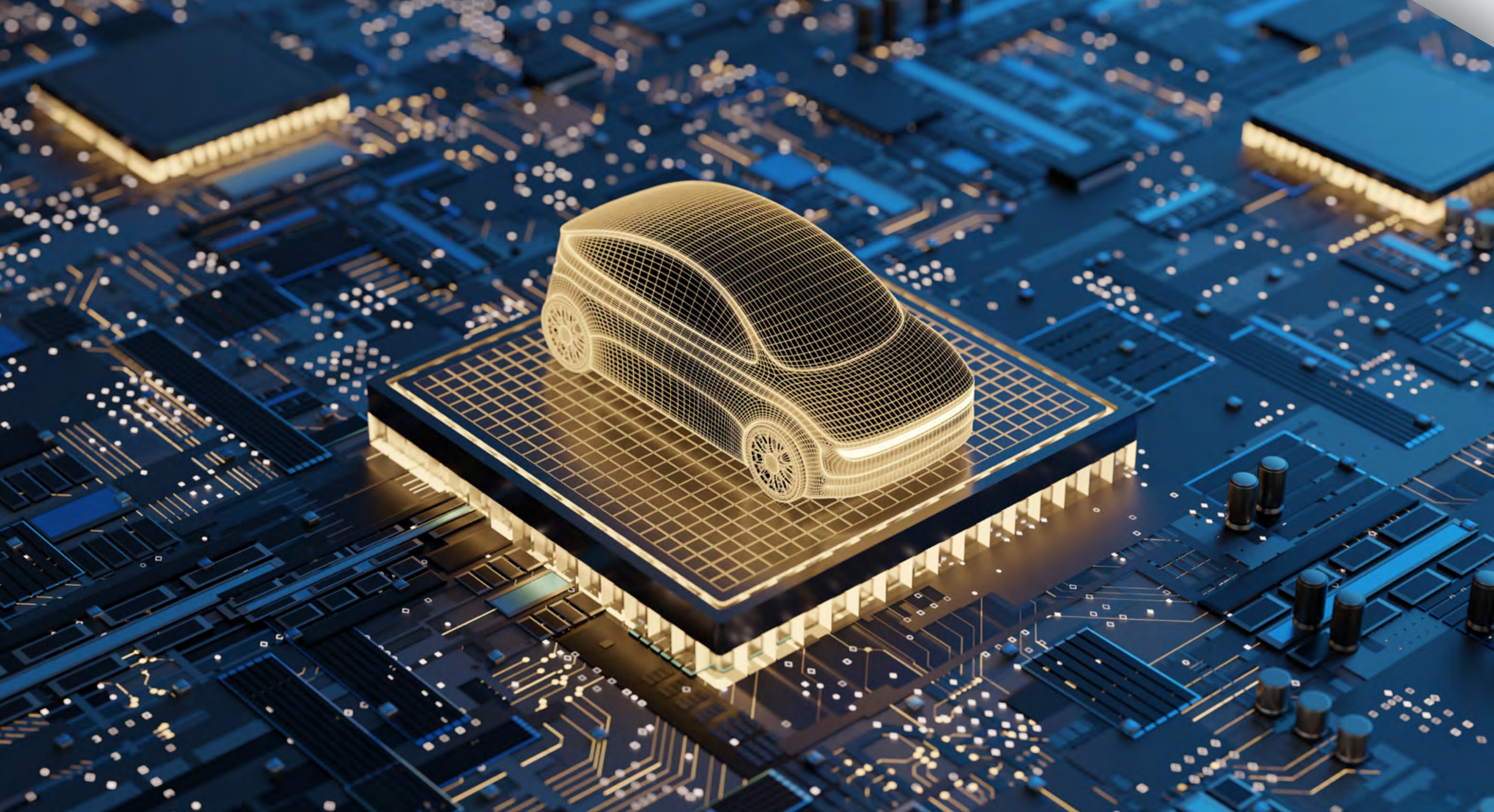




Contents

- The opportunity of V2X
- Main segments
- Communication technology
- Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Vehicle to Infrastructure, Vehicle to Pedestrians, Vehicle to Vehicle, Vehicle to Network

V2X = Vehicle to Everything

The opportunity of V2X

The impending realization of V2X (Vehicle to Everything) connectivity will bring dramatic advancements to driver safety, plus it holds the promise of significant environmental benefits. V2X is an extremely broad term and includes the merging of many new advanced sciences.

It is best to think of V2X not as a specific technology, but as an ecosystem with a collection of various platforms that will benefit drivers, pedestrians, and the environment. This ecosystem will unite the data produced by various technologies: cameras, sensors, radar, and LiDAR, which give vehicles “vision.”

This bundle of data will be connected using the existing DSRC/CV2X, (802.11p/Rel14,15 standard) and next generation DSRC/CV2X (802.11bd/Rel16 standard) technology providing both vehicles and infrastructure "ears" and a "voice"

The areas covered in this eBook include:

1. Basic definitions
2. Why V2X is important
3. Status today
4. Moving forward



Contents

- The opportunity of V2X**
- Main segments**
- Communication technology**
- Communication methodology**
 - Uu
 - PC5
- Messaging systems**
- Why is V2X important?**
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?**
 - Governing bodies
- The future of V2X**
- What to do moving forward**
- Murata technologies**
- References**

The four main segments of the V2X network

Before we continue, there are two quick clarifications. First, we use the term “**vehicle**” to cover cars, trucks, trains, buses, motorcycles, and bicycles. Second, the term “**connected vehicle**” (CV)^[1] is somewhat vague. Modern vehicles are not simply connected to the internet but are connected to and interacting with their cumulative operating environment, which includes other vehicles, the infrastructure, and pedestrians.

THE FOUR MAIN SEGMENTS OF THE V2X ECOSYSTEM ARE:

V2V (Vehicle to Vehicle): Enables vehicles to exchange information with each other and provide real time data, such as location, speed, and heading.

V2I (Vehicle to Infrastructure): Vehicles and roadway infrastructure work together and inform drivers of safety, mobility, or hazardous driving conditions.

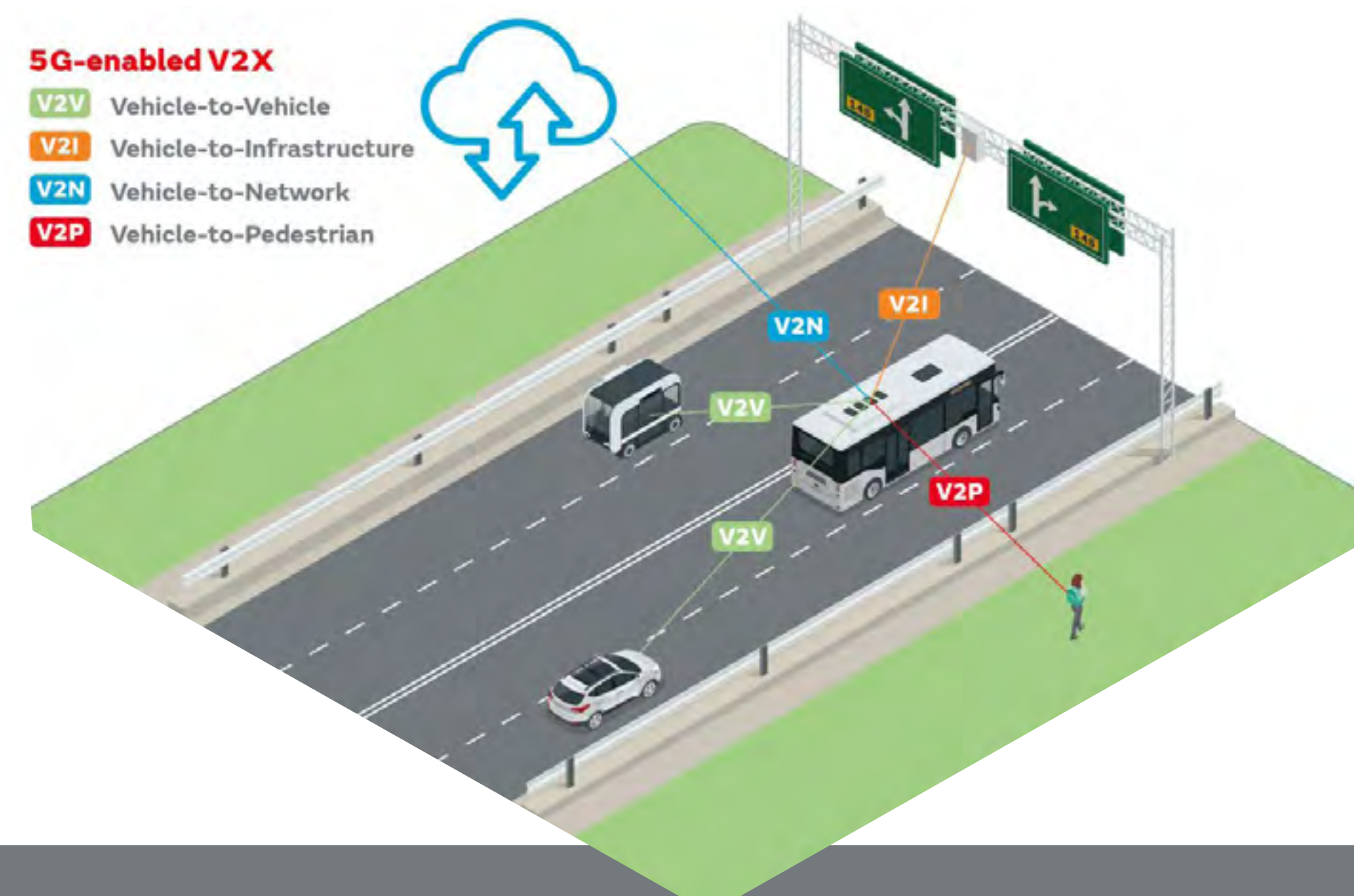
V2P (Vehicle to Pedestrian): Vehicles and pedestrians look out for each other and make each other aware of their presence.

V2N (Vehicle to Network): Vehicles receive and upload data to the network. The network will aggregate this data for improved efficiencies.

In its basic form the V2X network is comprised of two primary building blocks, the OBU and RSU.

OBU (On-Board-Unit): A communication device and transceiver are mounted into the vehicle that takes its telematic data (location, speed, and direction) and communicates, interacts with, and receives information from other vehicles (V2V), as well as the roadway infrastructure (V2I), and the network (V2N). OBUs typically have their software updated by manufacturers using an Over-the-Air (OTA) system that speeds up implementation of updates and minimizes the need for customers to return their vehicles to the manufacturer for updates.

RSU (Road-Side-Unit): The equipment embedded into the roadway system (infrastructure), including traffic signals, cameras, lane markers, and interstate signs along highways. This system communicates bi-directionally with vehicles (V2I) and the network (I2N).



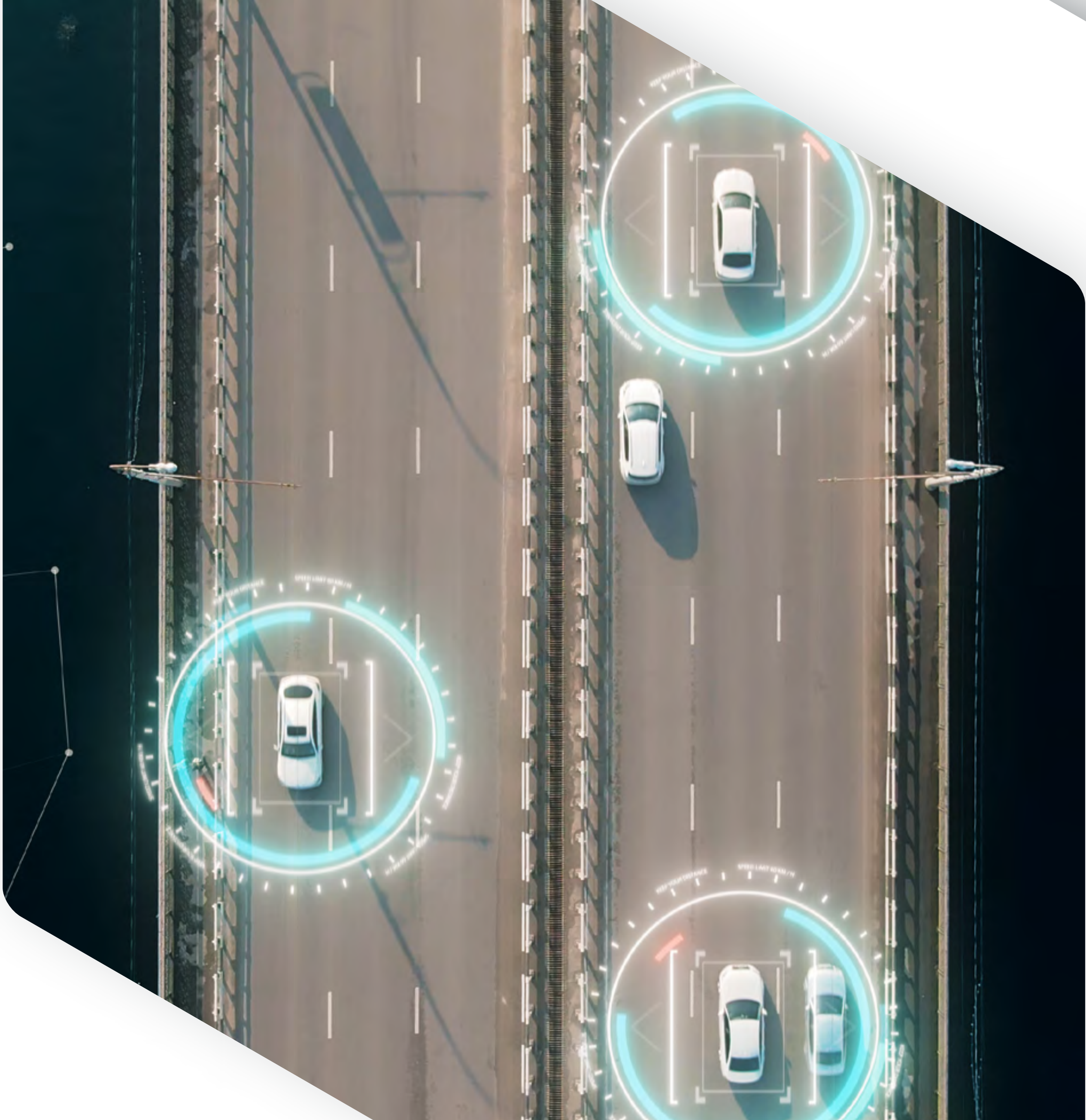
Contents

■	The opportunity of V2X
■	Main segments
■	Communication technology
■	Communication methodology
	Uu
	PC5
■	Messaging systems
■	Why is V2X important?
	Platooning
	Green wave
	Eco-lanes
	Smart routing
	Mobility as a Service
■	Where is V2X today?
	Governing bodies
■	The future of V2X
■	What to do moving forward
■	Murata technologies
■	References

Communication technology

3GPP has established standards to ensure consistent communication across all cities, states, and countries. While some countries like the USA and China have decided to advance with CV2X technology, Europe is still in a dilemma about DSRC and CV2X technology since they are already far ahead with DSRC deployment in European highways and vehicles. Also, some European cars already exist with a DSRC-based V2X system.

The current generation of our modules covers "Day 1" use cases, including awareness warnings like collision avoidance, road/intersection signage, etc. The "Day 2" use cases, like vulnerable road user protection, sharing sensor information with other vehicles, etc., can be covered using our next-generation V2X modules.



Contents

- The opportunity of V2X
- Main segments
- Communication technology
- Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Communication methodology

Extensive improvements are being made to both DSRC and C-V2X to suit next-generation vehicular applications with stringent requirements for availability, latency and throughput.

THERE ARE TWO PRIMARY COMMUNICATION TECHNOLOGIES IN THE V2X ECOSYSTEM.

1. **DSRC** (Dedicated Short-Range Communication) is a 5.9 GHz Wi-Fi signal defined by 802.11p. DSRC is focused on V2V and V2I communication and was designed for communication with vehicles traveling at high speeds. DSRC has been proven to be a robust solution, but it has not been widely implemented as the transition to faster cellular technology is imminent.
2. **C-V2X** (Cellular Vehicle to Everything) - Similar to DSRC technology, C-V2X (Cellular Vehicle to Everything) is a 5.9GHz but LTE-based system that enables wireless communication between vehicles, smart infrastructure, and pedestrians. This is defined within 3GPP Release 14^[2]. Please note that 3GPP formalized Release 16^[3] that is based upon the new, faster 5G NR technology, providing even more functionality to the V2X ecosystem.

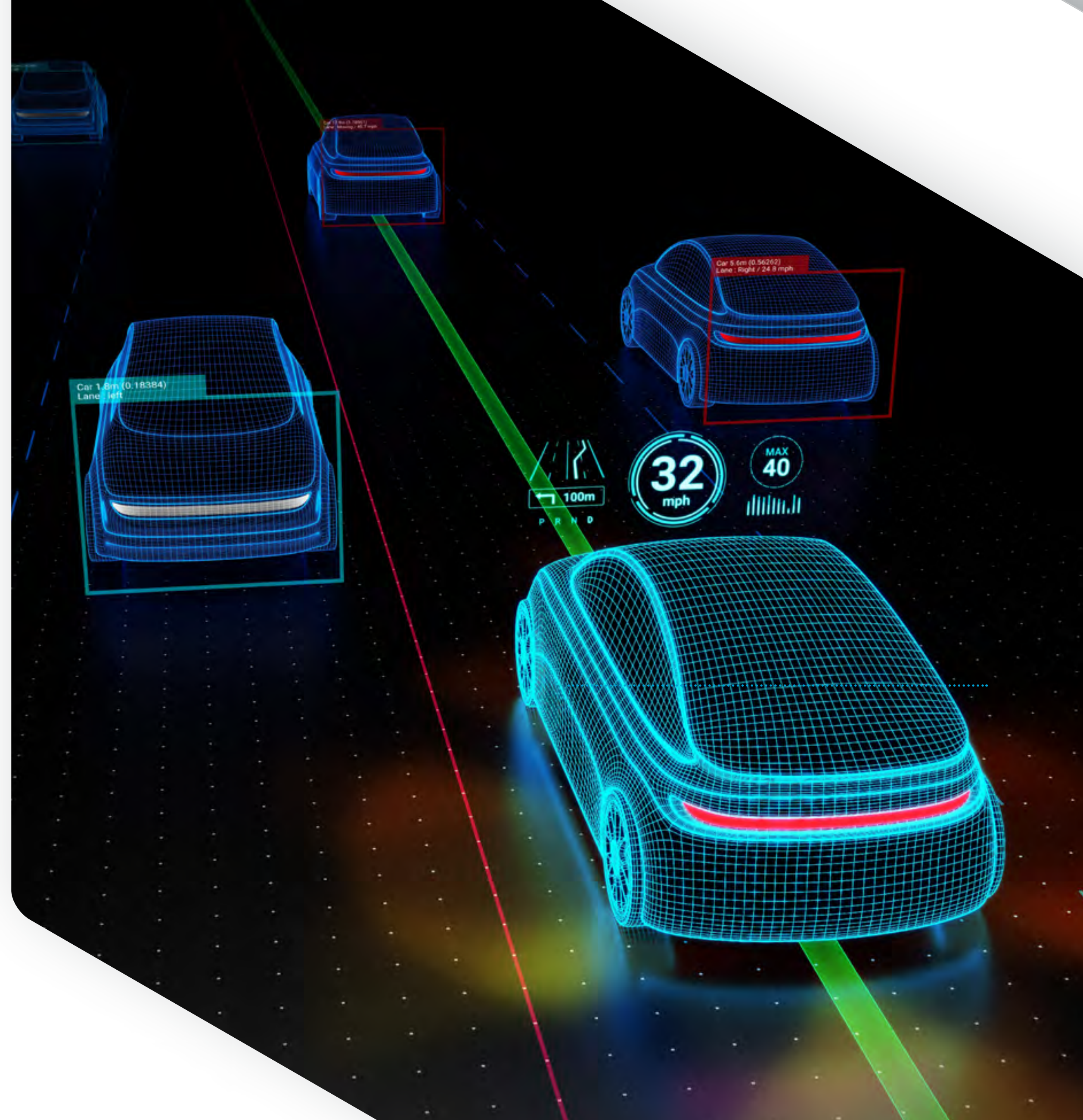


Contents

■	The opportunity of V2X
■	Main segments
■	Communication technology
■	Communication methodology
	Uu
	PC5
■	Messaging systems
■	Why is V2X important?
	Platooning
	Green wave
	Eco-lanes
	Smart routing
	Mobility as a Service
■	Where is V2X today?
	Governing bodies
■	The future of V2X
■	What to do moving forward
■	Murata technologies
■	References

WITHIN V2X THERE ARE TWO PRIMARY COMMUNICATION LINK STYLES:

1. Direct communication, "**PC5**" is focused on communication between vehicles (V2V), infrastructure (V2I) and pedestrians (V2P). This is used for shorter distances, under 1 kilometer, and is also referred to as Sidelink communication.
2. Network communication, "**Uu**," is focused on communication with the network (V2N or I2N). This is used for communication over 1 kilometer and is also referred to as Up/Downlink communication.



Contents

■	The opportunity of V2X
■	Main segments
■	Communication technology
■	Communication methodology
	Uu
	PC5
■	Messaging systems
■	Why is V2X important?
	Platooning
	Green wave
	Eco-lanes
	Smart routing
	Mobility as a Service
■	Where is V2X today?
	Governing bodies
■	The future of V2X
■	What to do moving forward
■	Murata technologies
■	References

Messaging systems

So that vehicles speak to each other and the infrastructure around them effectively, we need to ensure that they are all communicating using the same language. There are pre-defined sets of messages that will be used.^[4]

EXAMPLES INCLUDE:

Basic Safety Message (BSM): As your vehicle is traveling, it will issue Basic Safety Messages (BSM)^[5] approximately 10 times per second to update other vehicles (V2V) and the infrastructure (V2I) of your position, speed, path, and whether you are braking.

Intersection Mapping (MAP): The physical layout of the roadway intersection includes crosswalks, traffic signals, and suggested speed. These are updated to denote modifications based upon construction.



Contents

- The opportunity of V2X
- Main segments
- Communication technology
 - Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Signal Phase and Timing (SPaT): The current intersection signal light phases and anticipated time of change. The state of all lanes is provided, in real time, as well as any active priority that has been given to emergency vehicles. The SPaT also provides suggested speed to minimize stopping at a red light. This technology has been tested to 85% accuracy.^[6]

Road Safety Message (RSM): Allows the roadway to speak to the vehicle so it can be aware of worker presence, suggest a reduction of speed, and avoid other obstacles.

Signal Request Message (SRM): Emergency vehicles can request priority when approaching an intersection.

A unique high-level feature that occurs in a group of connected vehicles is that they create a vehicular information cloud which collectively share data to detect obstacles and predict traffic lights to optimize flow. The vehicles use **Collective Perception Messaging** (CPM), to improve safety and reduce congestion. Another use is **Maneuver Coordination Message** (MCM) that allows vehicles to coordinate driving activity such as lane changes and merging.



Contents

- The opportunity of V2X**
- Main segments**
- Communication technology**
- Communication methodology**
 - Uu
 - PC5
- Messaging systems**
- Why is V2X important?**
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?**
 - Governing bodies
- The future of V2X**
- What to do moving forward**
- Murata technologies**
- References**

Why is V2X important?

According to Decae [7] (2022), there were about 18,800 road fatalities in the EU year 2020, of which 9496 were caused by motor vehicle users, 3883 by pedestrians, 1,901 by cyclists, and 3,520 by motorcyclists or riders of mopeds.



Two-wheelers are more popular than ever: According to the Statistisches Bundesamt [8] (2022), in 2019, most EU people saw motorcycles as the second-most essential means of transportation after automobiles. Bikes and e-bikes are still in high demand after the pandemic, and sales of fast e-bikes have tripled since 2016 (Janson [9], 2022).

These figures are likely to rise due to the growing and aging population. V2X communication will therefore be essential for achieving the European Commission's goal of achieving zero traffic fatalities by 2050. ("Vision Zero"). It is estimated that the implementation of V2X will reduce the number of fatalities by 80%.

Contents

- The opportunity of V2X**
- Main segments**
- Communication technology**
- Communication methodology**
 - Uu
 - PC5
- Messaging systems**
- Why is V2X important?**
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?**
 - Governing bodies
- The future of V2X**
- What to do moving forward**
- Murata technologies**
- References**

Platooning: Long-haul trucks can follow each other closely, improving aerodynamics and reducing fuel costs by up to 12%. This feature will use CACC (Cooperative Adaptive Cruise Control) and heavily depend on sensors and cameras.^[10]

Green Wave: Synchronizes a vehicle's speed with traffic lights to maximize green lights and minimize braking to improve the flow of traffic.

Eco-Lanes: Highway lanes optimized for long-distance travel at fuel-efficient speeds. These are similar to high-occupancy vehicle (HOV) lanes on freeways that are optimized for long-distance travel.

Smart Routing: Optimized vehicle routing to maximize fuel efficiency and minimize travel time and congestion.

Mobility-as-a-Service (MaaS): In the future, travel of any distance will include a mix of shared vehicles and public transportation. An app on your phone allows you to plan your journey to meet your schedule and budget.

Another critical factor is the way that populations are migrating. Over the next 20 years, predictions are that urban population density will continue to increase, and two-thirds of the world (7 billion people) will live in metropolitan areas. The need for cities to efficiently and cleanly move people and freight will be critical.



Contents

- The opportunity of V2X
- Main segments
- Communication technology
- Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Where is V2X today?

Currently, the use of ADAS (Advanced Driver Assistance Systems) features are a vital building block for V2X infrastructure applications. Most ADAS features fall under Level 1 or 2 of driving automation (refer to the sidebar for additional details). Lane departure monitoring, adaptive cruise control, and blind spot detection make vehicles "aware" of their surroundings, features that are available in most new vehicles. These safety systems are a foundation that showcases how vehicles will operate in unison to optimize driver safety.^[11]

Several vehicle manufacturers have implemented an "autopilot" feature that enables your car to steer, accelerate and brake automatically within its lane. Current autopilot features require active driver supervision and do not make the vehicle autonomous. ADAS features are just the beginning of the journey to fully connected autonomous vehicles.

Coordinated standards ensure that all vehicles in different cities, states, and countries communicate efficiently and operate seamlessly. Successful implementation of V2X depends on communication that is uniform and consistent.

The 5 levels of autonomous driving

You will hear terms such as “Level 1” or “Level 3” with respect to the level of self-driving – below is a quick summary of the five levels per SAE J3016: ^[12]

Level 0 = No automation.

Level 1 = Some driver assistance features – such as adaptive cruise control, or lane departure alert.

Level 2 = Partial driving automation – requires the driver to have their hands on the steering wheel but the vehicle can actively steer, accelerate, and brake when traveling on highways. Example Tesla autopilot feature.

Level 3 = Driver is not driving the vehicle under certain pre-determined conditions. A driver must be present, but the vehicle may transfer responsibility back to the driver.

Level 4 = Driver is not driving the vehicle under pre-determined conditions. Example is an autonomous robot taxi. These vehicles may or may not have steering wheels and pedals.

Level 5 = Driver is not driving the vehicle under any conditions. There is no steering wheel or pedals. The vehicle will drive itself under all conditions. Clearly the implementation of Levels 3, 4 and 5 requires a full, robust rollout of V2X technology.



Contents

- The opportunity of V2X**
- Main segments**
- Communication technology**
- Communication methodology**
 - Uu
 - PC5
- Messaging systems**
- Why is V2X important?**
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?**
 - Governing bodies
- The future of V2X**
- What to do moving forward**
- Murata technologies**
- References**

Here is a list of the major governing bodies for V2X implementation:

- **3GPP** (3rd Generation Partnership Project) is an international group coordinating the global rollout of the new 5G NR standard for cellular V2X (C-V2X).
- **5GAA** (5th Generation Automotive Association) is an international group working to develop end-to-end solutions for future mobility and transportation services. Please note that the 5GAA joined the 3GPP in 2017. Murata is a member of the 5GAA.
- **IEEE** Connected Vehicles Initiative promotes a variety of technical activities for the advancement of connected vehicles.
- **SAE International** (formerly Society of Automotive Engineers) devises technical standards for the design and construction of transportation systems.
- Europe: **ETSI** automotive Intelligent Transportation System
- China: **NTCAS** (National Technical Committee of Auto Standardization), CCSA (China Communications Standards Association), and C-SAE (Chinese Society of Automotive Engineers)
- **US DOT**, NCAP, ITS involvement.



Contents

- The opportunity of V2X
- Main segments
- Communication technology
- Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

The future of V2X

The global growth of the V2X market will be dramatic. At this moment, the implementation is in its infancy, but it is estimated that the market will double every year for the next 10 years. The recent U.S. Infrastructure Improvement bill has dedicated funding for V2X implementation.

It is predicted that V2X will quickly move forward, especially in areas with a high population density (large cities) and in areas with very low population concentration (agriculture). These areas have the advantage of highly defined routes and slower traffic patterns. Agricultural areas are extremely suitable for this technology because there is a minimum of hazards, such as pedestrians and vehicle traffic. As urban density increases, we will see a need for additional public transportation such as robot taxis (**Mobility-as-a-Service**). New robotic vehicles (people movers) typically will travel at slower speeds and in a more rigidly defined pattern. This will have the short-term benefit of reducing congestion and provide valuable test data so the V2X network can be rolled out in less defined areas. Additionally, autonomous delivery vehicles will become a reality.



IHS Markit estimates that roughly 148,000 light vehicles equipped with some form of V2X system have been sold globally in 2020. They expect sales of such light vehicles to grow at a CAGR of nearly 106% to roughly 11.2 million units in 2026. Approximately 12% of new light vehicles sold in 2026 will be equipped with some form of V2X technology.

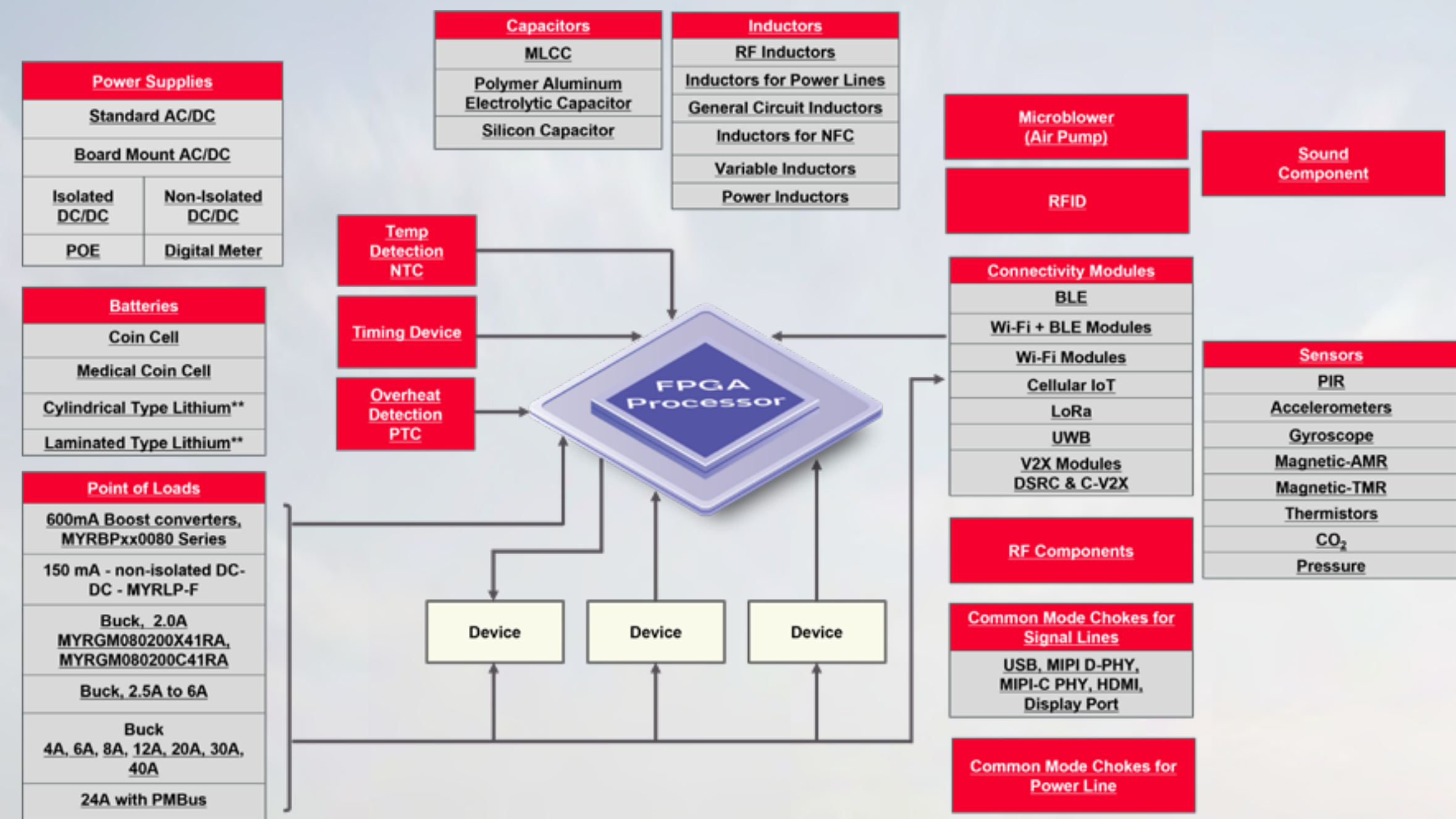
From IHS Markit report "Vehicle-to-everything (V2X) Communications Report" dated February 2021.

Contents

- The opportunity of V2X
- Main segments
- Communication technology
- Communication methodology
 - Uu
 - PC5
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Moving forward

This is an exciting time to be involved with V2X as hardware designers determine where and how these technologies will be implemented. With Murata's unique position of supporting all levels of the electronics industry, we can assist you with your designs for both in-vehicle and out of vehicle applications of V2X to the roll out of 5G NR cellular. Our product portfolio includes industrial and automotive grade, multi-layered chip capacitors (MLCCs), inductors, [V2X modules](#), [RADAR module](#) (important for ADAS applications), thermistors, Wi-Fi/BT modules, MEMS, IMU, 5G cellular modules, and power conversion (AC-DC and DC-DC) solutions.



Contents

- The opportunity of V2X
- Main segments
- Communication technology
 - Uu
 - PC5
- Communication methodology
- Messaging systems
- Why is V2X important?
 - Platooning
 - Green wave
 - Eco-lanes
 - Smart routing
 - Mobility as a Service
- Where is V2X today?
 - Governing bodies
- The future of V2X
- What to do moving forward
- Murata technologies
- References

Murata Technologies for Electric Vehicles & Charging Stations

[Inverter](#)

[BMS \(Battery management system\)](#)

[OBC \(On board charger\)](#)

[DC-DC converter](#)

[Engine ECU](#)

[TCU \(Telematics control unit\)](#)

[IVI \(In vehicle infotainment\)](#)

[ADAS \(Advanced driver assist system\)](#)

[IPA \(Intelligent parking assist\)](#)

[Lidar](#)

[Radar](#)

[Front camera](#)

[V2X Solutions](#)

[SCHA63-Dx](#) IMU for harsh environment with centimeter-level accuracy

LF Antennas High Reliability Products

[AEC-Q 200 Compliant Chip Multilayer Ceramic](#)

[Capacitors](#)

[Chip Multilayer Ceramic Capacitors for](#)

[Automotive](#)

[High Q Chip Multilayer Ceramic Capacitors for Automotive](#)

[Soft Termination Chip Multilayer Ceramic Capacitors for Automotive](#)

[Polymer Aluminum Electrolytic Capacitors](#)

Chip Ferrite Beads: [BLM](#), [NFZ](#)

Chip Inductors (Chip Coils) [LQM/LQH/DFE](#) [LQW](#)

[Accelerometers](#) [Inclinometers](#) [Gyro Sensors](#)

[Solutions for EV Chargers](#)

- AC/DC converters
- Non isolated DC/DC
- Isolated DC for RS485
- Isolated DC for gate driver
- Wireless connectivity
- Micro battery
- Isolated DC for RS485
- Current sensors
- High power high frequency transformer for DC/DC converter
- UWB modules

Contents

 The opportunity of V2X

 Main segments

 Communication technology

 Communication methodology

Uu

PC5

 Messaging systems

 Why is V2X important?

Platooning

Green wave

Eco-lanes

Smart routing

Mobility as a Service

 Where is V2X today?

Governing bodies

 The future of V2X

 What to do moving forward

 Murata technologies

 References



References

- [1] European Commission - "Connected and automated mobility"
<https://digital-strategy.ec.europa.eu/en/node/152/printable/pdf>
- [2] 3GPP. Specification has been created for release Rel-14.
www.3gpp.org/release-14
- [3] 3GPP. Radio enhancements.
www.3gpp.org/release-16
- [4] ITS America. The Future of V2X: 30 MHz Application Map.
<https://itsa.org/wp-content/uploads/2021/01/ITS-America-30-MHz-Application-Map-1-27-21.pdf>
- [5] CAR 2 CAR Communication Consortium
https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2050_Spectrum_Needs.pdf
- [6] Computers and Electrical Engineering
<https://reader.elsevier.com/reader/sd/pii/S0045790622007753?token=3787BE3B8AF05D9A4D0EE29C11CAB0B95D58FA1D50E2EBC6B907A229A61EEEEBB212FAF7901B5002677E31DA011DCC9E9&originRegion=eu-west-1&originCreation=20230323093930>
- [7] Decae, R. Institute for Road Safety Research.(2022). European Road Safety Observatory, Annual statistical report on road safety in the EU 202. 1
https://road-safety.transport.ec.europa.eu/system/files/2023-03/ERSO_annual_report_20220509.pdf
- [8] Statistisches Bundesamt (Destatis)(2022). Wichtigstes Verkehrsmittel im Alltag. Verfügbarunter.
https://www.destatis.de/Europa/DE/Thema/Verkehr/_inhalt.html#sprg248576%22https://www.destatis.de/Europa/DE/Thema/Verkehr/_inhalt.html#sprg2485.%2076
- [9] Janson, M. (2022).Fahrrad-Verkäufe, Fahrradnachfrage boomt auch im zweiten Pandemiejahr. Verfügbarunter.
<https://de.statista.com/infografik/17443/verkaufte-fahrraeder-und-e-bikes/>
- [10] Institute of Electrical and Electronics Engineers, Inc. (IEEE). Status of Project IEEE P802.11bd.
www.ieee802.org/11/Reports/tgbd_update.htm
- [11] Toyota Motor Corporation, V2X Technology.
www.toyota.co.jp/its/en/2021/v2x_technology/
- [12] SAE Levels of Driving Automation. SAE International.
<https://www.sae.org/blog/sae-j3016-update>

Contents

	The opportunity of V2X
	Main segments
	Communication technology
	Communication methodology
	Uu
	PC5
	Messaging systems
	Why is V2X important?
	Platooning
	Green wave
	Eco-lanes
	Smart routing
	Mobility as a Service
	Where is V2X today?
	Governing bodies
	The future of V2X
	What to do moving forward
	Murata technologies
	References