

Towards full road safety potential by means of Direct V2X

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Content

Introduction	2
About the Car2Car Communication Consortium	3
Executive Summary	3
Full potential of Direct V2X.....	4
The Euro NCAP scenarios and protocols	4
Interoperable and Backward compatible message exchange	4
Flexible Technology Approach	5
Interoperability and backward compatibility	6
Glossary (abbreviated).....	7

Introduction

Car2Car Communication Consortium (C2C) is committed to enabling the full road safety potential of Direct V2X communication, helping to make mobility safer for all road users. C2C's work ensures a flexible cost-effective implementation while maintaining alignment with European regulations.

This paper concentrates on the vehicle specific options to realize a common automotive OEM view on reaching the full potential of Direct V2X communication. It does so by referencing to the Euro NCAP's ongoing V2X integration into the Safety Assessment and Assisted Driving Grading schemes which should continue to evolve through the 2029 and 2032 cycles, while being interoperable and backward compatible with the Euro NCAP 2026 safety objectives which are based on the C2C and C-ROADS specifications.

Interoperability and backward compatibility are critical success factors for a cost-effective implementation. Specifically, C2C follows a general system approach that places interoperability and backward compatibility at its core while enabling stakeholders' flexibility and maintaining compliance with all relevant regulatory requirements.

To clarify interoperability and backward compatibility, this paper also includes a related Q&A.

About the Car2Car Communication Consortium

Vision: A world of safe, comfortable and efficient mobility using cooperative and resilient transport and traffic systems.

Mission: The CAR 2 CAR Communication Consortium provides (C2C) specifications, guidelines and best practices to facilitate the realisation of interoperable, innovative mobility services, serving as the landing hub of excellence for V2X.

Although the name of C2C indicates being Car centric, the C2C is much more and facilitates interoperability of Direct V2X services with other vehicle types, VRU and road infrastructure through strong collaboration with e.g., PTW industry (CMC¹), bike industry (C4CS²), road related stakeholders (C-Roads³ + Cities), and Agriculture Electronic industry (AEF⁴).

All activities of the C2C are driven by the C2C Functional Roadmap as reflected in Figure 1.

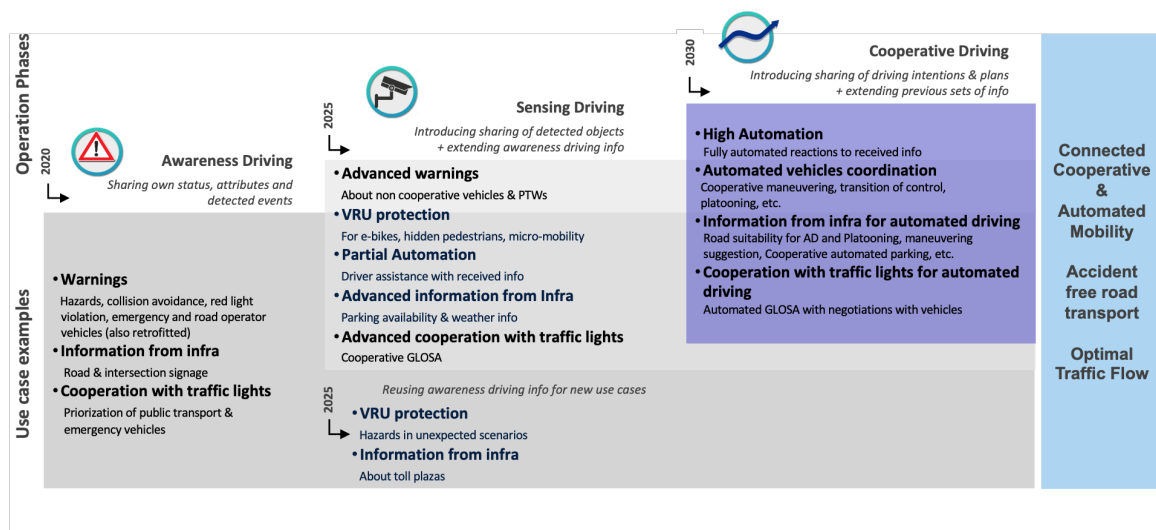


Figure 1: The C2C simplified Functional Roadmap

Executive Summary

- C2C considers Direct V2X feasible for extending safe-driving scenarios (complementing other sensors), including V2X soft intervention as part of ACC performance. C2C sees a potential in Direct V2X enhancement of initial crash-avoidance scenarios, like V2X enhanced Forward Collision Warning or V2X based soft intervention ahead of AEB.
- The C2C embraces the harmonisation of DENM and SRTI use cases incl. triggering conditions for providing choice for OEMs.

¹ PTW = Powered Two Wheelers, Connected Motorcycle Consortium; <https://www.cmc-info.net/>

² Coalition for Cyclist Safety; <https://coalitionforcyclistsafety.org/>

³ C-ROADS; <https://www.c-roads.eu/>

⁴ Agricultural Industry Electronics Foundation; <https://www.aef-online.org/home.html>

- C2C recognises OEMs' interest in configuring their equipment flexibly, including single- or dual-channel Direct V2X, with or without Cloud V2N.
- C2C recognises the potential of sensor data sharing via CPM. C2C works on inclusion of CPM requirements in its Basic System Profile (BSP), the reference for Direct V2X implementations.
- The C2C is open to realise additional requirements using another technology other than ITS-G5, provided that the additional technology is proven and not causing interference. At present, 5G-V2X is seen as a possible candidate. Analyses show that using one channel for all road users and, while keeping vehicle specific sensor data sharing (beyond CAM, DENM) in a separate channel looks reasonable.
- C2C recognizes that flexibility of choice is essential for the success of Direct V2X. Vehicles with different market segment and automation levels may opt for a cost-effective single channel or a dual channel approach. For bikes, on the other hand, a single channel currently seems to be the only feasible solution due to cost reasons..
- For interoperability, backward compatibility, and efficient spectrum use the essential safety messages CAM and DENM should remain on only one channel using ITS-G5.

Full potential of Direct V2X

The Euro NCAP scenarios and protocols

C2C analysed the different Euro NCAP scenario options and recognized that Safe Driving extension by Direct V2X are feasible. This includes V2X soft intervention as part of ACC performance. In Crash Avoidance, V2X Forward Collision Warning, and V2X soft interventions followed by e.g. AEB are feasible. However, Crash Avoidance based on Direct V2X hard intervention requires system improvements and is therefore not considered feasible for 2029. Once these improvements are achieved in the coming years, these scenarios could become relevant for future assessment frameworks.

Interoperable and Backward compatible message exchange

Safe Driving (local hazard warning) scenarios of the Euro NCAP 2026 protocol are being realized by both Cloud Communication (via DFRS) and Direct V2X communication. These technologies are seen complementary. Depending on data quality stakeholders can choose a specific technology or implement both.

When Direct V2X is used, safe driving is supported by the DENM (Decentralized Environmental Notification Message) and CAM (Cooperative Awareness Message) message sets. DENM covers local hazards, but also low-latency use cases, such as emergency electronic brake lights. CAMs are "here I am" messages providing a 360° view on surrounding vehicles.

The Euro NCAP 2029 scenarios identified in the previous paragraph benefit especially from sharing CAM and/or CPM (Collective Perception Messages).

From an automotive OEM perspective, CPM can be seen as an extension of CAM. While CAM provides information only about the transmitting vehicle, CPM also provides information about classified objects, including other non-connected vehicles and especially non-connected VRUs. Implementing CPM dissemination provides many advantages and supports various additional use-case realisations, providing flexibility for implementers.

Flexible Technology Approach

While some implementers may choose to implement an advanced system, others should not be obliged to do so as well.

Direct V2X implementations in bicycles should be possible on a single channel. Because bicycles use the same road segments as vehicles, CAM awareness information should be shared on the same channel. It is therefore recommended that vehicles and bicycles disseminate CAMs in the same channel.

Considering the dissemination analyses performed by various organisations and companies, the inclusion of all CAMs, DENMs, and road infrastructure messages occupy a single channel, especially when bicycles and powered two-wheelers (PTWs) also share CAMs. CPM analyses show that in the worst case it requires an entire channel. This means that for supporting both CAM and CPM dissemination a dual channel approach is required. Consequently, as reflected in Figure 2, CAM and DENM dissemination should be concentrated in the present operational ITS-G5 channel to support all road users. CPM dissemination should use a second channel, and because it is not yet in operation, the technology can be chosen.

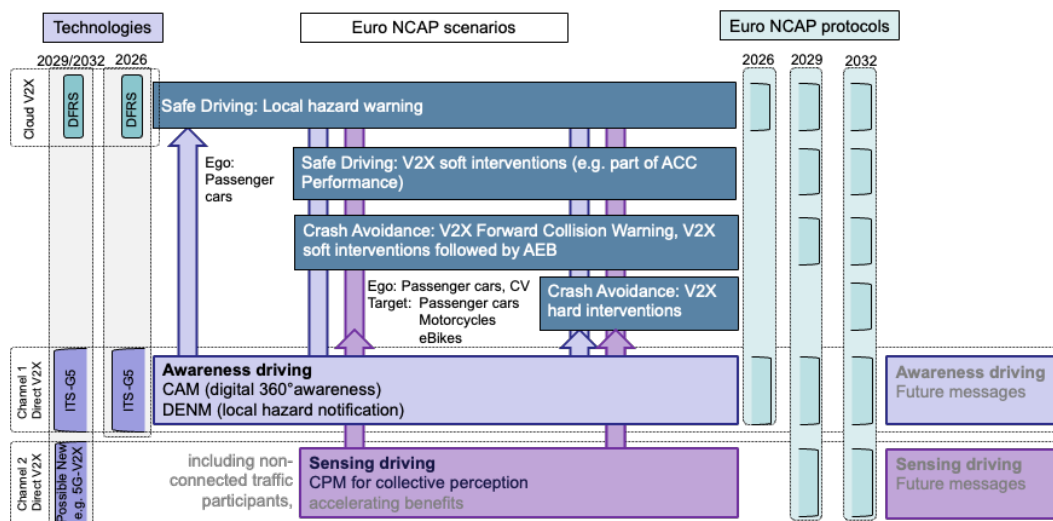


Figure 2: The Direct V2X support for realizing Euro NCAP scenarios

From C2C's perspective, the second channel technology choice (e.g. 5G-V2X as an option) is flexible as long as the newly selected technology is proven and coexistence with previously implemented technologies. This approach would provide flexibility for implementers while maintaining interoperability and backward compatibility.

Perspectives on present and future services using Direct V2X

Figure 3: Timeline of present and future servicesFigure 3 illustrates how messages, their extensions, and new message sets support present and upcoming scenarios.

The present services operated in the adopted channel sufficiently support the 2029 targeted safety scenarios and may be implemented with a single radio solution. In future assessment frameworks, CPM is envisioned to be provided in a second channel.

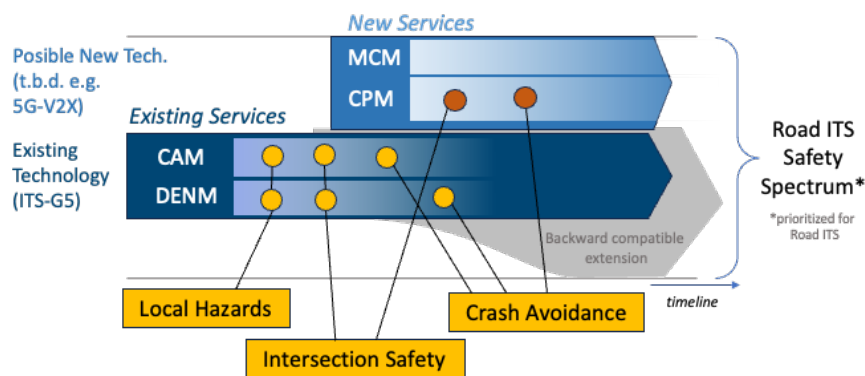


Figure 3: Timeline of present and future services

Interoperability and backward compatibility

- The EU ITS impact assessment report from 2021⁵ identified that Direct V2X is important for realizing road safety objectives of Vision Zero of the EU Commission, as it provides safety beyond the basic warnings. In the future it will enable machine-level cooperation between vehicles and infrastructure, that has the potential to unlock greater safety benefits.
- EU principles for Cooperative ITS (C-ITS)—interoperability, backward compatibility, trust, and privacy imply that all stations must exchange and interpret a common, standardized message set without prior knowledge (i.e. without pairing or negotiation), using spectrum efficiently, and at lowest costs.
- Operational safety-critical functions (e.g., safe driving support and crash avoidance) use data of CAM/DENMs. Any duplication of these messages (CAM, DENM) across

⁵ EU ITS impact assessment report <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021PC0813>

parallel technologies is spectrum inefficient, fragments safety benefits, increases costs and violates EU laws.

- System evolution should add capabilities through backward-compatible extensions and, where needed, complementary channels, while preserving the interoperable data exchange of the installed fleet's safety applications.
- Direct V2X interoperable data exchange can't rely on Cellular network interoperability mechanisms as there is no central management (base-station/central-station involved in the communication) managing different technologies. The interoperability in Direct V2X (AdHoc networks⁶) must be realized for each message set individually and decentrally. For each of the message set and the scenarios they support, the information path should be specified across industries before roll-out (including the technology used).
- Backward compatibility is only realized when older operational equipment can interpret information shared by newer versions of the equipment such that they can continue in realizing their safety related scenarios. New equipment may choose other methods and technologies for new functions which are not understood by older equipment.

Glossary (abbreviated)

- ACC: Adaptive Cruise Control
- CAM: Cooperative Awareness Message (periodic state broadcast).
- C2C: Car2Car Communication Consortium.
- C-ITS: Cooperative Intelligent Transport Systems.
- CPM: Collective Perception Message (shared sensor detections).
- CPS: Collective Perception Service.
- CV: Commercial Vehicle
- DENM: Decentralized Environmental Notification Message (event-driven hazard information).
- MCM: Manoeuvre Coordination Message.
- PTW: Powered Two-Wheeler (scooter, moped, motorcycle).
- V2X: Vehicle-to-Everything (vehicles, infrastructure, VRUs).
- VRU: Vulnerable Road User.

⁶ AdHoc networks; a decentralized, temporary wireless connection that allows devices to communicate directly with one another without relying on fixed infrastructure.

