M.2520, The use of the terrestrial component of International Mobile Telecommunications for the Cellular-Vehicle-to-Everything, https://www.itu.int/pub/R-REP-M/publications.aspx?lang=en&parent=R-REP-M.2520, dt. 11/2022.

[24] APT/AWG/REP-121, APT Report on cellular based V2X for ITS applications in APT countries, dt. 09/2022, https://www.apt.int/sites/default/files/2022/09/APT-AWG-REP-121_-_APT_Report_on_cellular_based_V2X_for_ITS_applications_in_APT_countries.docx

[25] 3GPP TS 23.286 – "Application layer support for Vehicle-to-Everything (V2X) services; Functional architecture and information flows".

[26] 3GPP TS 38.101-1 – "User Equipment (UE) radio transmission and reception Part 1: Range 1 Standalone".

Table 4-3: Operating bands in FR1 of NR V2X

V2X operating band	Sidelink (SL) transmission operating band	Sidelink (SL) reception operating band	Duplex mode	Interface
	FUL_low – FUL_high	FDL_low – FDL_high		
n381	2 570 MHz – 2 620 MHz	2 570 MHz – 2 620 MHz	HD	Sidelink
n47	5 855 MHz – 5 925 MHz	5 855 MHz – 5 925 MHz	HD	Sidelink

NOTE: When this band is used for V2X Side Link use cases, the band is exclusively used for NR V2X in particular regions.

LTE V2X: Band 47 (5 855 MHz – 5 925 MHz) is defined for PC5 operation, with 10 or 20 MHz channel bandwidth. The detailed band definition is in 3GPP TS 36.101.

NR V2X: Band 38 (2 570 MHz – 2 620 MHz) and Band 47 (5 855 MHz – 5 925 MHz) are defined for Sidelink operation, with 10, 20, 30, or 40 MHz channel bandwidth. The detailed band definition is in 3GPP TS 38.101-1.

5 Security considerations

5.1 Cybersecurity

Digitalization in the car-systems is increasing the connectivity and communication interfaces in the vehicle i.e Wi-Fi , Bluetooth, Cellular (2G, 3G, 4G,5G), and USB, directly to electronic control units, that dynamically increases the amount of software codes in design. In this way, the automobile is getting increasingly software-defined and the growth is being led mainly by software engineering Further use of emerging technologies like IoT, AI in the connected vehicles scenario, software vulnerabilities may arise, which may create significant cybersecurity risks.

In view of automotive safety and security, UN has released the following regulations:.

- UN Regulation No. 155 – Cyber Security and cyber security management system
- UN Regulation No. 156 – Software update and Software update management system

ISO/SAE 21434: 2021 Road vehicles - Cyber security Engineering

ISO and SAE collaborated for the development of a cybersecurity standard for road vehicles and released the standard ISO/SAE 21434 in 2021, which defines a structured process to ensure cyber-secure design.

ISO/SAE 21434 for cybersecurity is closely related to ISO 26262 (functional safety standard for electrical and electronic system) in the design and risk management methodology that it specifies.

UN Regulation no. 155 (R155) provides high-level objectives for security for automotive systems. Details on cybersecurity in the design process and on the management of cybersecurity within the automotive OEM & its suppliers are mentioned in the standard ISO/SAE 21434:2021. Overall cybersecurity risk management has been shown in Figure-8. The UN has formally stated in an interpretation document for R155 that compliance with ISO/ SAE 21434 satisfies compliance with the relevant parts of R155.

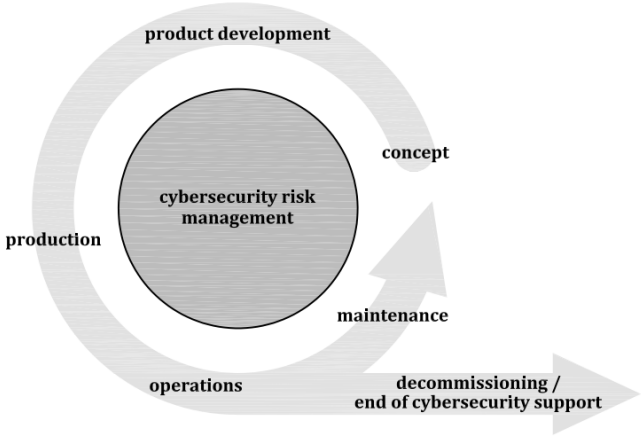


Figure 8: Overall Cybersecurity Risk Management (ISO/SAE 21434)

ISO/SAE 21434 address below key points

- Carrying out risk assessments

- Identifying, Analyzing, assessing, and managing cyber risks & vulnerabilities with connected vehicles
- Ensuring development is undertaken with in the correct safeguards in place to address these vulnerabilities.
- Use of cybersecurity 'by design' to reduce risks throughout the supply chain
- Rigorously testing applications and software/hardware components to make sure these risks have been mitigated
- Keeping vehicle software up to date securely
- Having systems in place which detect and mitigate security incidents in vehicles

ISO 27001: 2022 - Information Security management Systems

ISO 27001 and related documents provide a general template for cybersecurity management inside an enterprise. ISO 27001 certification can be considered as one mechanism that road operators can use to demonstrate acceptable cybersecurity management.

The ISO 27001 is more generic than ISO/ SAE 21434, therefore ISO/SAE 21434 may be used by automotive OEMs. However, other organizations that participate in ITS, such as road operators, must also meet cybersecurity management requirements in order to be trustworthy to other system participants, such as vehicles. In the EU, the ITS Security Policy[27] requires ISO 27001 certification. In the US, the Connected Intersections Implementation Guide[28] does not require formal certification due to the cost this would put on smaller road operators but does require self-assessment and self-assertion that cyber security risks have been addressed.

5.2 Security by Design

TEC has released the following technical reports on IoT Security in the recent past.

1. Security by design for IoT Device Manufacturers, released in March 2023
2. Framework of National Trust Centre for M2M/IoT Devices and Applications, released in March 2022
3. Code of Practice for Securing Consumer Internet of Things (IoT), released in August 2021

Technical Report ***Security by design for IoT Device Manufacturers*** (TEC 31328:2023) released in March 2023, highlights various threats and challenges related to IoT device security; includes study of national/ international standards (by ITU, ISO/ IEC, ETSI, ENISA, IoTSF, NIST, GSMA, 3GPP etc.), best practices and guidelines (UK DCMS, CSA Singapore, WEF, STQC etc.) to mitigate these challenges. This report also provides recommendations for IoT device manufacturers and related stakeholders, which will help in securing IoT ecosystem in the country.

This document also proposes IoT device classification (Level 0 to Level 4) based on cyber security requirements, harmonized with various global device classifications and labeling schemes.

The technical report on ***Framework of National Trust Centre for M2M/ IoT Devices and Applications*** (TEC 31188:2022) released in March 2022, visualises the implementation of national trust centre (NTC) in a phased manner for managing/ addressing the vulnerability related issues of the IoT devices reported by IoT/ Smart city platforms working in the network to NTC, by the device manufacturers / researchers.

[27]https://cpoc.jrc.ec.europa.eu/data/documents/c-its_security_policy_release_preparatory_phase_of_Delegated_Regulation_2019_1789.pdf
[28] https://www.standards.its.dot.gov/Standard/548

The report ***Code of practice for Securing Consumer IoT*** (TEC 31318:2021) released in August 2021, provides baseline requirements for securing Consumer IoT, aligned with global standards and best practices. Guidelines available in this report, will be helpful in securing consumer IoT devices & ecosystem as well as managing vulnerabilities. This technical report is based on the guidelines available in ETSI TS 103 645. This report is intended for the use of IoT device manufacturers, Service provider's / system integrators and application developers etc. This report has been endorsed by DoT to all related stakeholders including M2M Service providers to follow at-least the first three guidelines, i.e.,

- No universal default passwords
- Implement a means to manage reports of vulnerabilities
- Keep software updated

5.3 Security Services and Trust

It is important to establish a national security architecture for Intelligent Transport System (ITS). Further consideration needs to be given to the roles and locations of a range of security services for the protection of transmitted information and the management of essential security parameters. These include identifier and certificate management, PKI processes and interfaces as well as basic policies and guidelines for trust establishment.

There will need to be a policy organization/ task force responsible for making policy on the topics above. This policy organization should have a governance structure that allows a wide range of stakeholders to participate and takes into consideration the differing liability and other downside risks that those stakeholders are exposed to.

There will also need to be an operating organization responsible for determining which PKI providers conform to and correctly enforce the policy, so that participants in the system can be informed as to which PKI providers are operating in a trustworthy manner and therefore which credentials for system participants can be trusted to accurately state the permissions and properties of those system participants[29].

In Europe, the policy and operating organizations are directly run by the EU Commission under DG MOVE[30]. The policy organization is open to contributions from any expert with relevant expertise, subject to transparency requirements.

In the US, an industry-led process is developing policies and operating practices via an organization known as Security Credential Management System (SCMS) Manager, which is membership-based. SCMS is a public key infrastructure (PKI) designed to secure V2X messages.

Implementation of National Trust Center (NTC) based on the TEC technical report "Framework of National Trust Centre for M2M/IoT Devices and Applications" as detailed in Section 1 is in progress. It will help in managing the vulnerability / hacking related issues reported by IoT platforms to NTC portal, through device manufacturers / researchers.

[29]Securing PKI: PKI Process Security | Microsoft Learn- https://learn.microsoft.com/en-us/previous-versions/windows/it-pro/windows-server-2012-r2-and-2012/dn786431(v=ws.11)

[30]https://commission.europa.eu/about-european-commission/departments-and-executive-agencies/mobility-and-transport_en

6 Performance Testing and recent implementations

6.1 Interoperability testing

There has been rigorous testing for interoperability in plug-tests by ETSI[31] and 5GAA[32] showing the success rate of more than 93%. Few of the tested scenarios include:

- V2V line-of-sight (LoS)
- V2V non-LOS intersection
- Congestion / critical event

More details about the C-V2X performance testing have been mentioned in Annex A.2.

6.2 Recent developments

Several trials have been conducted for C-V2X in various countries namely USA, Europe, China, South Korea, Japan etc. as mentioned by 5GAA on its webpage[33]. Similar trials have also been conducted in multiple cities in India, as detailed in Annex A.4.

ITU-R WP5A[34] draft report on Connected Automated Vehicles includes information about initial trials, use-cases globally in all the ITU-R regions.

Many of the global New Car Assessment Programs (NCAP) are recognizing the importance of vehicle connectivity as a method to improve safety. Further details of the NCAP programs in different countries are provided in Annex A.8.

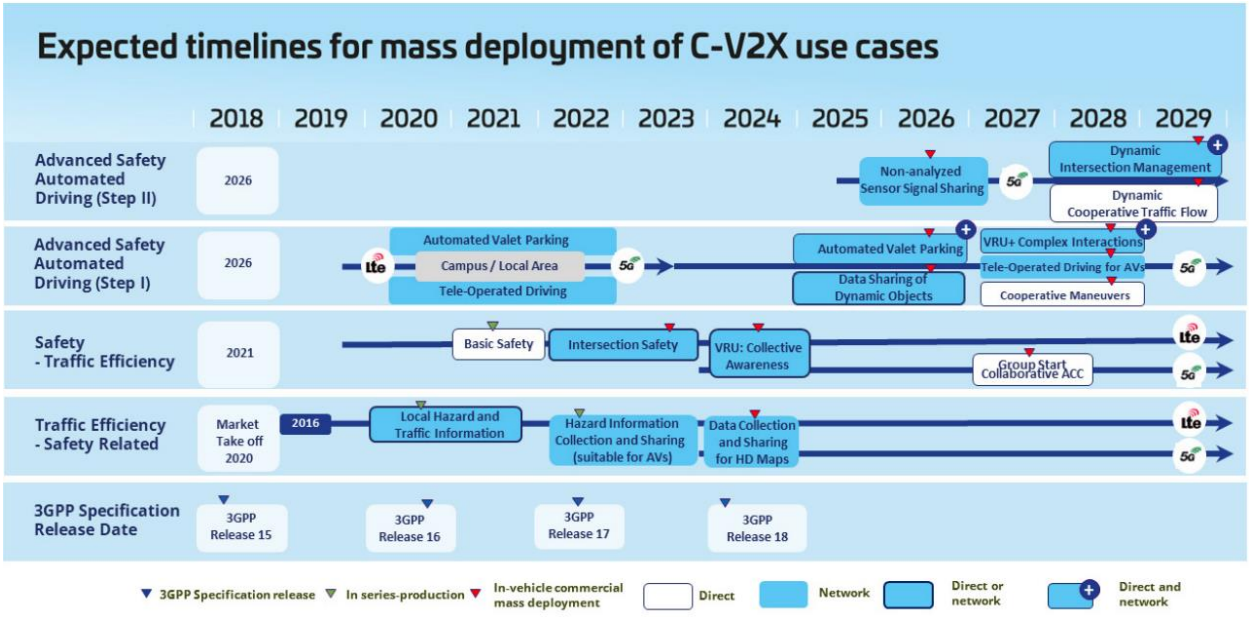
The Figure below provides the expected timeline for mass deployment of C-V2X use-cases as described by 5GAA and the corresponding 3GPP Release expectations.

[31] https://www.etsi.org/newsroom/news/2058-2022-04-etsi-c-v2x-plugtests-event-achieves-a-93-interoperability-success-rate

[32] https://5gaa.org/wp-content/uploads/2022/04/5GAA-Workshop-31-March-2022-ETSI-C-V2X-PlugtestsPart-1_.pdf

[33] https://5gaa.org/c-v2x-in-action/

[34] ITU-R WP5A, Preliminary draft new report ITU-RM.[CAV] – Connected Automated Vehicles, 5A/769 Annex 17



[Source: 5GAA[35]]

Figure 9: Expected timelines for mass deployment of C-V2X use cases

6.3 Ecosystem availability

5GAA published a listing of C-V2X devices[36] demonstrating a strong ecosystem availability for C-V2X chipsets, modules, devices, road-side units and outdoor units from the industry.

[35] https://5gaa.org/content/uploads/2023/01/5gaa-white-paper-roadmap.pdf
[36] https://5gaa.org/wp-content/uploads/2021/11/5GAA_List_of_C_V2X_devices.pdf

7 Recommendations

For the development of V2X ecosystem in India and for ensuring interoperability across various use-cases that improve safety and traffic efficiency, the recommendations on the following points are made:

1. Spectrum related aspects
2. Standards related aspects
3. General recommendations to enable implementation of V2X

7.1 Spectrum related aspects

- For a sustainable growth of ecosystem and to support evolving ITS applications, it is critical that the globally harmonized ITS band in the 5.9 GHz is utilized for V2X services in India. This has already been allocated for ITS in NFAP 2022, footnote IND 29.

- Further, the regulatory rules and gazette notifications need to be developed on priority encompassing the aspects like the transmit power, out of band emissions of ITS equipment operating in the 5 875 to 5 925 MHz.

- Regulatory provisions of *license exempt* for building and integrating ITS technology in vehicles need to be developed to foster the adoption of C-V2X in India.

7.2 Standards related aspects

- As discussed in earlier sections, Access layer standards for ITS should be based on 3GPP C-V2X[37] for harmonized ecosystem, interoperability, long-term roadmap, and wider usage of ITS applications.

- Develop TEC Specifications related to testing and certification for OBU and RSU.

- For the non-access layer, the automotive ecosystem need to converge on using a common ITS stack to enable wider application support and full interoperability across various end-users, vehicle manufacturers and road side unit implementations. This will facilitate integration of the V2X services with a national ITS digital platform.
    - A listing of global standards (e.g. ETSI, SAE) is provided in Annex A.9.

7.3 General recommendations to enable implementation of V2X

- Inter-ministerial coordination between the related ministries such as DoT/ TEC and MoRTH is required to study the Indian requirements, develop the use-cases, and enable regulatory provisions required to facilitate the implementation of ITS and V2X in India.

[37] Explanation: *C-V2X continually evolves over multiple releases in 3GPP. Cellular-V2X (C-V2X) is the umbrella term which encapsulates all 3GPP V2X technologies, including both direct (PC5) and mobile network communications (Uu). This includes LTE-V2X and 5G-V2X* (https://5gaa.org/c-v2x-explained/)

- It is required to establish a multi-stakeholder task force to make and enforce policy for the V2X PKI to ensure consistent trust of V2X messages.

- Further, V2X communication be considered for the Bharat NCAP. This is consistent with similar global developments that are provided in an Annex A.8.

- V2X services need to interwork with smart cities platforms at the services / application layer.

7.4 Recommendations related to security implementation in V2X

- Industry standards as mentioned in Section 5 above and other may be utilized to secure V2X communications.

- Use PKI to authenticate the source of messages and ensure trustworthiness between communication parties.

- Implement strong end-to-end encryption mechanisms for V2X communications to protect data transmitted between vehicles, infrastructure, and other devices.

- Platform to be used in ITS should have provision to be integrated with National Trust Center (NTC) for managing vulnerabilities related issues. NTC is being implemented by C-DOT on the basis of framework as mentioned in TEC Technical Report on NTC.

Abbreviations

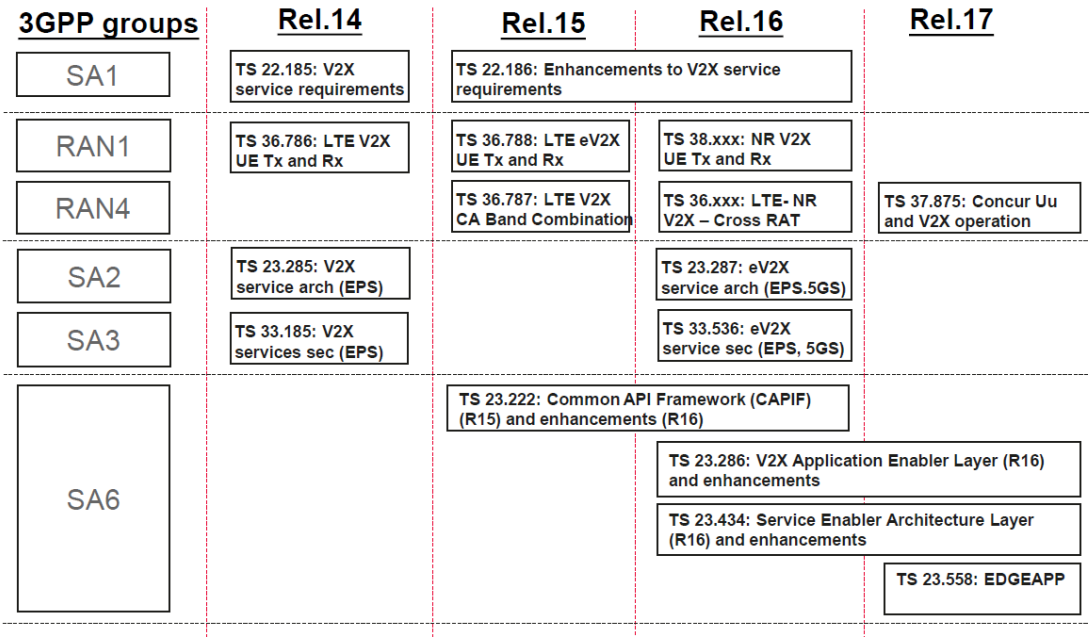
S. No.	Abbreviation	Full Form
1.	3GPP	3rd Generation Partnership Project
2.	5GAA	5G Automotive Association
3.	ATS	Abstract Test Suite
4.	APT	Asia Pacific Telecommunity
5.	ASN	Abstract Syntax Notation
6.	CAICT	China Academy of Information and Communications Technology
7.	DEN	Decentralized Environmental Notification
8.	C-V2X	Cellular Vehicle-to-Everything
9.	DoT	Department of Telecommunications
10.	DSRC	Dedicated Short Range Communication
11.	ETSI	European Telecommunications Standards Institute
12.	ENISA	European Network and Information Security Agency
13.	FCC	The Federal Communication Commission
14.	GSMA	Global System for Mobile Communications Association
15.	IEEE	Institute of Electrical and Electrical Engineering
16.	IEC	International Electrotechnical Commission
17.	ISO	International Organization for Standardization
18.	ITS	Intelligent Transport System
19.	ITU	International Telecommunication Union
20.	IPv6	Internet Protocol 6
21.	LOS	Line of sight
22.	LTE	Long Term Evolution
23.	M2M	Machine- to- Machine
24.	MQTT	Message Queuing Telemetry Transport
25.	NCAP	New Car Assessment Programme
26.	NDCP	National Digital Communication Policy
27.	NFAP	National Frequency Allocation Plan

28.	NIST	National Institute of Standards and Technology
29.	NLOS	Non-Line-of-Sight
30.	NTC	National Trust Center
31.	OBU	On-Board Units
32.	OEM	Original Equipment Manufacturer
33.	PICS	Protocol Implementation Conformance Statement
34.	PIXIT	Protocol Implementation eXtra Information for Testing
35.	RSUs	Road-Side Units
36.	SAE	Society of Automotive Engineers
37.	SCMS	Security Credential Management System
38.	SECUR	Safety Enhancement Through Connected Users on the Road
39.	SPV	Special Purpose Vehicle
40.	TEC	Telecommunication Engineer Center
41.	TSS & TP	Test Suite Structure and Test Purposes
42.	UTAC	United Test and Assembly Center Ltd
43.	V2N	Vehicle-to-Network
44.	V2X	Vehicle-to-everything
45.	WAVE	Wireless Access in Vehicular Environments
46.	WEF	World Economic Forum

Annexures

A.1 Summary of 3GPP V2X Specifications

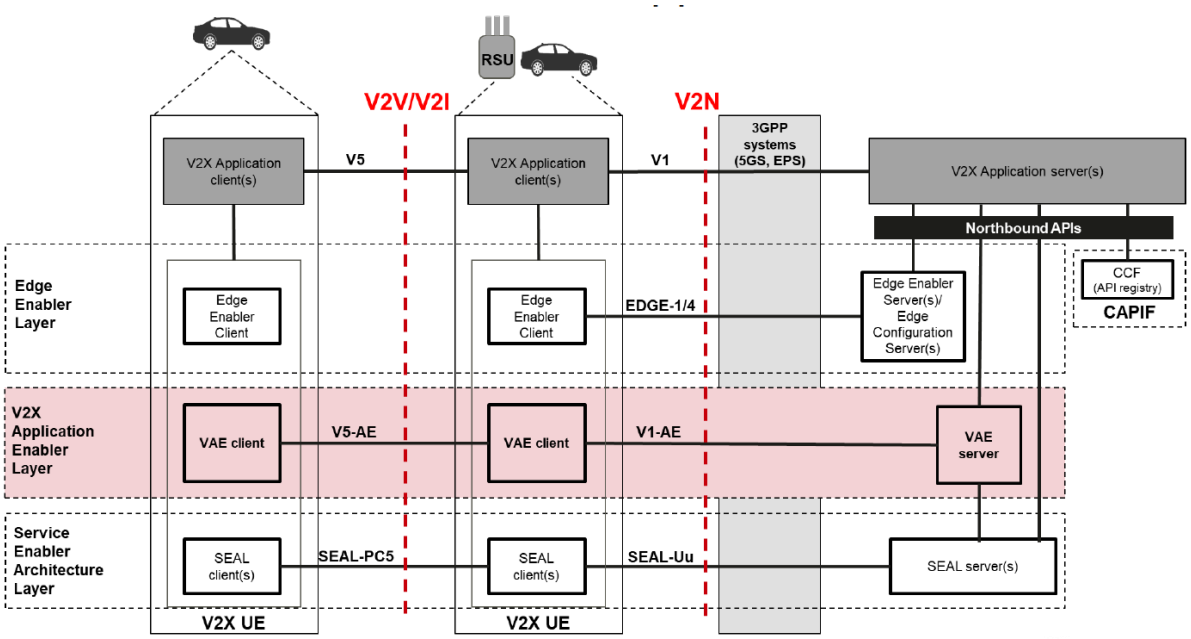
As detailed in Section 2.4, 3GPP continued to add functionality in its releases since release 14 to release 17 (as shown in Figure -10) and now further enhancing the sidelink communication to support vehicular devices used in V2X services[38] in Release 18[39]. One evolution objective is to increase sidelink data rate by adding the Carrier Aggregation (CA) feature in sidelink communication, extending sidelink operation to unlicensed spectrum, and enhancing sidelink support in the frequency range 2 (FR2). Besides, 3GPP is considering to study mechanisms to support LTE V2X and NR V2X devices co-existing in the same frequency channel.



[Source: 3GPP]

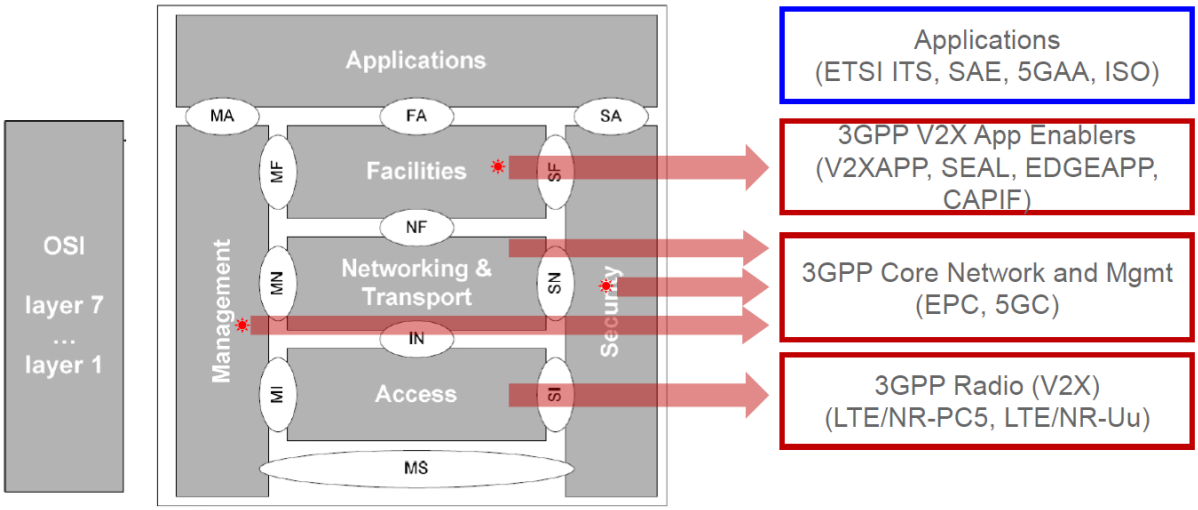
Figure 10: 3GPP C-V2X and its evolution

[38]M. Harounabadi et al., "V2X in 3GPP standardization: NR sidelink in release-16 and beyond," IEEE Communications Standards Magazine, vol. 5, no. 1, pp. 12-21, March 2021.
[39] https://www.3gpp.org/specifications-technologies/releases/release-18



[Source: 3GPP]

Figure 11: 3GPP Enabler Service for V2X Applications



[Source: 3GPP]

Figure 12: 3GPP and OSI Layer Mapping

Main focus is to simplify usage of 3GPP transport especially considering the V2X UE mobility and corresponding resource management by 3GPP system (EPS, 5GS)

- Applies to Unicast, Multicast, Broadcast, Groupcast

A.2 C-V2X Performance Testing

C-V2X performance has been tested for in rigorous conditions for V2V LoS and NLoS situations[40] by CAMP. The findings of these testing indicate the following key observations:

- Excellent range in LOS and non-LOS field geometries for V2V and V2I scenarios
- Good performance at high speeds
- Good performance in mixed, real-world traffic
- Reliable and predictable performance in congested environments

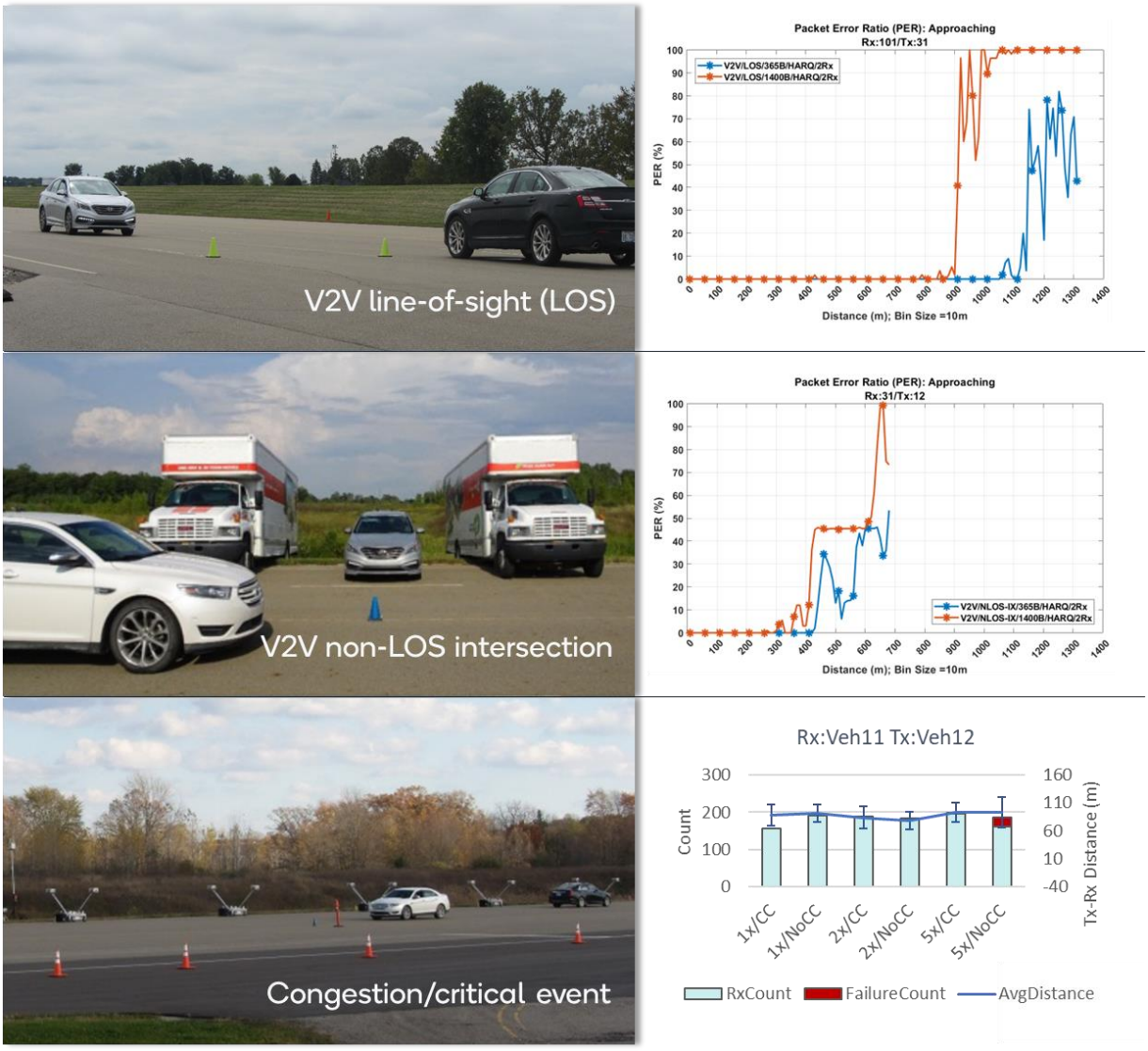
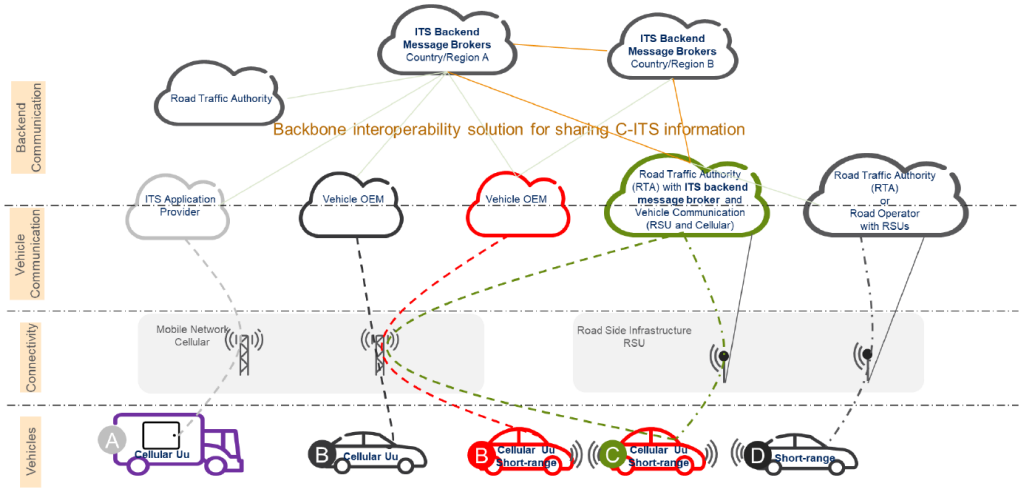


Figure 13: C-V2X performance testing by Project Crash Avoidance and Metrics Partners (CAMP)

[40] Project on "Cellular V2X Device-to-Device Communication (C-V2X) Project" by Crash Avoidance Metrics Partners LLC (CAMP) , https://www.campllc.org/project-cellular-v2x-device-to-device-communication-c-v2x/

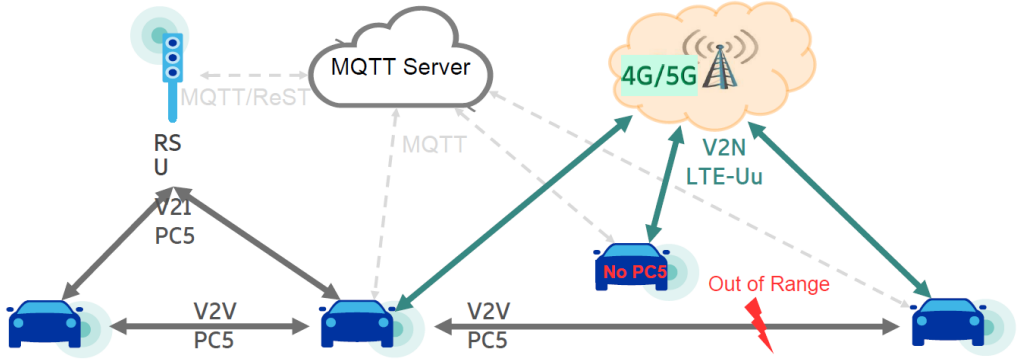
A.3 Cellular infrastructure and ITS backend-based C-ITS solutions – Implementation models by Ericsson



[Source: Ericsson]

Figure 14: Elements in ITS backend based C-ITS solution

- Using cellular communication
  - Vehicles at further distances can be reached
  - Normal smartphones or vehicles with LTE Uu but without PC5 can be reached
- MQTT and GeoFencing for efficient message exchange

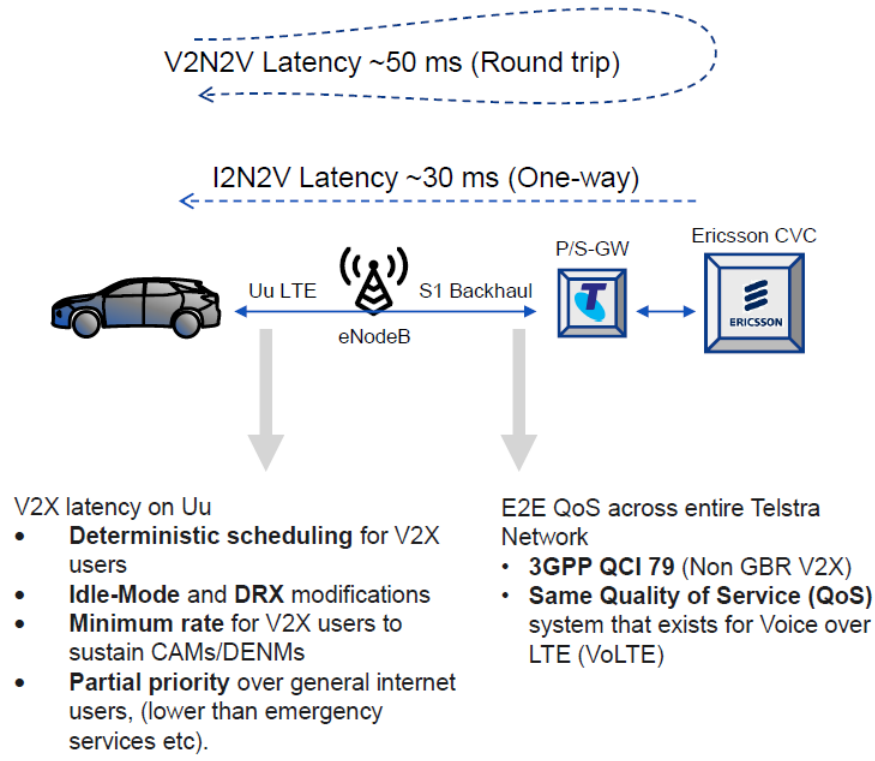


[Source: Ericsson]

Figure 15: Example using MQTT Server for C-ITS implementation

A 4G Uu optimized for V2X may be able to enable a deterministic latency required by V2X. One example deployment for V2V via the cellular network on the Uu interface is shown in the figure below. This is from Australia's C-V2X[41] project by Ericsson[42].

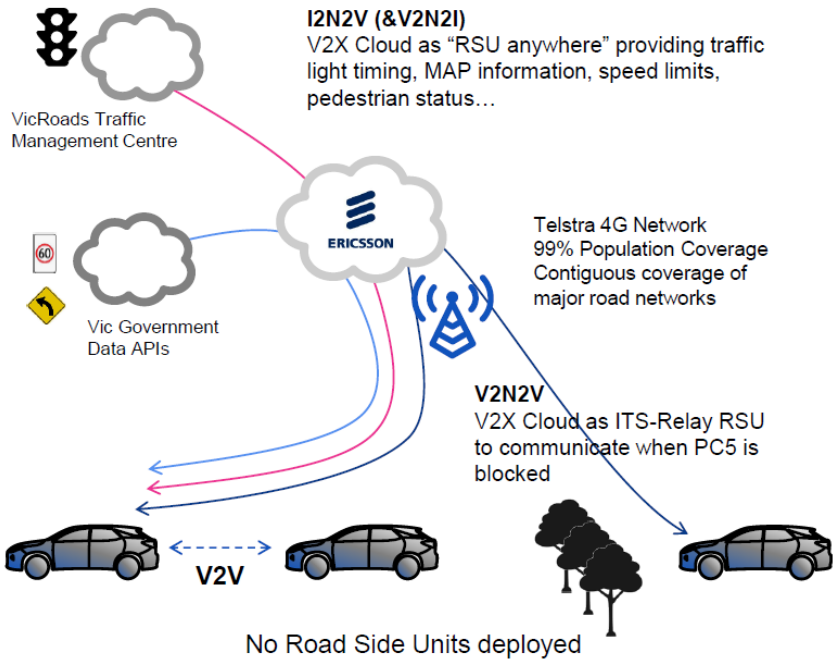
[41] https://5gaa.org/content/uploads/2019/05/06.Virtual_RSU_Architecture.pdf
[42] https://www.ericsson.com/en/cases/2020/cellular-v2x-creating-safer-roads



[Source: Ericsson]

Figure 16: Example deployment for V2V via the cellular network on the Uu interface

Such a mechanism may also enable a method to implement a virtualized RSU as depicted in the figure below:



[Source: Ericsson]

Figure 17: Virtualized RSU for V2V via the cellular network

A.4 ITS Application Examples and Experiments in India

A.4.1 Trial 1: Green Corridor for Emergency Vehicles using V2X Infrastructure

A trial was conducted to integrate the VMS's along with existing and new signaling systems using V2X infrastructure to enable a 'green corridor' for emergency vehicles such as ambulance. This allowed the changing of red signal cycle to green and extending green signal cycle to provide priority passage for such emergency vehicles.

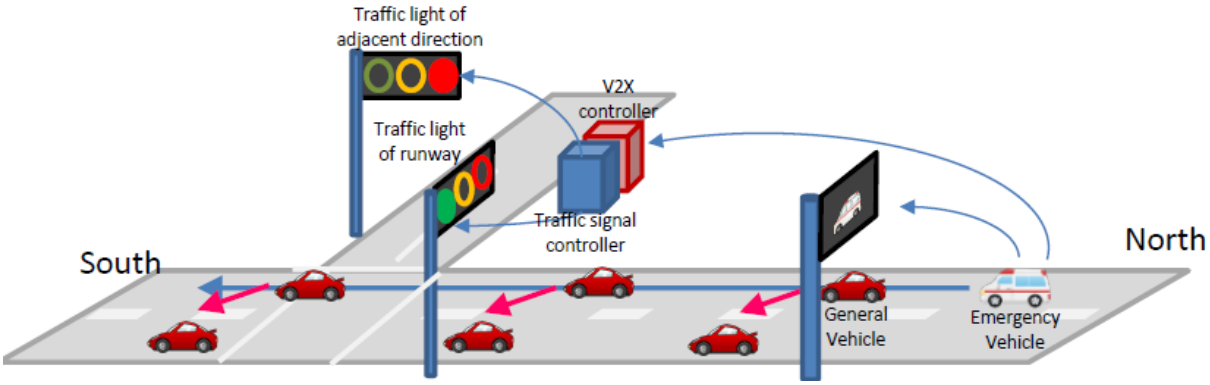


Figure 18: Trial for V2X infrastructure to enable a 'green corridor' for emergency vehicles

M/s Zero Sum ITS Solutions India Pvt Ltd conducted trials for ITS applications (ITS-Connect technology) in Ahmedabad in the sub-1 GHz band, as below:

- Phase-I: (February 2018): in 755-765 MHz for a duration of 3 months for detection of a certain class of vehicles (VIP).

- Phase-II :(July 2018): in 755-765 MHz for a duration of 3 months for detection of emergency vehicles and facilitate their passage by changing the signal.

- Phase-III: (November 2021): in 598.5-607.5 MHz for experiment in a wider area on 10 ambulances.

  Further in January 2022, an experimental trial was conducted with SPV of the Ahmedabad Municipal Corporation to showcase a public transportation vehicle priority system.

A.4.2 Trial 2: Research Demonstration of V2X (Vehicle-to-Everything) Communication

C-V2X technology for improving road-safety and reducing traffic congestion has been trialed and tested in the 5875-5925 MHz band for a range of safety-of-life use-cases by M/s Suzuki in collaboration with IIT Hyderabad in May 2022[43]. Some of the use case scenarios showcased were:

- **Ambulance Alerting System:** Car drivers are alerted about an approaching emergency vehicle and its path through V2X communication. It helps the driver to safely plan maneuvers and make way for an emergency vehicle. The alert system will also share minute details like the distance between the vehicles on a real-time basis.

[43] https://pr.iith.ac.in/pressrelease/V2X.pdf

- **Wrong-way Driver Alerting system:** Car drivers get a pre-alert about the existence of a wrong way-driver approaching using V2X communication.

- **Pedestrian Alerting System:** This alert assists car drivers about a pedestrian nearby, using V2X communication, who could be coming in the way of the car. This will help the drivers to take precautionary measures to avoid a potential collision.

- **Motorcycle Alerting System:** Car drivers learn through V2X communication about a fast-moving 2-wheeler approaching from a blind spot and likely to collide. Real-time information is shared with the driver about the distance and direction of the approach.

- **Road Condition Alerting System:** The driver receives an alert of bad road conditions and cautions the driver to tread carefully ahead in the journey.

- **Car as a computer:** Enables all interested car users to share the idle computing capacity of the microprocessor in the car when it is not being used for driving.

A.5 Changing Role of Telecom Service Providers (TSPs) in New Transportation Ecosystem

As shared autonomous vehicles could become mainstream, telecom companies can play a significant role in supporting such integration across mobility solutions.

- Telecom providers have an upper hand, as the smartphone becomes the hub of our increasingly digital lives, including not just our multiple interconnected and personalized smart devices but also our access to transportation.
- Content sourcing, creation, aggregation, pricing, bundling, and distribution will likely undergo a gradual change as the mobility landscape evolves.
- The in vehicle infotainment experience will be more immersive and engaging , delivering an augmented experience for the passenger as compared to media consumption on today's tablets and smartphones.

Mobility Management

- Telecom companies can play a vital role in enabling mobility services given their expertise in billing, payments, analytics for planning and optimization, and asset management services.
- Customer profile data or biometric authentication to manage vehicle access on behalf of fleet operators, ensuring the safety and security of both vehicles and co passengers.
- Telecom companies can also play a key role in enabling fleet management services, including automated fleet scheduling, dispatching, and tracking as well as assisting in managing the rapid anticipated growth of autonomous fleets.

The new ecosystem will likely enable telecom companies to penetrate vehicle operations. Established functions such as remote start/stop and lock/unlock to enabling systems as complex as self driving, telecom companies have opportunities to add entirely new revenue streams.

Telecom companies can provide vehicle/infrastructure data integration services for gathering, storing, cleansing, and analyzing high volume data today with their mediation platforms.

As more vehicles become connected and driverless, cybersecurity threats could rise, as the number of vulnerabilities is forecast to grow significantly. This creates an additional requirement for telecom companies to provide stronger vehicle and device security solutions. In the future of mobility, mobile network operators and telecom infrastructure providers can provide scalable cloud security solutions to help detect and mitigate potential threats.

A.6 Detailed Use Cases

Some use-cases for V2X can be classified as listed below.

Transactional Applications:

- Tolling Related Applications
- Restricted access at a certain time-period or permanently.
- Data Collection / Monitoring
- Speed Limit Violation

Emergency/ VIP Vehicles:

- Traffic Light Related Applications like Traffic Light Information, Request for preemption (helpful in setting up a green corridors)

Safety broadcast information:

- Traffic jam alert etc.
- Public service information.
- Bad Road / Roadworks warning.
- Disaster Zone communication.

Enabler of Services:

- V2X as a sensor to work in combination with other sensors at Edge/Cloud where applications can run based on sensor fusion.

In this annexure, a few use-cases are described in further detail to understand the entities and message exchange better.

A.6.1 Tolling applications

General Description:

- In India, in most places today we have a fixed tolling system and there are plans to use GPS based Tolling systems to enable variable tolling based on the length of the toll road used.
- However, V2X can bring many benefits to this application.

Benefits of V2X:

- A comprehensive solution to provide the tolling functionality along with other use-cases, without the need to setup separate infrastructure.
- Easily extensible for other kinds of tolls, eg, based on vehicle type, number of people in the vehicle, lane, day and time.
- The information from the RSU can be used by the user to decide and plan on the usage of the toll road.
- Apart from Toll charges, other informative applications can be easily built with V2X e.g., toll lane closures, timings, parking related tolls, speed Limits, work Zones, congestion etc.
- The inbuilt security and privacy mechanisms of V2X can be reused to build a secure and safe system.

The sample message flow for this use-case is described below:

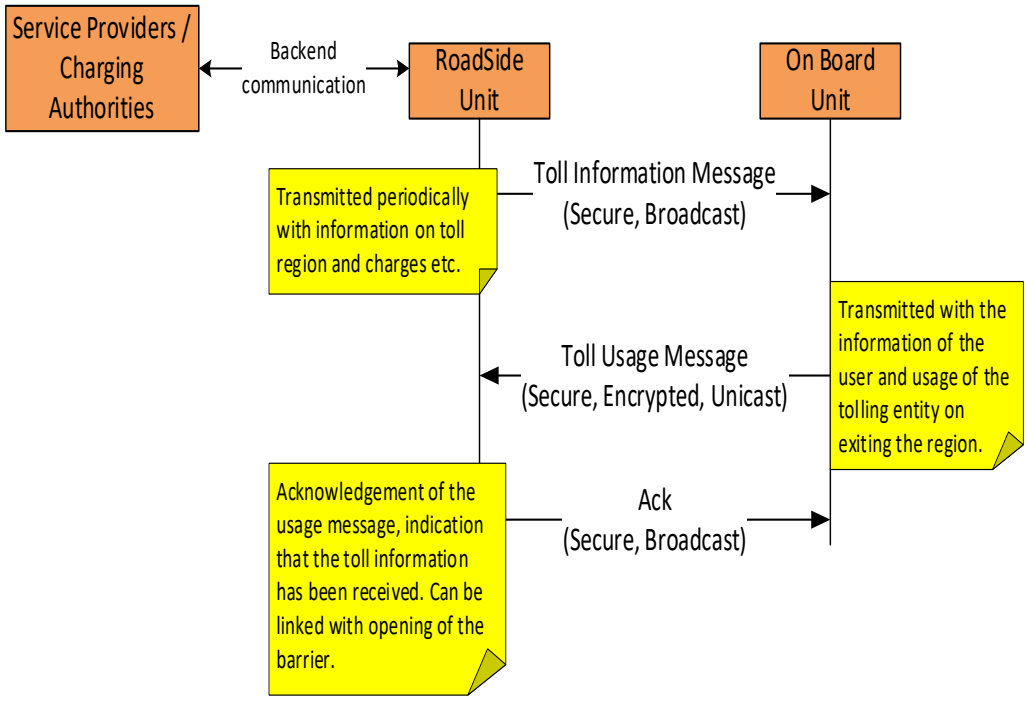


Figure 19: Example message flow for V2X Tolling applications

A.6.2 Restricted access and speed limit and Broadcasting applications

General Description:

- There can be Dynamic or Permanent restrictions for certain types of vehicles in a region/lane. Currently this information is conveyed through signs alongside road or relies on driver's knowledge, e.g., to drive the heavy vehicles on the leftmost lane.
- V2X can bring in a lot of benefits by supporting seamless broadcast.

Benefits of V2X:

- Periodic broadcast of information by the infrastructure unit.
- Application on the OBU gives warning to the driver if they are violating the rule.
- Applications can give an advisory alert to the driver regarding the restriction or speed-limit etc. in the approaching zone.
- Dynamic changes because of some accident, road conditions, lane closures, roadworks can be easily brought in.
- Not easy to implement dynamic changes on signs alongside road. The signs may be hidden out of sight, vision may be poor because of weather conditions, or the signs could be in a language which the driver doesn't understand.
- This can be initially rolled out for commercial vehicles (trucks etc) which experience a lot of accidents which contribute to a high level of fatalities and are also a big reason for fines and delays causing avoidable expense.

The sample message flow for this use-case is described below:

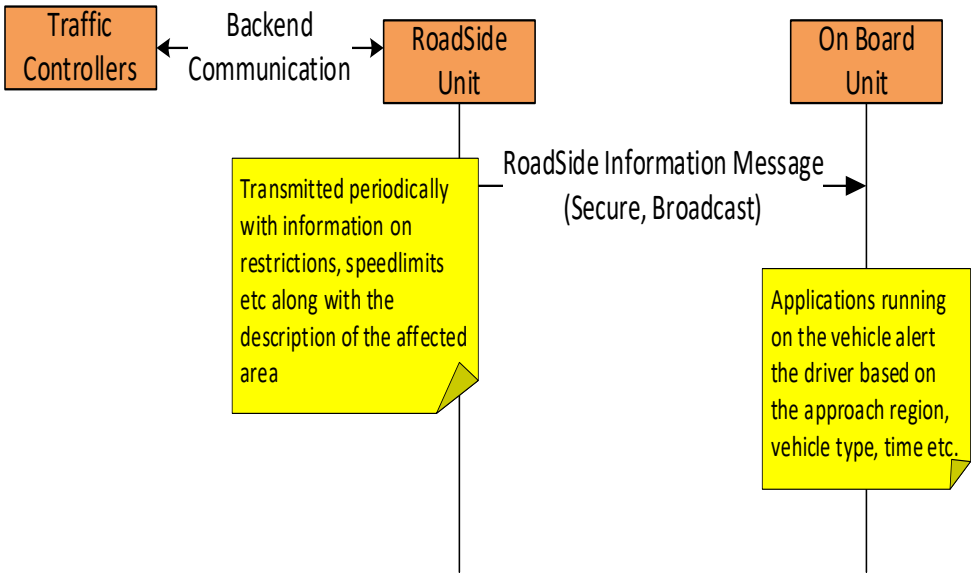


Figure 20: Example message flow for Restricted access and speed limit and Broadcasting applications

A.6.3 Data collection and monitoring

General Description:

- For a traffic controller to take decisions and enforce rules, data collection and monitoring are important.
- Today most of the monitoring and enforcement is done manually either by daily monitoring or conducting drives. This could be hassle for the enforcement officer and the surrounding traffic if the pulling off of the offending vehicles causes a slowdown in the surrounding area.
- V2X can aid in this process and the data can be used for multiple use cases without compromising the privacy.

Benefits of V2X:

- The vehicles periodically send information on the location, speed, acceleration etc, and other vehicle information. This data could be useful for the traffic controller to understand the traffic type at different timings and the number of violations etc (eg, speed limit violations happening) and enforce rules accordingly.
- This data and traffic monitoring could also be useful for further planning activities.
- Further enhancements can be done to get alert information too (number of vehicles alerted and a possible violation avoided).
- Several use cases can be developed once data is available even if it is only from commercial and emergency vehicles.

The sample message flow for this use-case is described below:

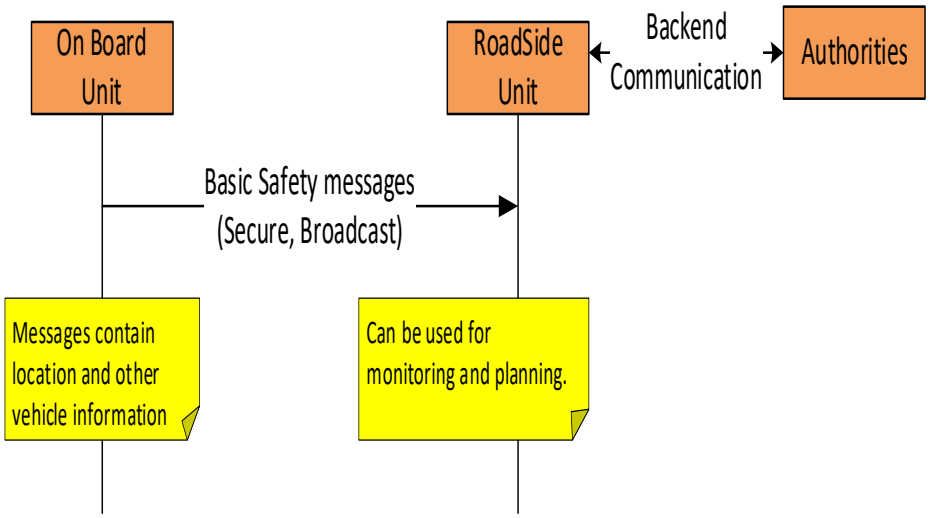


Figure 21: Example message flow for Data collection and monitoring

A.6.4 Traffic light applications

General Description:

- It is important for an emergency vehicle or a VIP vehicle to get a green corridor to be able to pass quickly and easily. Today getting a green corridor is not only expensive but, also very difficult to achieve.
- Letting the emergency vehicles cross on Red Light is also not always safe as there may be multiple emergency vehicles from different sides of the intersection.
- V2X can aid in implementing the green corridor and also avoid any possible collision between two emergency or special vehicles.

Benefits of V2X:

- Traffic light information is used by applications at the emergency vehicles or VIP vehicles to request for an extension of green light.
- This information can also be used amongst the emergency vehicles to get information in case more emergency vehicles are trying to pass an intersection at red light from intersecting directions and give an alert to the driver in case there is a possibility of a collision.
- Using V2X will not only provide additional safety but, will also aid in cost reduction in managing the traffic in emergencies and VIP movement.

The sample message flow for this use-case is described below:

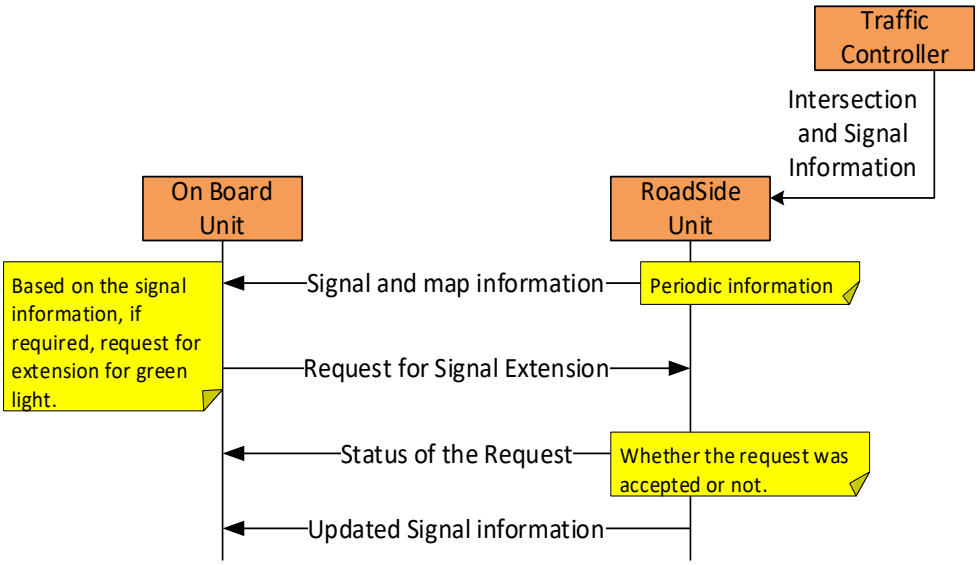


Figure 22: Example message flow for Traffic light applications

A.6.5 Emergency/VIP vehicle warning

General Description:

- When an emergency vehicle/VIP is passing through an intersection, it informs the surrounding vehicles by alarm lights and siren.
- This doesn't give information on which lane and direction of the vehicle.

Benefits of V2X:

- With V2X these special vehicles will broadcast their information periodically which can be used by the surrounding vehicles to warn the driver and give way.
- Using V2X will not only provide additional safety but, will also aid in cost reduction in managing the traffic in emergencies and VIP movement

The sample message flow for this use-case is described below:

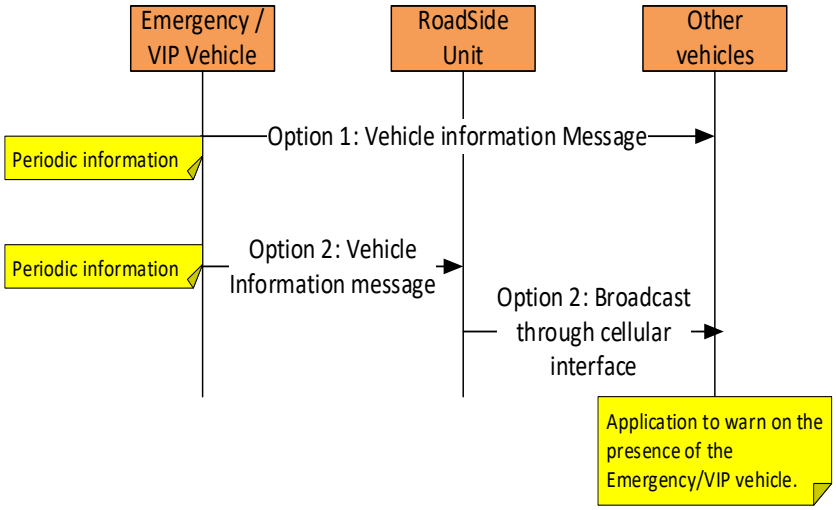


Figure 23: Example message flow for Emergency/VIP vehicle warning

A.7 Use-cases considered by CAICT, China

The following use-cases have been identified in the China C-V2X industry developments across 4-cross interoperability trials and four national V2X pilot areas.

Sr. No.	Type	Communication Type	Application
1	Safety	V2V	Forward Collision Warning
2		V2V/V2I	Intersection Collision Warning
3		V2V/V2I	Left Turn Assist
4		V2V	Blind Spot Warning
5		V2V	Do Not Pass Warning
6		V2V-Event	Emergency Brake Warning
7		V2V-Event	Abnormal Vehicle Warning
8		V2V-Event	Control Loss Warning
9		V2I	Hazardous Location Warning
10		V2I	Speed Limit Warning
11		V2I	Red Light Violation Warning
12		V2P/V2I	Vulnerable Road User Collision Warning
13	Efficiency	V2I	Green Light Optimal Speed Advisor
14		V2I	In-vehicle Signage
15		VI2	Traffic Jam Warning
16		V2V	Emergency Vehicle Warning
17	Information Service	V2I	Vehicle Near-field Payment

A.8 Global New Car Assessment Program (NCAP) developments related to V2X

Euro NCAP:

Euro NCAP 2025 roadmap[44] included V2X communication as an important element for vehicle safety rating. Further, Euro NCAP 2030 roadmap[45] recognizes that leveraging vehicle connectivity is one of the main milestones towards crash avoidance. V2X relevant items in Euro NCAP:

- From 2023
  - Small portion within Speed Assistance Assessment is dedicated to Local Hazards – maximal contribution to rating ~1,5%
- From 2026
  - Increased portion within Speed Assistance Assessment by Day 1 Applications.
- From 2029
  - Further increased portion within Speed Assistance Assessment by Day 1 Applications.
- From 2032
  - In addition to Safe Driving / Speed Assistance, also for Crash Avoidance it is expected that non-safety critical scenarios based on vehicle communication will be added
  - For Crash Avoidance it is expected that safety critical scenarios based on vehicle communication will be added
- UTAC secure V2X project[46]
  - The SECUR (Safety Enhancement Through Connected Users on the Road) project co-ordinated by UTAC was formed to define V2X testing and assessment protocols for Euro NCAP.
  - As a first step, the most frequent and severe accident scenarios found on European roads were identified. Then, current knowledge on V2X communication systems was analyzed. Next, multi-technology connected targets were specified and developed and then use cases were derived from accident research and mapped with V2X technology types and messages, the latter being seen as a new sensor.

K-NCAP:

- Initial discussions on V2X communications in the Korea NCAP[47]

[44] https://cdn.euroncap.com/media/30700/euroncap-roadmap-2025-v4.pdf
[45] https://cdn.euroncap.com/media/74468/euro-ncap-roadmap-vision-2030.pdf
[46] https://www.utac.com/your-needs/automated-connected-vehicles/
[47] https://www.safetywissen.com/object/B04/B04.g37738591uq4y2xpurf616831nqhdx63814237683/safetywissen

A.9 List of Specifications for V2X

A.9.1 List of ETSI Specifications for V2X

The ETSI ITS Release-1 minimum set of specifications are listed in this Annexure.

A.9.1.1 Core Specifications

Profile

- ETSI TS 103 723 V1.2.1; Intelligent Transport Systems (ITS); Profile for LTE-V2X Direct Communication

Access Layers

- ETSI EN 303 613 V1.1.1; Intelligent Transport Systems (ITS); LTE-V2X Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band
- ETSI TS 103 574 V1.1.1; Intelligent Transport Systems (ITS); Congestion Control Mechanisms for C-V2X PC5 interface; Access layer part

Applications / Facilities

- ETSI EN 302 637-2 V1.4.1; Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service
- ETSI EN 302 637-3 V1.3.1; Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service
- ETSI TS 103 301 V1.3.1; Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services

GeoNetworking

- ETSI EN 302 636-4-1 V1.4.1; Intelligent Transport System (ITS); Vehicular communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality
- ETSI TS 102 636-4-3 V1.1.1; Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 3: Media-dependent functionalities for LTE-V2X

A.9.1.2 Testing specifications

Access Layers testing

- ETSI TS 103 794 V1.1.1; Intelligent Transport Systems (ITS); LTE-V2X Access layer for Intelligent Transport Systems operating in the 5 GHz frequency band; Test specification

Applications / facilities testing

- ETSI TS 102 868-1 V1.4.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Cooperative Awareness Basic Service (CA); Part 1: Test requirements and Protocol Implementation Conformance Statement (PICS) pro forma
- ETSI TS 102 868-2 V1.4.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Cooperative Awareness Basic Service (CA); Part 2: Test Suite Structure and Test Purposes (TSS & TP)

- ETSI TS 102 868-3 V1.4.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Cooperative Awareness Basic Service (CA); Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)
- ETSI TS 102 869-1 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Decentralized Environmental Notification Basic Service (DEN); Part 1: Test requirements and Protocol Implementation Conformance Statement (PICS) pro forma
- ETSI TS 102 869-2 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Decentralized Environmental Notification Basic Service (DEN); Part 2: Test Suite Structure and Test Purposes (TSS & TP)
- ETSI TS 102 869-3 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for Decentralized Environmental Notification Basic Service (DEN); Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)

GeoNetworking testing

- ETSI TS 102 871-1 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for GeoNetworking; Part 1: Test requirements and Protocol Implementation Conformance Statement (PICS) pro forma
- ETSI TS 102 871-2 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for GeoNetworking; Part 2: Test Suite Structure and Test Purposes (TSS & TP)
- ETSI TS 102 871-3 V1.5.1; Intelligent Transport Systems (ITS); Testing; Conformance test specifications for GeoNetworking; Part 3: Abstract Test Suite (ATS) and Protocol Implementation eXtra Information for Testing (PIXIT)

ETSI is in the process of updating the ITS Specification list TR 101 607. The updated list will include the latest revisions to the ITS specifications.

A.9.2 List of SAE Specifications

The core SAE specifications are listed below.

- SAE J2735, V2X Communications Message Set Dictionary, J2735_202211, Standard
- SAE J2735 ASN, V2X Communications Message Set Dictionary™ ASN file, J2735ASN_202211, ASN.1 definitions files
- SAE J2945/1, On-Board System Requirements for V2V Safety Communications, J2945/1_202004, Standard
- SAE J3161/1A, Vehicle Level Validation Test Procedures for V2V Safety Communications, J3161/1A_202204, Recommended Practice
- SAE J2945/1B, On-Board System Requirements for V2V Safety Communications by Non-Light-Duty Vehicles and Motorcycles, J2945/1B_202212, Standard
- SAE J2945/4, Road Safety Applications, J2945/4_202305, Standard
- SAE J3161/1, On-Board System Requirements for LTE-V2X V2V Safety Communications, J3161/1_202203, Standard
- SAE J3217, V2X-Based Fee Collection, J3217_202206, Standard

List of Working Group (WG) meetings

S. No.	Date of the virtual meeting of WG
1.	12th July 2022
2.	22nd August 2022
3.	26th September 2022
4.	4th November 2022
5.	16th December 2022
6.	23rd January 2023
7.	27th February 2023
8.	24th March 2023
9.	11th May 2023
10.	26th June 2023

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