White paper

Anritsu envision : ensure

How V2X is Changing Automotive Design

A New Automotive Era

The automotive industry is in the midst of a new era, one in which the car is much more than a mode of transportation. It is quickly transforming into a communication device, much like the smartphone. Vehicle-to-everything (V2X) is a key technology in this evolution.

V2X allows automobiles to directly connect with each other, roadside infrastructure, and pedestrians to deliver benefits ranging from road safety, traffic efficiency, and smart mobility to environmental sustainability and driver convenience. It is also a key technology to support autonomous vehicles, especially when 5G Cellular Vehicle-to-everything (C-V2X) is available, allowing cars to signal intent to other automobiles.

While the benefits of V2X are many, so are the engineering challenges. Vehicles are becoming, in essence, mobile data centers that connect with the entire transportation ecosystem. Considering the safety-based nature of many of these use cases, verifying performance is critical.

Engineers were familiarizing themselves with two technologies – Dedicated Short Range Communications (DSRC) and Cellular-V2X (C-V2X) – when designing V2X products. A recent ruling by the United States Federal Communications Commission (FCC), though, has changed the course of V2X designs for the U.S. market. Now, engineers need to turn their attention to C-V2X when designing chipsets, systems, and networks used in this new generation of transportation. Their test processes must also follow that direction and provide the necessary C-V2X support to verify performance.

V2X: Creating A Global Highway

Over the past several years, the United States Department of Transportation (USDOT) and its operating administrations have engaged in numerous activities related to connected vehicles. The U.S. is hardly alone with this initiative, however. Figure 1 provides a snapshot of the rollout of this automotive technology globally.

Figure 1: *Global rollout of V2X technology.*

Global spending on V2X communications technology is expected to grow at a CAGR of more than 170% between 2019 and 2022. SNS Telecom & IT predicts that by the end of 2022, V2X will account for a market worth $1.2 billion, with an installed base of nearly 6 million V2X-equipped vehicles worldwide (figure 2).

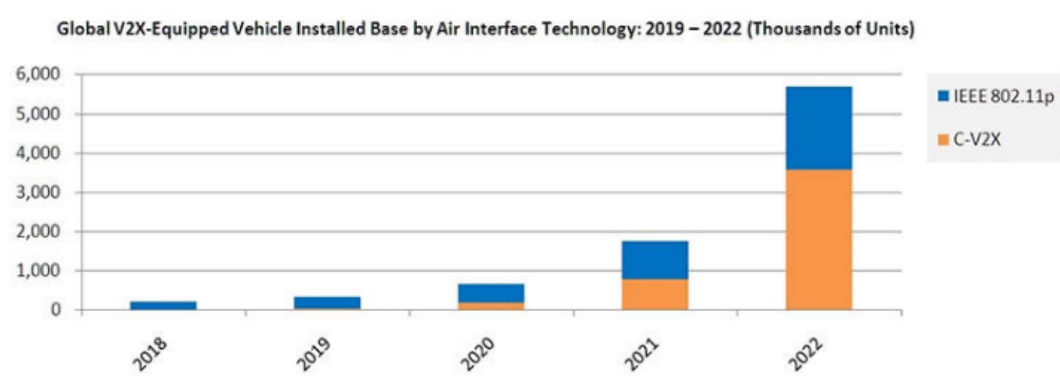

Figure 2: *Courtesy of SNS Telecom & IT.*

Safety is the key initial driver of V2X. According to the USDOT, V2X is expected to reduce unimpaired vehicle crashes by 80%. Drilling a bit deeper, Vehicle-to-vehicle (V2V) – one element of V2X – can prevent 615,000 motor vehicle crashes, according to the National Highway Traffic Safety Association (NHTSA). In short, connected vehicle technologies will provide drivers with the tools to anticipate potential crashes and significantly reduce the number of lives lost each year.

While safety is the primary initiative, it is not the only advantage to come from V2X. Subsequent use cases will be on cooperative driving that leads to benefits to the environment and society overall.

V2X: Creating A Global Highway

5.9 GHz is the preferred frequency for V2X in nearly every country worldwide. It needs to be noted that the European Automobile Manufacturers Association (ACEA) has had discussions on expanding to 3.4 – 3.8 GHz and 5.9 – 7.2 GHz frequency ranges. Millimeter wave (mmWave) spectrum is preferred for Line-of-Sight (LOS) and high data rate V2X applications.

Data exchange in a V2X system is between on board units (OBUs) and roadside equipped devices called road side units (RSUs). As their respective names indicate, OBUs are designed into the vehicles while RSUs are integrated into traffic lights, along roadsides, in parking garages, and in other transportation infrastructure. OBUs allow C-V2X and DSRC communications with other OBUs or RSUs.

V2X is broken down into four pillars:

1. **Vehicle-to-vehicle (V2V)** – Cars, trucks, buses, motorcycles, and emergency vehicles can all use V2V technology. V2V systems wirelessly exchange information about the speed and position of surrounding vehicles to ease traffic congestion and improve the environment. It is the culmination of more than a decade of development, which began when the NHTSA collaborated with the automotive industry and academic institutions.

   With V2V, vehicles broadcast and receive omni-directional messages (up to 10 times per second), creating a 360° "awareness" of other vehicles in proximity. Vehicles use the messages from surrounding automobiles to determine potential crash threats. V2V communication messages can have a range of more than 300 meters and can detect dangers obscured by traffic, terrain, or weather.

2. **Vehicle-to-infrastructure (V2I)** – The next generation of Intelligent Transportation Systems (ITS), V2I captures vehicle-generated traffic data. Enabled by a network of hardware, software, and firmware, V2I shares information between several vehicles using network elements, such as RFID readers, signage, cameras, lane markers, streetlights, and parking meters. V2I also communicates the timing of the traffic lights to vehicles, so they can decelerate as they approach a light changing from green to red, rather than having to perform last-moment braking.

   State and local agencies are installing V2I infrastructure alongside or integrating it with existing ITS equipment. Systems provide information that inform the driver of safety, mobility, or environment-related conditions. V2I captures data, such as traffic congestion, weather advisories, and bridge clearance levels, and then wirelessly transmits it to inform drivers of said conditions with the goal of improving safety.

3. **Vehicle-to-pedestrian (V2P)** – V2P involves a wide category of road users that go beyond automobiles when this V2X technology is integrated into smartphones. It incorporates pedestrians, passengers embarking and disembarking buses and trains, and cyclists. It is particularly important given data from the Society of Automotive Engineers (SAE) that states 45% of all accidents occur at intersections, where many of these non-vehicle crossings are made.

4. **Vehicle-to-network (V2N)** – V2V communications is enabled by V2N, which uses broadcast and unicast signals between vehicles and the V2X management system, as well as the V2X Application Server (AS). Vehicles receive broadcasted alerts regarding accidents further down the road or warnings of congestion. In C-V2X, the V2N connection is via LTE to the cellular network. V2N will also leverage 5G for connections using network slicing and Ultra-Reliable Low-Latency Communication (URLLC).

   Cellular V2N connectivity enables a wide range of road transport and automotive services, including regulated Cooperative Intelligent Transport Systems (C-ITS), and Advanced Driver Assistance Systems (ADAS). It can also connect road infrastructure services; vehicle-centric OEM telematics and aftermarket services; fleet management and logistics services; and convenience and infotainment services.

Organizations Provide Pathway Forward

Emerging technologies in expanding use cases has led to multiple industry groups creating standards and guidelines for engineers to follow. Among the more prominent organizations, as well as their contributions, are:

- **5G Automotive Association (5GAA)** is a global organization of which Anritsu is a member. This group of market leaders from the automotive, technology, and telecommunications industries is working to develop end-to-end solutions for future mobility and transportation services based on C-V2X. 5GAA has developed predictive Quality of Service (QoS) that enables mobile networks to provide advance notifications about anticipated QoS changes. This allows necessary parties to adjust application behavior before the predicted QoS change occurs – vital for use cases such as remote and autonomous driving.

- **OmniAir Consortium** promotes interoperability and certification for connected vehicles, ITS, and transportation payment systems. OmniAir's membership includes public agencies; companies (including Anritsu); manufacturers of chipsets, OBUs, and RSUs; as well as research institutions and independent test labs.

  The OmniAir Certification Program was established to provide consistency in the behavior of DSRC-enabled devices by confirming that products conform to OmniAir's process, which has test procedures derived from agreed upon requirements and standards. Test specifications developed by OmniAir are now available for LTE-based C-V2X, as well. Members have access to independent, third-party device testing and certification through OmniAir Authorized Test Laboratories (OATL), which are ISO-17025 accredited facilities.

- IEEE established the original V2X standard and based it on Wi-Fi derivative IEEE 802.11p. A new standard – IEEE802.11bd – is in the early stages and will address enhancements to the MAC and PHY specifications of DSRC.

- **3GPP Release 14** created a path for V2X to integrate 5G, whose high reliability and low latency are key benefits to the mission critical use cases of many V2X applications. It defines two C-V2X transmission modes that, together, enable a broad range of use cases. C-V2X has a technology evolution roadmap that is backward compatible.

  V2V is based on device-to-device (D2D) communications defined as part of ProSe services in 3GPP Release 12 and Release 13. ProSe designates a new D2D interface – PC5 (aka sidelink at the physical layer) – that has been enhanced for vehicular use cases, specifically addressing high speed (up to 250 kph) and high density (thousands of nodes). 3GPP V2X phase 2 in Release 15 introduces new features in sidelink, including carrier aggregation, high order modulation, transmission diversity, and short Transmission Time Interval (TTI).

- SAE passed the J2735 standard, which established the data frame and elements associated with DSRC. Another DSRC-based standard, SAE J2945/3, specifies interface requirements for weather data collection and distribution using V2X communications.

  Additionally, SAE created the J3161 standard that describes a reference system architecture based on C-V2X technology, in particular, using 3GPP Release 14 and Release 15 PC5. SAE International developed a chart (figure 3) to clarify its "Levels of Driving Automation" that defines six planes, from SAE Level Zero (no automation) to SAE Level 5 (full vehicle autonomy). Representatives from traditional automotive industry segments, including insurance companies, the American Automobile Association, and the Transportation Research Board, provided input for the chart. It serves as the industry's most-cited reference for automated-vehicle (AV) capabilities.

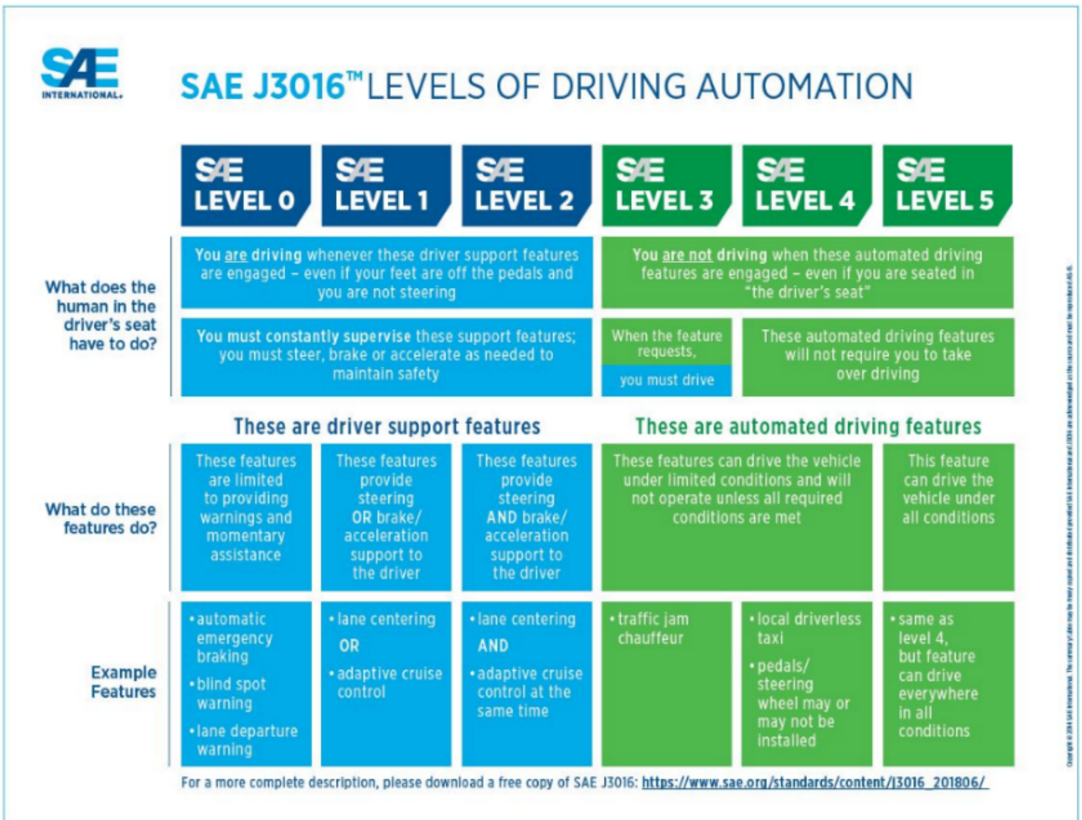

Figure 3: *Society of Automotive Engineers Levels of Driving Automation chart. (Courtesy of SAE).*

- ETSI supports the development, ratification, and testing of globally applicable standards for ICT (Information and Communication Technology) systems and services. ETSI released EN 303 613 to define the use of C-V2X as an access layer technology for ITS devices. The physical layer, data link layer, and radio resource configuration are grouped into the access layer of the ITS station reference architecture ETSI EN 302 665.

  ETSI standards that define other ITS protocols above the access layer have also been updated to support utilization of C-V2X as the underlying access layer. They are included in ETSI TR 101 607. The access layer of the PC5 interface is covered in ETSI TS 136 300. The LTE-V2X standards are defined in ETSI TS 136 331 and ETSI TS 136 414.

Table 1 provides an outline of the respective standards and their global implementation.

WAVE (US)	ITS-GS (Europe)	ITS Connect (Japan)	Cellular-V2X
• IEEE 802.11p • IEEE 1609.x • SAE J2735 & J2945/x	• IEEE 802.11p • ETSI specifications (ITS-G5/C-ITS protocol stack)	• IEEE 802.11p • ARIB STD-T75/T109 • ITS Connect TD-001 ITS Info-Communications Forum guidelines	• 3GPP releases 14, 15 & 16 • SAE J3161 & SAE J3186 • CCSA's C-V2X spec for China • T/CSAE 53-2017

Table 1: *Various V2X standards and worldwide deployment*

DSRC Running Out of Gas

For years, design engineers' efforts were complicated by having to consider two technologies: Supporting Wi-Fi-based DSRC and C-V2X, which leverages cellular. There were compatibility, cost, and complexity concerns with this scenario. All that seems to be rectified by the November 2020 decision by the FCC.

DSRC, the original V2X standard, had one major advantage – a track record. The real-world deployment of DSRC meant developers were able to fix bugs and verify the performance of DSRC. Maturity is a desired trait given the high reliability levels demanded in automotive use cases.

Deployment, particularly of ITS, however, was not fast enough for the FCC. In November 2020, the FCC adopted new rules for the 5.9 GHz band. The plan approved by the FCC designates the upper 30 MHz (5.895-5.925 GHz) for ITS services and C-V2X as the technology standard for safety-related transportation and vehicular communications. The lower 45 MHz (5.850-5.895 GHz) of the band is allocated for unlicensed uses, especially Wi-Fi.

The action by the FCC begins a transition away from DSRC services, much to the dismay of the USDOT. Opposition was voiced by the federal transportation agency but the FCC made its ruling nonetheless.

C-V2X is Gaining Ground

For years, design engineers' efforts were complicated by having to consider two technologies: The decision by the FCC to select C-V2X exclusively for ITS continues the momentum the technology has experienced in V2X applications. Cellular and chip providers created the C-V2X specifications in 2017. 5GAA established a roadmap that identifies the required use cases and services, which are expected to be enabled by 5G-V2X in the coming decade (figure 4).

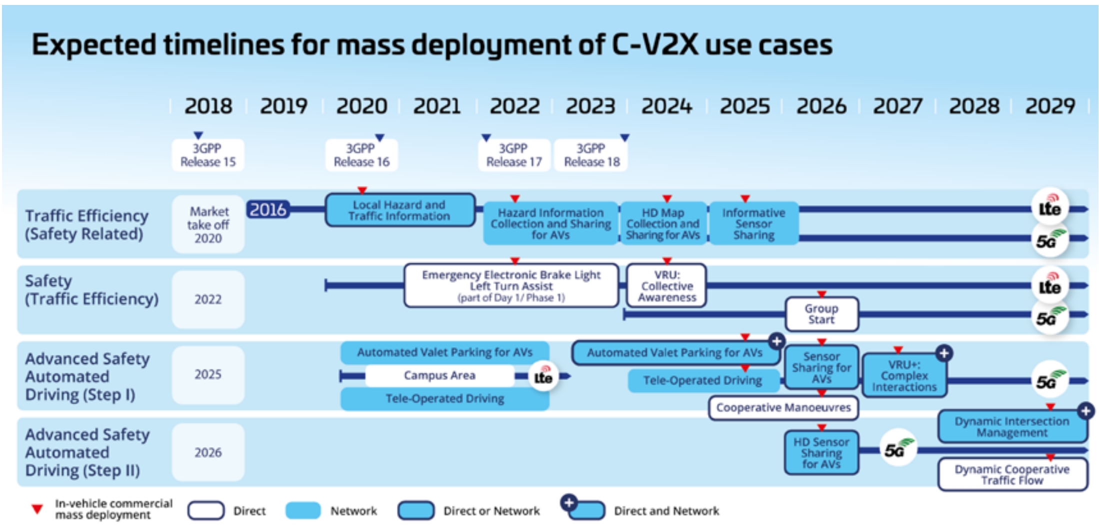

Figure 4: *Projected timeline for C-V2X use case deployment. (Courtesy of 5GAA)*

Leveraging the 3GPP standards, C-V2X utilizes 4G LTE and 5G. V2X applications in the vehicle can request one or more communication links with a V2X application server through the mobile network, setting specific Key Performance Indicators (KPIs) based on the 5GAA QoS for designated links. For example, it will establish KPIs for sending or receiving video streams, downloading maps, and software updates.

A key advantage of C-V2X is that it has two operational modes, as outlined in 3GPP Release 14. Between the two modes, most scenarios are addressed. Figure 5 provides an outline of each.

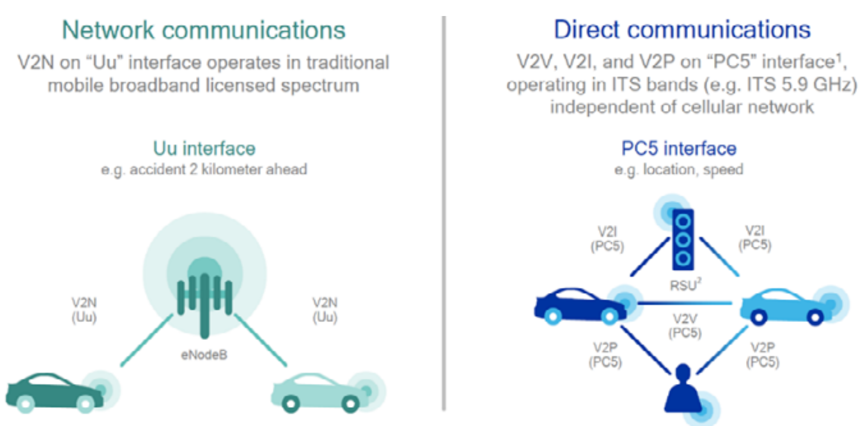

Figure 5: *Two operational modes of C-V2X.*

The first mode is low-latency C-V2X Direct Communications over the PC5 interface on the unlicensed 5.9 GHz band. It is designed for active safety messages such as immediate road hazard warnings and other short-range V2V, V2I, and V2P situations. This mode aligns closely with DSRC.

The second mode uses the LTE-Uu interface on the regular licensed-band cellular network. This V2N connection is used for a wide variety of services, including telematics, connected infotainment, real-time navigation, and traffic optimization. It is also for safety services, such as eCall and similar automatic crash notifications (ACNs), the recognition of slow or stationary vehicle(s), and informational events. Because it doesn't use cellular connectivity, DSRC can only match this mode by making ad hoc connections to roadside base stations. Table 2 provides C-V2X use cases and performance.

Use Cases	C-V2X Rel-14/15	C-V2X Rel-16(expected design)
Target Use Cases	Day 1 safety & enhanced safety use cases	Advanced use cases to assist in autonomous driving including, ranging assisted positioning, high throughput sensor sharing & local 3D HD map updates
Performance		
High density support	✓ Can guarantee no packet loss at high densities	✓ Can guarantee no packet loss at high densities
High mobility support	✓ Up to relative speed of 500 km/hr as a minimum requirement.	✓ Up to relative speed of 500 km/hr as a minimum requirement
Transmission range @ 90% error, 280 km/hr relative speed	-Over 450m using direct mode -Very large via cellular infrastructure	-Over 450m using direct mode -Very large via cellular infrastructure
Typical transmission frequency for periodic traffic	Once every 100ms (20ms is also possible)	Supports packet periodicities of a few ms.

Table 2: *Use cases and performance of V2X. (Courtesy of Qualcomm, Inc.).*

C-V2X Test Environment

Design teams should take a system-level approach when testing C-V2X systems. The process must integrate the C-V2X modem with other system elements, such as the application processor, security module, and positioning device. Implementing this procedure will help ensure functions up to the application layer will perform according to specification.

A comprehensive test environment combining hardware and software should be created, whether it is a chipset, OBU, RSU, or network element being verified. The environment needs to reproduce specific field issues in the lab using a traffic scenario editor and network simulator. Table 3 list specific use cases defined in 3GPP and regional ITS standards that need to be tested.

• Forward Collision Warning (FCW)	• Stationary Vehicle Warning (SVW)
• Intersection Collision Warning (ICW)	• Emergency Vehicle Warning (EVW)
• Hazardous Location Warning (HLN)	• Cooperative Adaptive Cruise Control (CACC)
• Blind Spot Warning (BSW)	• Left Turn Assist (LTA)
• Do Not Pass Warning (DNPW)	• Abnormal Vehicle Warning (AVW)
• Emergency Brake Warning (EBW)	• Control Loss Warning (CLW)
• Speed Limit Warning (SLW)	• Green light optimized speed advisory (GLOSA)

Table 3: *Use cases that need to be tested, according to 3GPP and ETSI.*

The roll-out of 5G technologies into automotive designs is creating an emphasis on cybersecurity testing. 5G employs a software-defined network that employs virtualization functions that can be susceptible from multiple points. Other vulnerabilities arise because of the high bandwidth and large number of devices connecting to the network.

UE manufacturers need to employ a Practical Security Testing process to ensure product performance. Practical Security Testing uses a network simulator that serves as a base station to connect with the UE and a testing server that exercises the device using commercial or proprietary software (figure 6). Functional security measurements are one of a series of tests necessary to verify the UE performs according to specification.

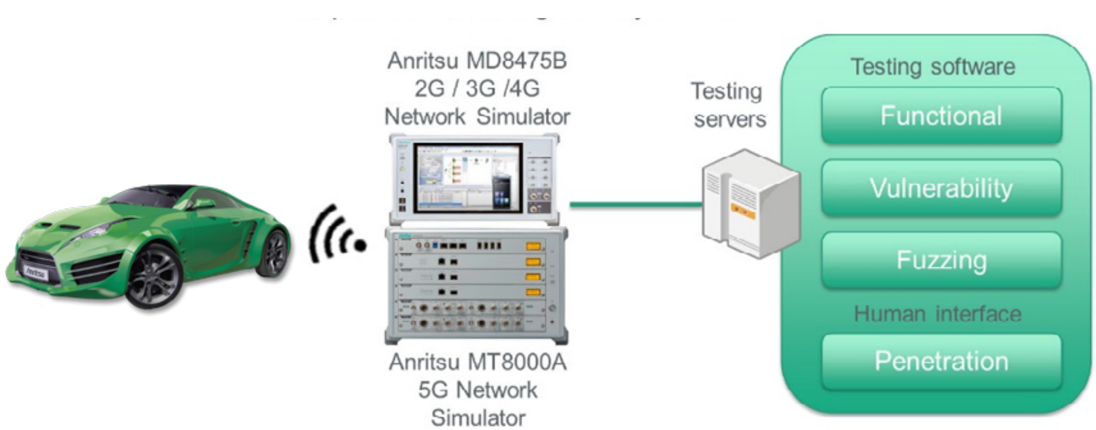

Figure 6: *Network simulator platform for testing security in a lab.*

Emerging Use Cases

3GPP has identified 25 use cases for Release 16 base V2X services and categorized them into four use case groups.

- **Vehicle Platooning –** Using electronic coupling, vehicle platooning allows multiple automobiles or trucks to accelerate or brake simultaneously. All the vehicles in the platoon obtain information via a V2V device from the leading vehicle, allowing them to drive closer than normal in a coordinated manner, going in the same direction and travelling together.

- **Extended Sensors –** V2X systems rely on numerous extended sensors such as light detection and ranging (LiDAR), mmWave radar (MWR), cameras, and global navigation satellite system/inertial navigation system (GNSS/INS). These sensors, as well as dedicated software, help vehicles identify certain safety risks so they can be avoided. The exchange of data acquired by these sensors from other vehicles, RSUs, pedestrian devices and V2X Application Servers allow for the effective operation of ADAS systems and autonomous vehicles.

  Because of the environments in which extended sensors are used, high data rate is one of the key characteristics. Testing solutions must accurately ensure the systems are meeting the required speed based on industry specifications.

- **Advanced Driving –** ADAS systems enable semi-automated or full-automated driving. Each vehicle and/or RSU shares its own perception data obtained from its local sensors with vehicles in proximity and that allows vehicles to synchronize and coordinate their trajectories or maneuvers. It is Level 4 of the SAE J3161 standard.

- **Remote Driving –** Level 5 of SAE J3161 is remote driving, which enables vehicle operation for passengers incapable of driving themselves. Based on cloud computing, it is particularly beneficial in dangerous environments. High reliability and low latency are the main requirements that engineers need to verify in these designs.

Conclusion

V2X is ushering in an evolutionary period in automotive design. Gone are the days where vehicles are strictly a mode of transportation. Integration of wireless technologies have expanded how engineers must design and test automobiles. Understanding these technologies and creating the proper evaluation environments can verify designs, shorten development cycles, and lower test costs.

Anritsu has automotive measurement solutions to verify V2X, IEEE802.11p, 2G/3G/4G/5G cellular/telematics testing, cybersecurity, ITS, eCall/ERA-GLONASS, automobile radar, and Remote Keyless Entry (RKE). These solutions can be used by automobile manufacturers, chip/TCU/IVS suppliers, and test houses during all stages of the automotive design ecosystem.

For more resources on the technology and testing that drives Automotive innovation,
visit Anritsu's Next Generation Automotive Test Solutions Center.

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