© metamorworks | Shutterstock

Increased Traffic Safety through V2X Information Exchange

Connecting one's own vehicle with other road users and the infrastructure opens up new possibilities for data transmission via the cloud. This allows comfort and traffic safety to be further increased. S.E.A. Datentechnik has compiled a list of concepts that are being pursued and provides an assessment of their level of maturity for series introduction.

AUTHORS

Dr. Gerd Schmitz
is Managing Director of
the S.E.A. Datentechnik GmbH
in Troisdorf (Germany).

Dr. Jonas Weinen
is Head of V2X Test Systems
at the S.E.A. Datentechnik GmbH
in Troisdorf (Germany).

CONNECTED MOBILITY

Increasing global mobility meets overloaded infrastructure and the desire for increasing comfort and safety. At the same time, there is a rapid development of communication possibilities based on new technologies. The catchword connected car – the vehicle that constantly exchanges information with its environment – stands for one of the technologies for the disruptive change and improvement of the world of transport. The driver has access to extensive infotainment functions via radio links, and the vehicle can receive firmware updates, traffic information to control traffic flow or high-precision maps for autonomous driving. The transmission of sensor data from the vehicle to the infrastructure (cloud), for example to improve map material, is in preparation.

These functions of largely wide-range information exchange are typically not time-critical, but in some cases they require high data bandwidths to transmit large amounts of data. The existing (3G, 4G) or especially upcoming (5G) mobile radio technologies provide these features.

V2X COMMUNICATION

An important component of the connected vehicle approach is the so-called V2X (Vehicle-to-Everything) communication. In contrast to the infotainment functions mentioned above, the basic objective of this communication is to improve traffic safety and traffic flow over short- and mid-range distances (up to approximately 600 m). In the V2X concept (X = V (Vehicle), M (Motorcycle), P (Pedestrian), I (Infrastructure), N (Network)) each participant sends its status data via direct communication in real time with low latency. These sent messages enable each V2X participant to generate a constantly updated traffic situation map of the environment, which enables short-term decisions. Special V2X infrastructure components pass on information that extends beyond the mid-range environment (for example traffic flow) or communicate with the traffic infrastructure (such as traffic lights). These functions are and can be partially performed by mobile networks, while safety-critical direct communication also functions independent from mobile radio coverage.

REQUIREMENTS

Standardized transmission media (frequency bands), transmission methods (protocols), message contents and control mechanisms are essential prerequisites for V2X. The basic concept of information exchange is the periodical or event-based transmission of the current state of a traffic object (broadcasting) without setting up a network. This allows for fast information transmission without management overhead. The first V2X applications planned (day-one use cases) for driver information. For cooperative autonomous driving applications envisaged for the future, the targeted exchange of information between two or more vehicles is required, for example for driving in a convoy or platoon or when threading on the highway (cooperative maneuvering). In addition, sensor data can also be exchanged between vehicles via V2X in the future to improve the safety and quality of autonomous driving decisions (cooperative sensing) [1]. This requires additional functions as well as medium-term improved robustness, lower latency and increased data throughput in V2X communication.
A special situation in V2X communication are channel effects in Radio Frequency (RF) transmission caused by the environment (topography, buildings), atmospheric effects (such as weather) and speed effects (Doppler shift). These affect the reception quality and must be considered in the transmission method and processor development.

In addition, situations with high traffic density and thus a large number of transmitters pose a challenge. This can lead to an overload of the communication channel (congestion) and must be solved in the overall V2X concept. For this purpose, different control mechanisms in different protocol layers, such as the reduction of message generation at high load, are defined in the standards. Security, integrity and data protection are key components of the V2X standard definitions. The authenticity of V2X messages is guaranteed by signatures, with complex certificate management in the background.

SYSTEM STRUCTURE

V2X information processing is defined in a layered structure with defined interfaces. **FIGURE 1** shows the layers in a highly simplified form. The mostly strictly modular definition enables the replacement of individual modules, such as the access layer by alternative technologies, as well as testability at module level.

COMMUNICATION STANDARDS (ACCESS LAYER)

The direct, robust real-time exchange of information between road users requires adapted communication technology and defined frequency bands. At the end of the 1990s, frequencies in the range between 5.850 and 5.925 GHz were exclusively designated and reserved

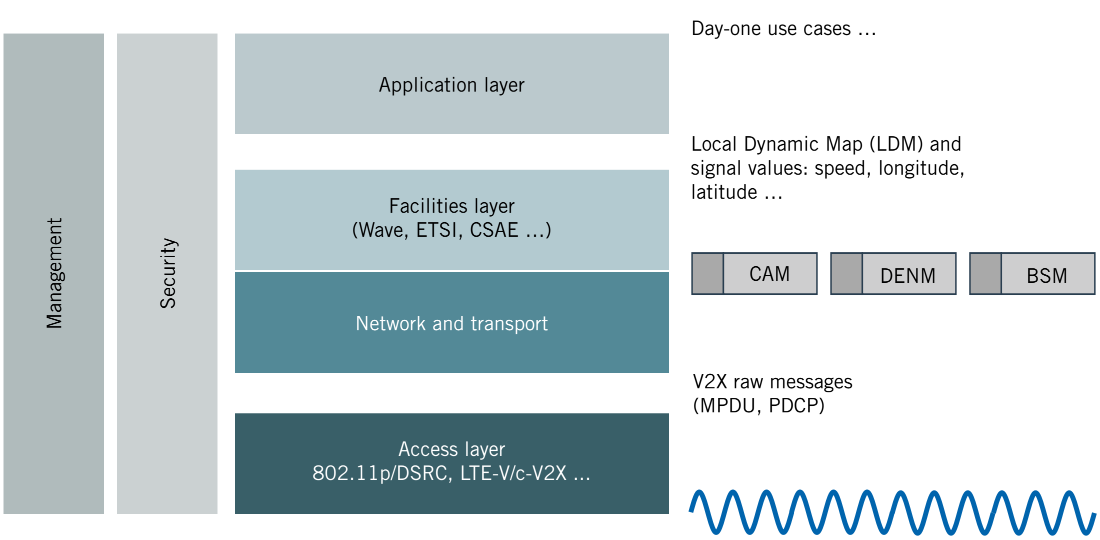

FIGURE 1 Schematic layer structure of the V2X model (© S.E.A. Datentechnik)

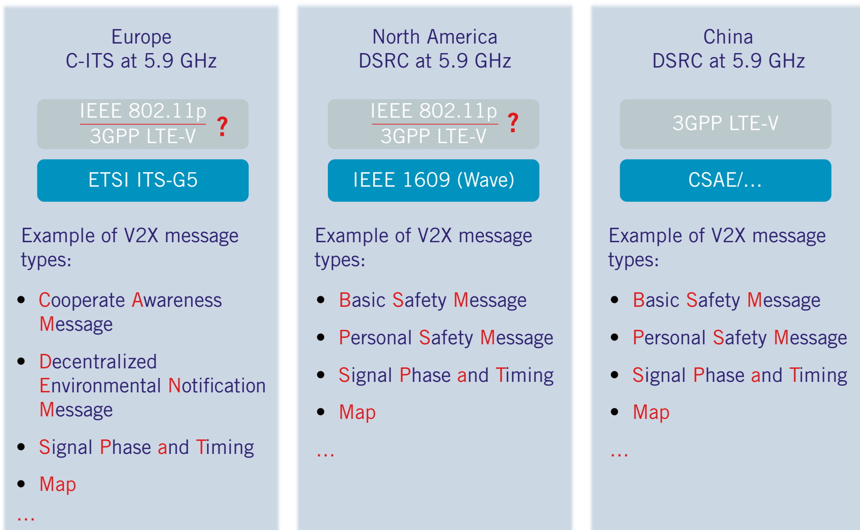

FIGURE 2 Overview of regional V2X standards (© S.E.A. Datentechnik)

for V2X communication. Currently, the Federal Communications Commission (FCC) in the USA has launched an initiative to reduce this range in favor of expanding the WLAN frequency band. Two communication standards for V2X data transmission compete worldwide [2]: the 802.11p protocol, also known as DSRC (Dedicated Short Range Communication) in the USA, and the LTE-V2X derived from the LTE mobile communications standard, often referred to as c-V2X. Future improvements are in preparation for both technologies. The new standard 802.11bd is currently being defined as the successor to 802.11p, c-V2X will also include 5G-NR technology (3GPP Release 16 in 2020) [3].

The 802.11p protocol for V2X use was defined as an IEEE standard in 2010. This protocol is an adapted variant of the WLAN technology 802.11a. With 802.11p, message packets with a bandwidth of 10 or 20 MHz are sent by a transmitter using the CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) method. In simple terms, this means before sending a message, the transmitter checks whether the medium is free. If an occupancy is detected, the system checks again after a short random time and sends if the medium is free. In this way, it is avoided that a disturbed transmission by several senders occurs. Each transmitter (vehicle) sends its message event-based and thus time-unsynchronized.

As an alternative to 802.11p, the LTE-based technology called Cellular-V2X (c-V2X) was specified by the 3GPP mobile communications standardization committee in 2016. The communications standard is referred to as LTE-V2X. This standard extends LTE for direct communication without infrastructure (Mode 4, sidelink) or under coordination by a base station (eNB, radio cell) (Mode 3). In both cases, communication between road users takes place directly via the so-called PC5 protocol. Currently, Mode 4 defined in the 3GPP Standard Release 14 is mainly used.

A key difference of LTE-V2X is the time-synchronized transmission of messages, which is typical of LTE. Data is exchanged at millisecond intervals. A transmitter uses one or more of the available subcarriers for packet transmission. Collisions are avoided by the participants in LTE-V2X Mode 4 trying to “guess” which subcarrier will not be used, based on the detected subcarrier activity of the previous cycles, and use this for their own transmission in the upcoming time slot. In this periodic time-based procedure, the time signal from a GNSS receiver (such as GPS or Galileo) is used as an exact clock. Direct synchronization without GNSS signal is also possible in principle.

THE MESSAGE LAYER

The flow control and content processing of V2X information takes place in the network and transport layer and the higher-level facility layer. Here, the V2X messages are processed. These layers are defined for different global regions by standard committees (EU: ETSI ITS-G5, USA: SAE Wave; China: CSAE), **FIGURE 2**. They provide the language, semantics, and grammar for information exchange. The partially harmonized but incompatible stan-

Day-one services (C-ITS)	
1	Emergency electronic brake light
2	Emergency vehicle approaching
3	Slow or stationary vehicle(s)
4	Traffic jam ahead warning
5	Hazardous location notification
6	Road works warning
7	Weather conditions
8	In-vehicle signage
9	In-vehicle speed limits
10	Probe vehicle data
11	Shockwave damping
12	Green Light Optimal Speed Advisory (GLOSA) / Time-To-Green (TTG)
13	Signal violation/Intersection safety
14	Traffic signal priority request by designated vehicles

FIGURE 3 European Telecommunications Standards Institute (ETSI) (EU) day-one use cases [4] (© S.E.A. Datentechnik)

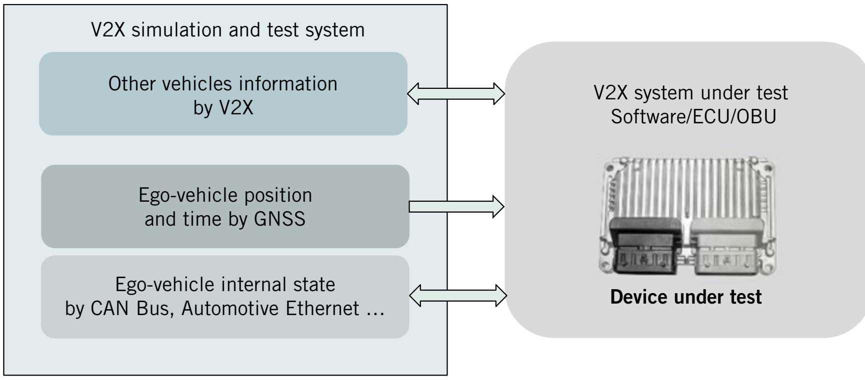

FIGURE 4 Test system for functional tests (schematic) (© S.E.A. Datentechnik)

dards define message structure/content and sender behavior.

The control of the communication (for example transmission rate, forwarding, prioritization) of the message exchange takes place in the network and transport layer. Typically, each participant transmits its data at 1 to 10 Hz. The facilities layer defines the standard-compliant structure of the message packets. It provides the extracted contents available to the applications or receives these contents from the applications and takes care of the transmission with the subordinate layers.

APPLICATIONS

The focus of V2X applications is on increasing traffic security. V2X can provide useful support especially where the driver's view or that of Advanced Driver Assistance Systems (ADAS) sensors such as radar, lidar or cameras is restricted. The V2X day-one use cases, **FIGURE 3**, describe typical critical traffic situations and the desired behavior of the implemented V2X applications, which should be available at the beginning of the first rollout.

SCOPE OF TESTS

V2X in its entirety is a multi-layered, complex technology. Tests of the different RF layers or protocols, have different requirements [5]. RF test systems for the V2X environment address automated testing of the compliance of the radio interface with the specifications of the standards (such as 3GPP for LTE-V2X) and the legal regulations of the respective region, for example. The functional test of a system or onboard unit with V2X applications requires the reproducible simulation of real traffic situations in the laboratory by means of time-based simulation of different signals, **FIGURE 4**: traffic scenario (V2X traffic participants), position of the test object in the scenario (GNSS simulation) and driving situation of the test object (vehicle dynamics). Automated test systems are required to cover the variety of possible situations.

IMPLEMENTATION STATUS

All basic definitions and technologies of V2X communication are available. Over the years, experience has been gained in a large number of pilot projects and test tracks. Commercial test and simulation systems for validation and qualification in laboratory and field tests are available. Currently, there is no legal requirement to use V2X in any region of the world. So far, only China has made a binding commitment to communication technology (c-V2X). In Europe and the USA, the decision for a radio technology is still open. Few car manufacturers have so far launched the first car models with V2X technology (Dedicated Short-Range Communications, DSRC) on the market.

SUMMARY

In the future, V2X technology will make an indispensable contribution to the safety and coordination of traffic for both driver-supported, semi-autonomous (SAE levels 1 to 3) and fully autonomous driving (SAE levels 4 and 5). In the long term, V2X communication as a further source of information in addition to sensors such as camera, radar and lidar will make an important contribution to autonomous driving a nd enable cooperative behavior.

REFERENCES

[1] Hobert, L.; Festag, A.; Llatser, I.; Altomare, L.; Visintainer, F.; Kovacs, A.: Enhancements of V2X Communication in Support of Cooperative Autonomous Driving. In: IEEE Communications Magazine 53 (2015), pp. 64-70

[2] Shimizu, T.; Kenney, J.; Nakamura, S.; Hongsheng, L.: Comparison of DSRC and LTE-V2X PC5 Mode 4 Performance in High Vehicle Density Scenarios. Paper ID AM-TP2188, 26th ITS World Congress, Singapore, 2019

[3] Naik, G.; Choudhury, B.; Park, J.: IEEE 802.11bd & 5G NR V2X: Evolution of Radio Access Technologies for V2X Communications. In: IEEE Access (2019), No. 7, pp. 70169-70184

[4] C-ITS-Plattform (publisher): Final Report January 2016. Online: https://ec.europa.eu/transport/sites/transport/files/themes/its/doc/c-its-platform-final-report-january-2016.pdf, access: March 19, 2020

[5] Meinen, A.; Glöckner, S.: Freie Fahrt für V2X. In: Elektronik automotive 02 (2020), pp. 30-33