V2X White paper

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INTRODUCTION

V2X is a revolutionary technology that lets us reimagine a new world where cars don't just move but also think, predict and communicate - alerting each other of dangers before they even appear. This white paper aims to provide a comprehensive perspective of this technology, including its functional safety aspects.

What is V2X?

Vehicle-to-everything (V2X) technology consists of the sensors, cameras and wireless connectivity - like Wi-Fi, Radio frequencies, LTE and 5G cellular technology - that would allow cars to share information such as road construction zone and accident location with each other, their drivers and their surroundings. It allows vehicles to communicate with other vehicles and road users (such as Bicyclist, Pedestrians etc.,) to avoid fatalities and injuries by providing alerts for hazards that drivers may not be able to see.

For e.g.,

If a vehicle and a bicyclist are approaching a 90-degree intersection which presents a blind spot for both, then the V2X technology can alert both the drivers of each other's presence allowing them to take measures such as emergency braking thereby improving road safety.

Why do we need V2X technology, when our industry already has perception-based sensors such as Camera, LiDAR, Radar?

01 See beyond line-of-sight

V2X is critical for safety because it allows road users to “see” beyond their line of sight. Current perception-based sensors are limited by their FOV (Field-of view) and range, but V2X offers a 360-degree unobstructive detection angle with a range extending from at least 600 metres to 1.5 km.

02 Reduce Intersection crashes

Intersection crashes are one of the costliest crash types when measured in terms of economic impact, accounting for about 22% of the total motor vehicle crashes in US. These crashes are not particularly well served by conventional sensors since they cannot see around corners/through buildings, and this is where V2X technology can be particularly advantageous.

03 Better detection performance

A recent Virginia Tech study, funded by the USDOT, showed that on average, V2X detects road dangers 0.5 seconds before any line-of-sight sensors (LOS). LOS sensors are any sensors that use vision-based technology for object detection (such as

cameras, RADAR, or LiDAR). Statistics show that even an additional 0.5 seconds to react can make a crucial difference in preventing accidents.

04 Autonomous Vehicles

V2X could have a transformative impact in autonomous vehicles (AVs). The number and sophistication of sensors in an autonomous vehicle are vast and increases with the level of autonomy. AVs currently depends on line-of-sight sensors for the majority of their perception, but these sensor systems have limitations. Autonomous vehicles can transmit information at a dedicated frequency (~5.9GHz), with V2X acting as an extra sensor that works in all weather conditions and can go through walls and obstacles, effectively solving the line-of-sight problem. We could use V2X to broadcast the location-related information of each car. A connected vehicle receiving the information, can calculate the possibility of collision with the other vehicle using onboard computer. If the risk is high, the driver (or passenger of an autonomous vehicle) will be immediately warned, and the system will adjust accordingly to avoid a collision safely and effectively.

05 Better NCAP ratings

V2X technology contributes to improved NCAP ratings. E.g., In Euro NCAP, Local hazard warnings are rewarded with up to 10 safety assist points. These include warnings for traffic jams, construction zones, accidents ahead, stopped vehicles on the

hard shoulder, and emergency vehicles. While any communication method for these alerts can be used, V2X direct communication solutions are awarded maximum points.

06 Increase traffic efficiency

V2I (Vehicle-to-Infrastructure) increases traffic efficiency by speed harmonization which reduces traffic congestion and improves traffic performance while approaching lane merge.

07 Platooning

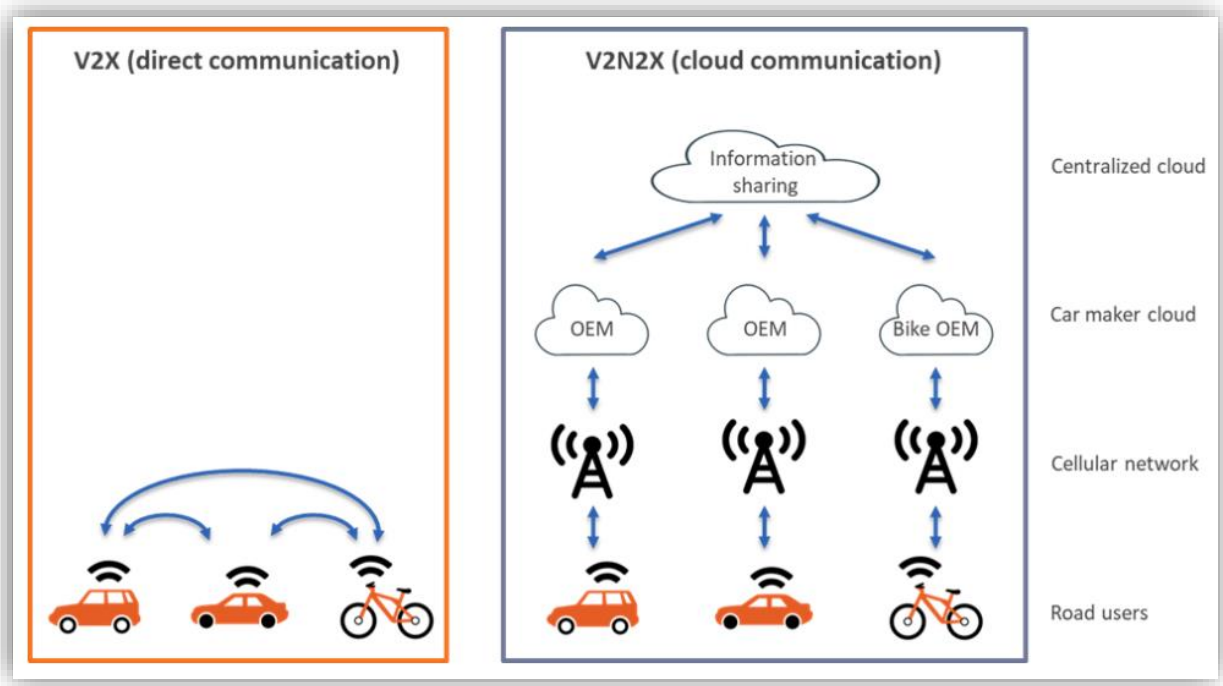
Vehicle platooning is envisioned as an advanced use of V2X communications. Platooning offers the potential for enhancing traffic densities while improving safety, reduced fuel consumption and lowering CO2 emissions.

What are the different approaches of V2X?

V2X can be implemented using following two approaches:

a. Direct Vehicle-to-everything communication

b. Network communication



Topic	Direct V2X	V2N2X	Hybrid
Medium	Uses a dedicated channel such Dedicated short-range communication (DSRC) as to directly exchange information between nearby road users, without involving cellular network	Uses the cellular network (such as LTE-V2X, 5G-V2X) to exchange information via multiple clouds	Combination of both direct V2X and network communication
Architecture	A road user broadcasts a message, and all	• Road user transmission begins by connecting to the OEM's cloud via the	Combination of both direct V2X and network communication

	nearby road users receive it	cellular network, which may be a different mobile operator for each OEM. • After processing, the OEM cloud sends the data to a centralized information-sharing cloud, which then distributes message to relevant OEM's clouds. • Finally, the message is sent through the cellular network back to the intended road user.

Comparison of different V2X approaches

The table below summarizes technical aspects of direct V2X and V2N2X for each of these decision factors.

Decision Factors	Direct V2X	V2N2X
Service Availability	Does not need infrastructure & guarantees full availability	• Relies on cellular coverage which is poor on rural roads and some cities • Cannot guarantee constant availability
Business Model	• Requires additional hardware • V2X operation is free of charge since no communication charges, and processing is done for free on-board	• Requires additional hardware • V2N2X operation incurs a substantial monthly fee for cellular network usage

	• Overall vehicle's lifetime cost is significantly lower than V2N2X	• Cloud computing costs contribute to the expense • Overall vehicle's lifetime cost is significantly higher than V2X
Privacy	Safety data such as vehicle's location, road user's identity are concealed using a random & frequently changing ID	• Sharing safety data such as Road user's identity and the information about OEM to other vehicles through OEM's cloud and cellular network violates the EU C-ITS security policy. • Cannot ensure anonymous vehicle identity.
Latency	V2X latency is deterministically bounded to 100 milliseconds	• V2N2X latency is higher since it entails complex processing across three clouds (source OEM, information sharing, and destination OEM) • Cellular latency, potentially involving multiple operators
Cybersecurity	V2X wireless communication are: • Security-hardened • Rigorously certified • Uses robust cryptographic measures • Advanced plausibility checkers. • An attack could be launched by staying near the attacked vehicle. Thus, number of attack vectors is small, and the damage is confined to small geographical area.	• V2N2X wireless communication involves multiple cloud servers • An attack could be launched from anywhere in the world, potentially affecting every connected vehicle. Thus, there are more attack vectors than V2X.

Based on the above analysis, the summary is:

- V2N2X approach is valuable for enhancing situational awareness, such as alerting drivers about road closures ahead. However, it is not suitable for safety purposes because it requires hefty lifetime costs and cannot ensure anonymous vehicle identity, continuous service availability particularly in rural areas, deterministic short latency and minimal cybersecurity threats.

- Direct V2X is suitable and reliable for safety purposes such as providing warnings to driver during safety-critical scenarios because it does not require hefty lifetime costs, ensures privacy, continuous service availability & low latency and provides better security against cybersecurity threats.

What are the current trends regarding V2X technologies?

- **The USA**: DSRC based V2X technology (Wi-fi protocol).
- **China**: C-V2X based V2X technology (Cellular-V2X e.g., 4G/5G protocols)
- **Europe**: Europe has taken decision to be technology neutral but has strong existing DSRC/ITS-G5 base (EU DSRC equivalent) (Supports both Cellular-V2X and Wi-fi-protocol).
- **India**: V2X technology holds significant promise for enhancing road safety and traffic management, its widespread adoption is still a few years away. Ongoing efforts by the government and industry stakeholders are expected to pave the way for its future integration.

Which cars currently have V2X?

- **Japan**: Toyota is already offering vehicles with V2X technology.
- **Europe**: Volkswagen Golf 8 vehicles launched in 2019 already have V2X fitted as standard. Volkswagen also has announced in 2019 that all their latest ID.X electric vehicles will have V2X fitted as standard.
- **India**: V2X technology is currently not available in any production vehicles. In 2022, a demonstration using five prototype vehicles was performed by Suzuki, Maruti Suzuki and IIT – Hyderabad in IIT-H campus. Some of the scenarios that were showcased are Ambulance Alerting

System, Wrong-way Driver Alerting system, Pedestrian Alerting System, Motorcycle Alerting System and Road Condition Alerting System.

- As per industry experts, in India for the V2X technology to arrive in vehicles, it is estimated that it would take 3-5 years. But efforts from Indian government to bring V2X technology into the market are already in progress.
- An Indian government panel has circulated a draft copy and has asked stakeholders for their feedback, in which they talk about how V2X car technology can help in boosting road safety. The panel has recommended V2X to be taken into consideration for inclusion in India's Bharat New Car Assessment Programme (BNCAP) for automobile protection ratings, consistent with tendencies abroad, however, did not set any closing date for adoption of its recommendations. The panel also has suggested incentives and benefits for cars with higher connectivity ratings such as lower taxes, insurance premiums, toll charges, and parking fees. The draft report is yet to be finalized and approved by the government and the panel aims to submit its final report by the end of this year.

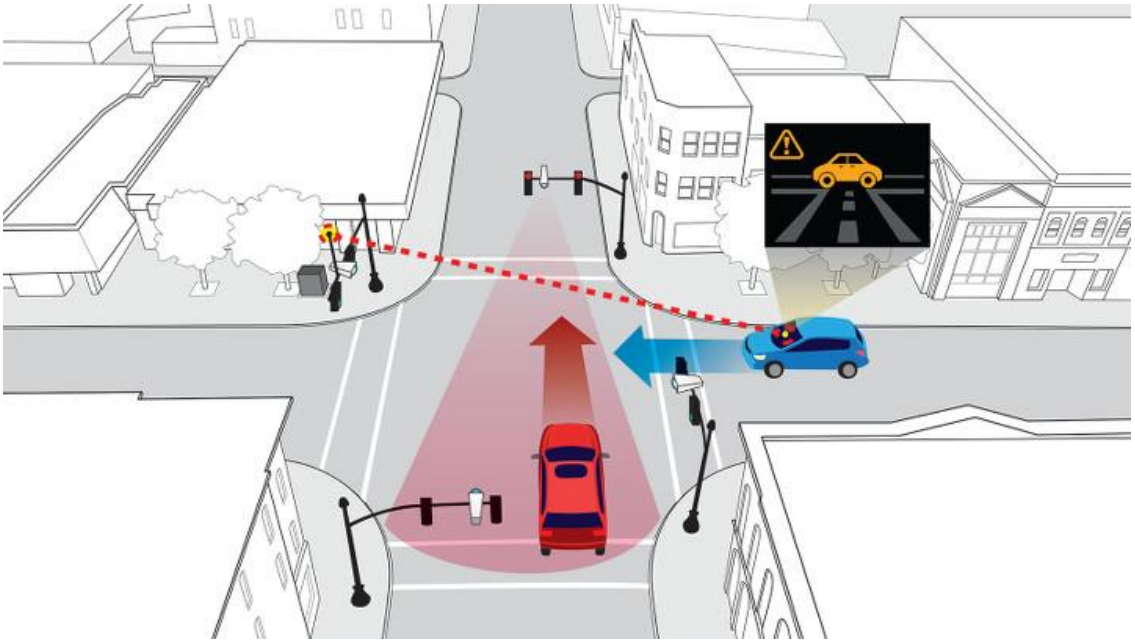
Use Cases of V2X

Vehicle-to-everything (V2X) communication can improve traffic safety and efficiency. V2X sensor data from other vehicles/infrastructure can be used for two kinds of applications:

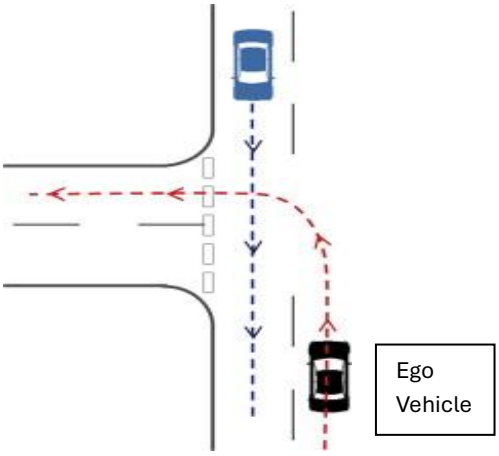
1. Providing lifesaving situational awareness by alerting the driver
2. Controlling Ego vehicle controls (Acceleration, Braking or steering) to prevent or significantly reduce severity of a possible accident.

Below are some use cases where V2X sensor data can be used to alter the driver:

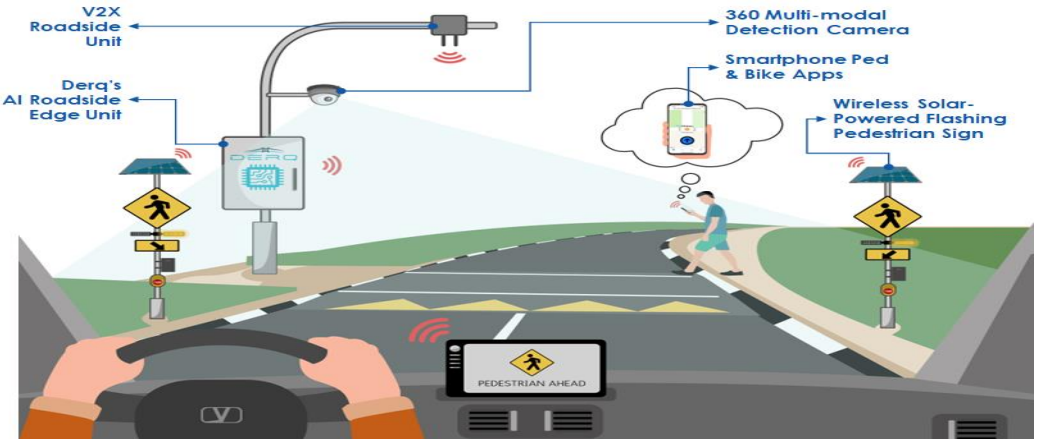
Target Vehicle approaching from cross traffic at a 90-degree intersection



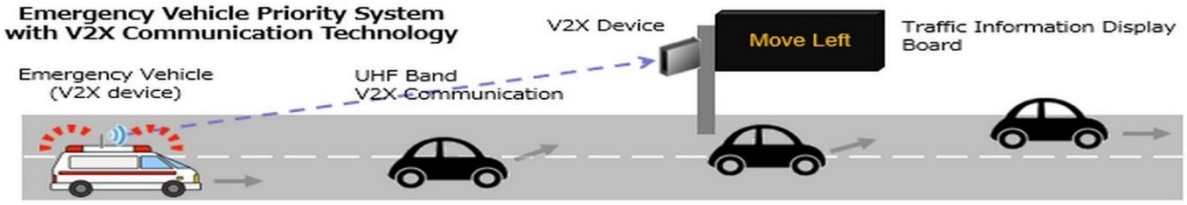
Target Vehicle approaching from oncoming direction while Ego vehicle is taking a left turn



Pedestrian and Bi-cyclist crossing at a junction



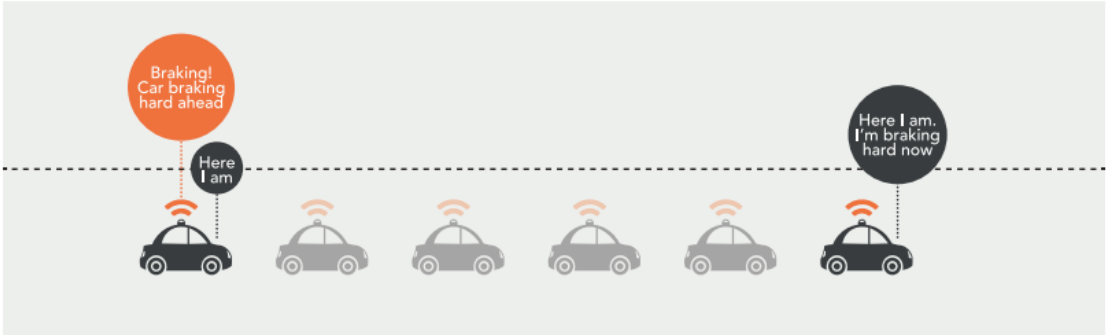
Making way for Approaching Emergency vehicles informed through V2X



Below are some use cases where V2X sensor data can be used by Ego vehicle to prevent/reduce severity of possible accident by controlling Ego vehicle longitudinal/lateral motion:

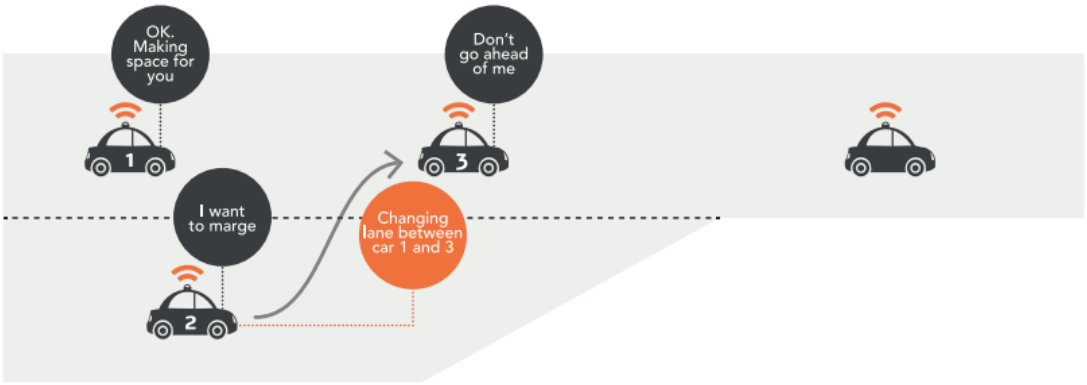
V2X sensor use case of controlling longitudinal motion of Ego Vehicle

Description: Target vehicle moving in the same lane as Ego vehicle in the forward direction, suddenly applies hard brake due to driver error or road hazard, Ego vehicle can detect this early using V2X sensor data and apply soft brake or change the course of ego vehicle.



V2X sensor use case of controlling longitudinal motion of Ego Vehicle

Description: Ego vehicle trying to do a lane change manoeuvre to merge from country road to highway can interact with other vehicles moving in the same direction in highway to safely merge.



What are the current trends regarding V2X technologies?

If V2X sensors are used in automotive systems, then the industry practice is to analyse its malfunctions and check whether the malfunctioning behaviour of V2X sensors can endanger human lives as per functional safety ISO26262 standard.

If the V2X sensor data is used to provide only situational awareness related alerts to driver, then the V2X sensor can be developed as per QM process

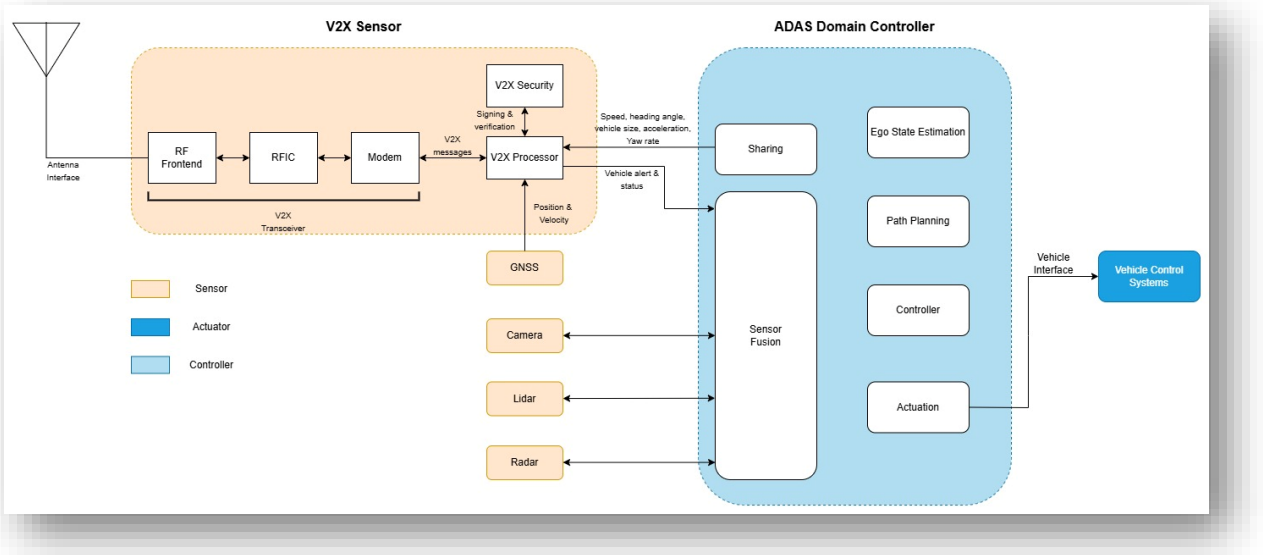
and there is no need for sensor to be developed according to functional safety (ISO26262) standard.

If the V2X sensor data is used for any vehicle control circuitry, then the V2X sensor application/use case shall be analysed for potential malfunctions that may risk lives as per the functional safety analysis (HARA) method recommended in functional safety ISO26262 standard. Hazards are evaluated and classified according to their potential severity (S), exposure (E) and controllability (C). As a result of HARA activity, safety goals are derived and for each safety goal Automotive Safety Integrity Levels (ASIL A, B, C or D) is classified based on severity (S), exposure (E) and controllability (C) of the hazardous event. According to the ASIL level of system, ISO26262 processes and methods are applied.

Safety goals are translated into:

- **Functional safety concept** which defines what the system is expected to do to achieve functional safety and
- **Technical safety concept** which defines how the system will achieve functional safety

This white paper proposes a high-level system architecture of a V2X sensor and its interaction with the ADAS domain controller.



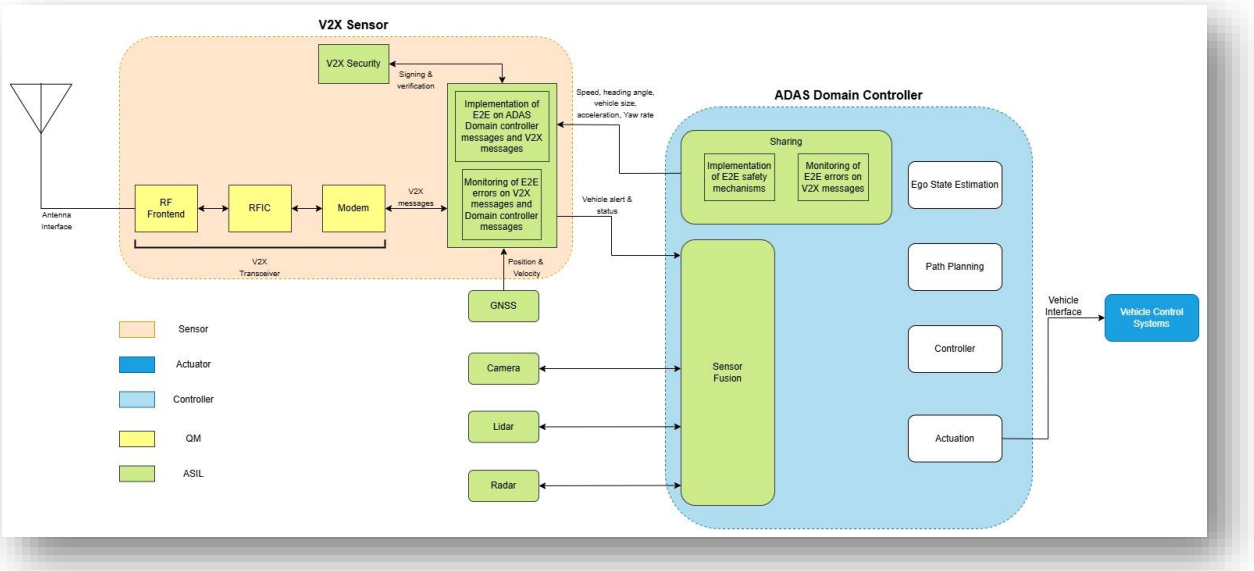
The V2X sensor design consists of:

- Wireless interface such as V2X transceiver to send/receive V2X messages from other V2X-enabled devices,
- V2X security to perform message authentication (signing and verification),
- V2X processor to encode and decode the V2X data with headers such as Message ID, Message count and appropriate encryption algorithm.

V2X Sensor Safety architecture

Safety concept requirements result in adding dedicated hardware and software mechanisms to the V2X sensor. The main objective of the safety architecture is to ensure sufficient resilience to failures, detecting them in a timely manner and transitioning to a well-defined safe state.

V2X sensor safety architecture is shown in the diagram below:



In the safety architecture,

01 The ADAS Domain controller shall provide safety critical data such as speed, yaw rate, acceleration, vehicle size with ASIL X integrity to V2X sensor along with End-to-End protection.

02 Safety mechanisms are implemented in V2X processor to ensure integrity of V2X data (Message count, ID, encryption algorithm) and provide security against cyberattacks (message authentication) when V2X messages are transmitted to other vehicles. Hence, the V2X transceiver can be developed as QM (X) and their corresponding safety mechanisms in V2X processor as ASIL X(X).

03 Since the encoding & decoding of V2X data is performed by V2X processor, it shall be developed as ASIL X.

04 The ADAS Domain controller shall perform E2E checks on safety critical data that it receives from V2X processor.

05 The V2X processor shall perform E2E checks on V2X messages that it receives from other vehicles/infrastructure

NOTE: X can be A/B/C/D and it represents ASIL of the safety goal.

Additional Functional Safety Considerations

The V2X device would additionally have to undergo:

01 Selection of Automotive grade (AEC-Q100) HW component/elements

02 Selection of ASIL compliant building blocks such as processor running the V2X stack, MAC and security

03 Safety analysis, considering all elements potentially impacting V2X operation, as well as their interaction paths, for identifying potential failure modes and their causes and effects

04 Addition of safety mechanisms such as voltage monitoring, clock monitoring, ECC to avoid common cause failure

05 Addition of safety mechanisms such as WDG, MPU or redundant storage etc., to achieve FFI

06 Addition of safety mechanisms such as self-tests to achieve HW architectural metrics

07 Quantitative analysis with FIT calculation

CONCLUSION

This white paper provides a comprehensive overview of Vehicle-to-Everything (V2X) technology, its critical role in enhancing road safety, and its integration into the evolving landscape of automotive innovation. V2X allows vehicles to communicate with each other and their environment, offering significant advantages over traditional perception sensors like cameras and LiDAR. By enabling vehicles to "see" beyond their line of sight, V2X can reduce accidents, improve reaction times, and optimize traffic flow. The paper discusses various V2X communication approaches, including direct and network-based methods, and compares their benefits and limitations in terms of availability, cost, privacy, latency, and cybersecurity. Additionally, it outlines real-world use cases, current trends, and examples of V2X implementation in cars, with a focus on the integration of functional safety standards, such as ISO 26262, to ensure system reliability. Lastly, it proposes a safety architecture for V2X sensors, emphasizing the need for rigorous safety mechanisms to protect against failures and cyberattacks.

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