CANoe.Car2x

Product Information

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1   Introduction

Invisible to most road users, the comprehensive networking of road users and road infrastructure (ITS, Intelligent Transport Systems) is already finding its way into individual vehicle models (ITS Vehicle Stations), infrastructure components (ITS Roadside Stations, RSU) of individual cities and road works warning trailers on various highways. Conventional communication between public transport (buses and trams) and light signal systems or traffic computers is also being replaced step by step. The direct wireless communication is referred to as V2X (vehicle to everything) or Car2x (car to everything).

The Option Car2x expands CANoe to include functions for analysis, stimulation and testing of V2X-based ADAS functions for this. This domain-specific functionality enables direct analysis of both the V2X-specific network and transport protocols and their related application messages, including the Cooperative Awareness Message (CAM) and the Decentralized Environmental Notification Message (DENM) in Europe and the Basic Safety Message (BSM) in China and the US, for example. The respective security mechanisms are also supported here.
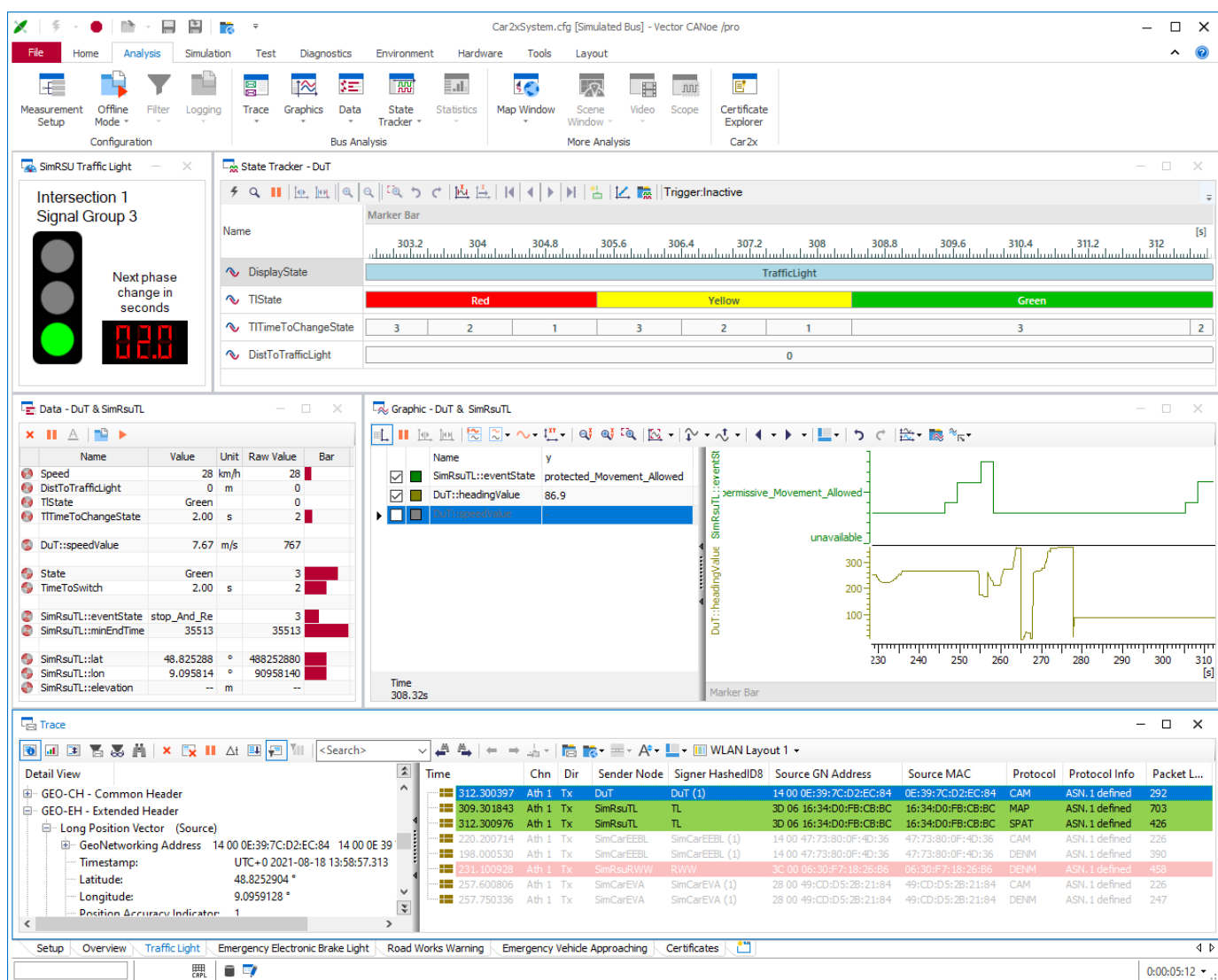

Figure 1: CANoe.Car2x simulates and visualizes V2X traffic light scenarios with ITS vehicle stations. The measurement windows aid in the analysis of positions, content of application messages and in the monitoring of selected signals.

1.1 Benefits at a Glance

> **>General:**

>> Access to the WLAN packets according to IEEE 802.11p in conformance with ETSI ITS-G5 and IEEE 1609

>> Access to packets transmitted over 4G/5G mobile radio (3GPP C-V2X PC5)

>> Management of ASN.1-based application messages in a flexible database

>> Supporting of security mechanisms for all regions, including the management of certificates and private keys

> **>Analysis:**

>> Interpretation of V2X-specific China (CN), EU and US communication protocols

>> Protocol analyzer for checking basic conformity of the network protocols and application messages (CAM and DENM)

>> Checking of the signature of "secured packets" (authentication and integrity check)

>> Support for any application messages defined in ASN.1 thanks to the integrated dynamic ASN.1 interpreter

>> Display of transferred vehicle and infrastructure information on a road map: This visualizes the link between positions, driving situation and sequence.

>> Synchronization of the Map Window and the Protocol Analyzer Window with other measurement windows for subsequent analysis

>> The assignment of received messages to ITS stations using the accompanying certificates enables station-based analysis as an alternative to message-based analysis

>> Use of the GNSS time as the measurement time

>> Logging and interpretation of received certificates

> **>Simulation/Stimulation**

>> Creation and sending of packets for stimulation and testing of real V2X ECUs/V2X systems

>> Easy creation and sending of correct and falsified packets for easy stimulation

>> Simulation of individual ITS stations up to and including complex traffic scenarios with vehicles, infrastructure and vehicle networks using the Scenario Editor, the V2X stack and domain-specific programming libraries

>> Scenario Editor for creation of individual traffic scenarios as basis of test cases (which can be executed in CANoe)

>> Gateway functionality for measurements or data exchange between wireless networks and vehicle networks, such as CAN and Ethernet: This is used to establish a connection between vehicles and internal bus systems, as well as the communication with the outside world.

1.2 Application Areas

CANoe.Car2x supports network designers, development engineers and test engineers of OEMs and suppliers over the entire development process, from planning and simulation of the ECUs and the ECU network to residual bus simulation and analysis, testing and commissioning of the overall system. The Option Car2x is especially well-suited for application development of ECUs in vehicles and traffic infrastructure components which communicate using the following standards:

> **Physical layer**

>> IEEE 802.11p

>> 3GPP C-V2X PC5

> **GB/T standards (China)**

>> DSMP (DSRC Short Message Protocol) including the Adaption Layer (AL) (GB/T 31024.3)

>> Security Header

>> C-SAE 0053 application messages

- – Basic Safety Message (BSM)

- – Map Data Message (MAP)

- – Signal Phase and Timing (SPAT)

- – Roadside Safety Message (RSM)

- – RoadSide Information (RSI)

> C-SAE 0157 application messages (Draft)

> **ETSI ITS standards (Europe)**

> GeoNetworking
(ETSI TS 102 636-4-1 and ETSI EN 302 636-4-1)

> Security Header
(ETSI TS 103 097)

> Basic Transport Protocol (BTP)
(ETSI TS 102 636-5-1 and ETSI EN 302 636-5-1)

> ETSI ITS application messages, such as

- – Cooperative Awareness Message (CAM)

- – Decentralized Environmental Notification Message (DENM)

- – MAP (topology) Extended Message (MAPEM)

- – Signal Phase And Timing Extended (SPATEM)

- – Infrastructure to Vehicle Information Message (IVIM)

- – Signal Request Extended Message (SREM)

- – Signal request Status Extended Message (SSEM)

- – Collective Perception Message (CPM)

> **IEEE 1609 – WAVE (US)**

> WAVE Short Message Protocol (WSMP)
(IEEE 1609.3)

> WAVE Service Announcement (WSA)
(IEEE 1609.3)

> WAVE Security Services (WSS)
(IEEE 1609.2)

> WAVE Peer-To-Peer Protocol
(IEEE 1609.2)

> SAE J2735 – DSRC application messages, such as

- – Basic Safety Message (BSM)

- – Map Data Message (MAP)

- – Signal Phase And Timing (SPAT)

To test the behavior of the application in various scenarios, environment simulations are necessary. The Scenario Editor is used for this. CANoe.Car2x then simulates both the configured environment comprised of vehicles (ITS Vehicle Stations) and the infrastructure (ITS Roadside Stations), as well as the vehicle's own on-board networks like CAN, LIN, FlexRay, Ethernet etc. (note: this requires the use of additional bus-specific CANoe options). All boundary conditions are then present for testing the ECU and the ADAS applications connected to it.

To send and receive 802.11p wireless frames, CANoe.Car2x supports the dedicated interface VN4610. This network interface – which is certified for CE (EU), FCC (US) and KC (Korea) – makes it possible to configure physical parameters like the channel

number and transmission power directly in CANoe. The transmission power can therefore also be changed according to the test specifications and depending on the distance to the toll stations at runtime in CAPL, for example.

To send and receive PC5 wireless frames, CANoe.Car2x supports a variety of different C-V2X interfaces from other manufacturers. It is also possible to configure different physical parameters like the channel number and transmission power directly in CANoe here.

During the analysis, the contents of the data packets and their physical packet properties like the radio channel and reception strength are evaluated. Domain-specific measurement windows are available for this purpose. Logging of the radio packets for subsequent analysis, documentation purposes or repeat playback for stimulation of ECUs, is also possible. Synchronization of the Map Window with other windows is especially helpful when analyzing logged packets. This allows fast location of certain traffic situations and analysis of the associated communication.
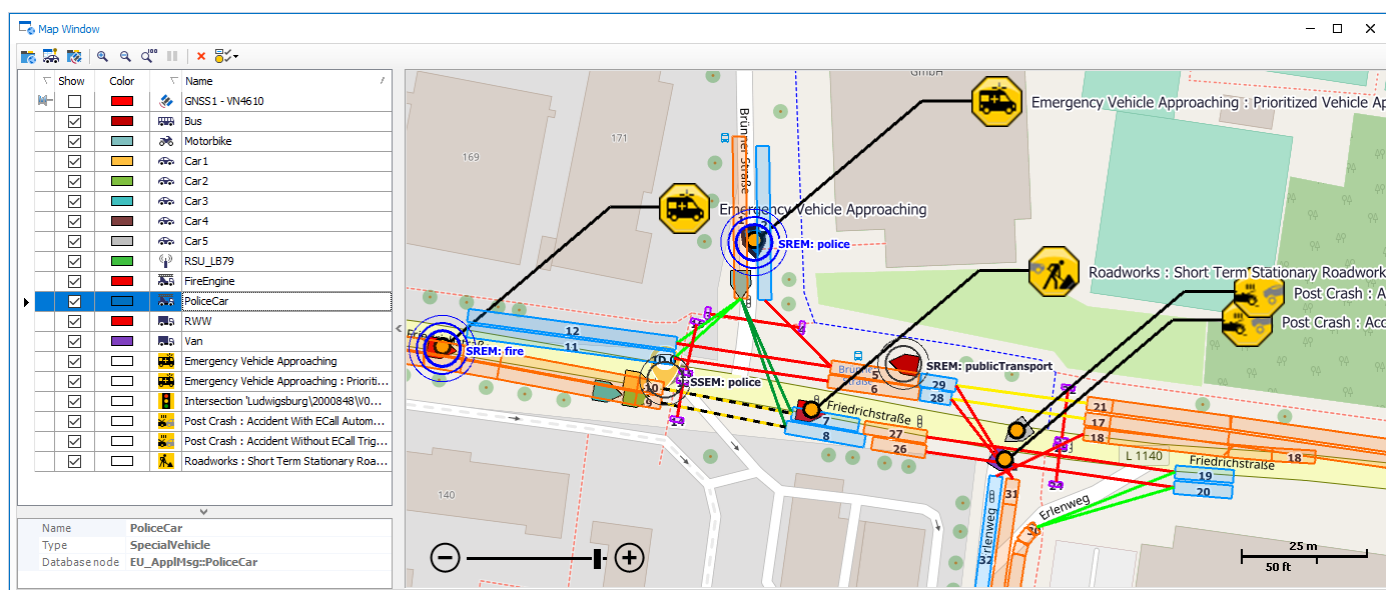

Figure 2: Map Window for geographic display of transferred vehicle and infrastructure information

You can perform comprehensive automated tests using the CANoe Test Feature Set and the Car2x Test Service Library. Complex scenarios and recorded or live measured data can be automatically analyzed and the application tested with it.

1.3 Further Information

> >**CANoe Website**

Various documents are available on the Internet for CANoe. The demo version also comes with sample configurations for the various application areas and detailed online help in which all CANoe functions are described. You also benefit from valuable expertise in the form of technical articles and application notes.

> **CANoe Feature Matrix**

Additional information on variants, channel support and bus system support is available in the feature matrix.

2   Functions

The Option Car2x expands CANoe to include V2X-specific functions. Application channels are supported in accordance with IEEE 802.11p and 3GPP C-V2X PC5 communication. The configuration of up to 32 channels according to IEEE 802.11p or up to 8 channels according to 3GPP C-V2X PC5 for simultaneous analysis and stimulation of control and service channels is possible here.

2.1   General Configuration

2.1.1   Car2x Network Explorer

The Car2x Network Explorer is the editor for Car2x databases.

> Display of the contents of any ASN.1-based application messages with a type, range and format

> Addition and editing of application messages (by the user) are possible using the database concept.

> Locating of specific elements within the complex structure of an application message

> Generation of CAPL code for application messages

> Configuration of node names and addresses

> Configuration of the sending behavior of messages (for the interaction layer (IL))
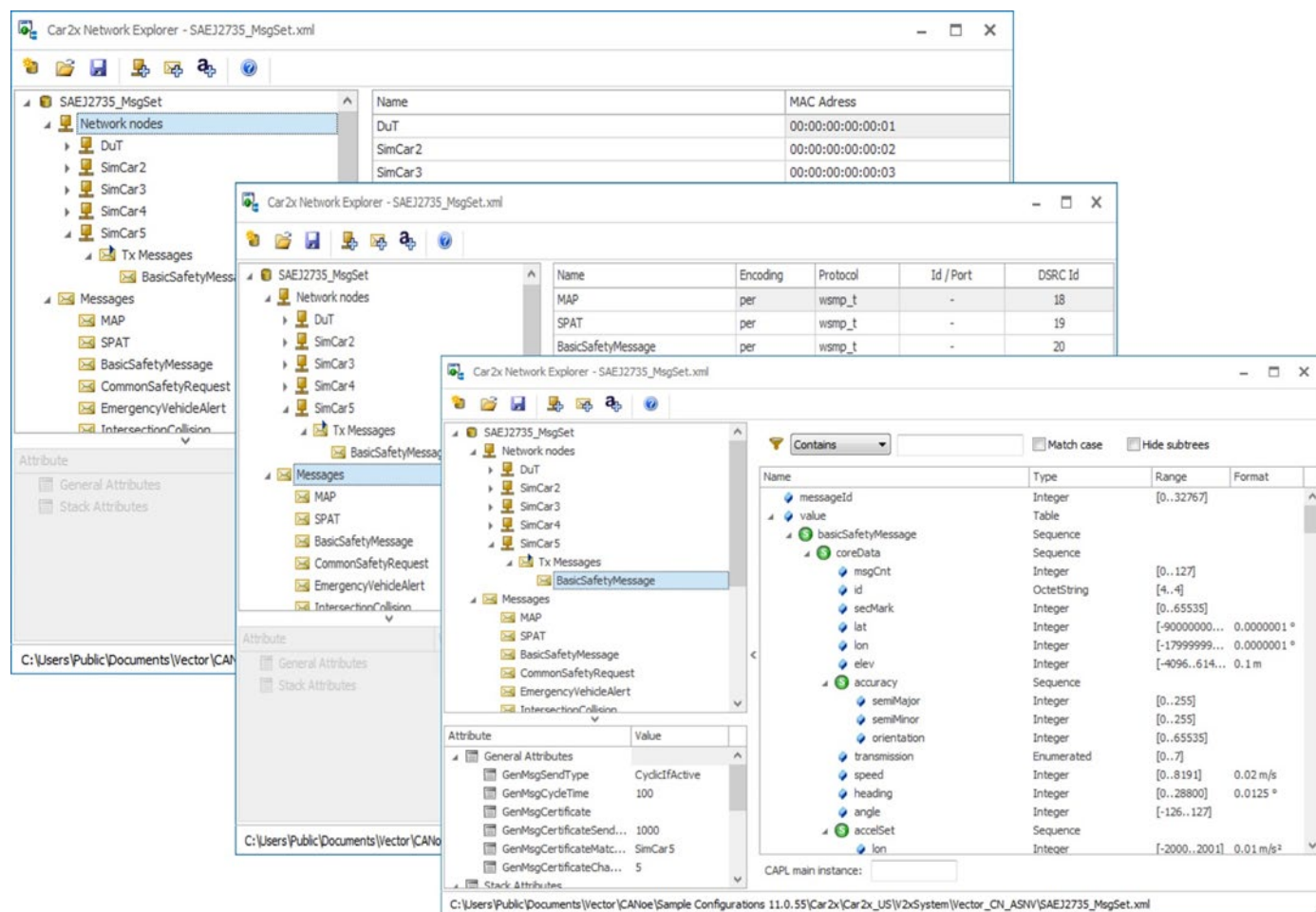
> Configuration of the V2X stack

Figure 3: The Car2x Network Explorer features various functions for Car2x databases: from basic node and message configuration (incl. sending behavior) and location of certain signals to generation of CAPL code for access to individual signals/data fields.

2.1.2 Car2x Station Manager

The Car2x Station Manager is the main unit for managing ITS stations. When receiving messages, they are assigned to the ITS station from which they are sent. By assigning stations to network nodes, CANoe can handle the data of the individual stations in the measurement windows.

> Manual or automatic assignment of messages to ITS stations using

  – Signer HashedId8 and MAC addresses

  – Signer HashedId8 only

  – MAC addresses only

> Network nodes can be linked to the ITS stations. This enables access to the application messages of individual ITS stations.

> Definition of individual colors for ITS stations

> Optional use of the defined colors for coloring the V2X packets sent by the ITS stations in question in the Trace Window

> Saving and loading of assignments of MAC addresses and Signer HasehedId8 onto network nodes

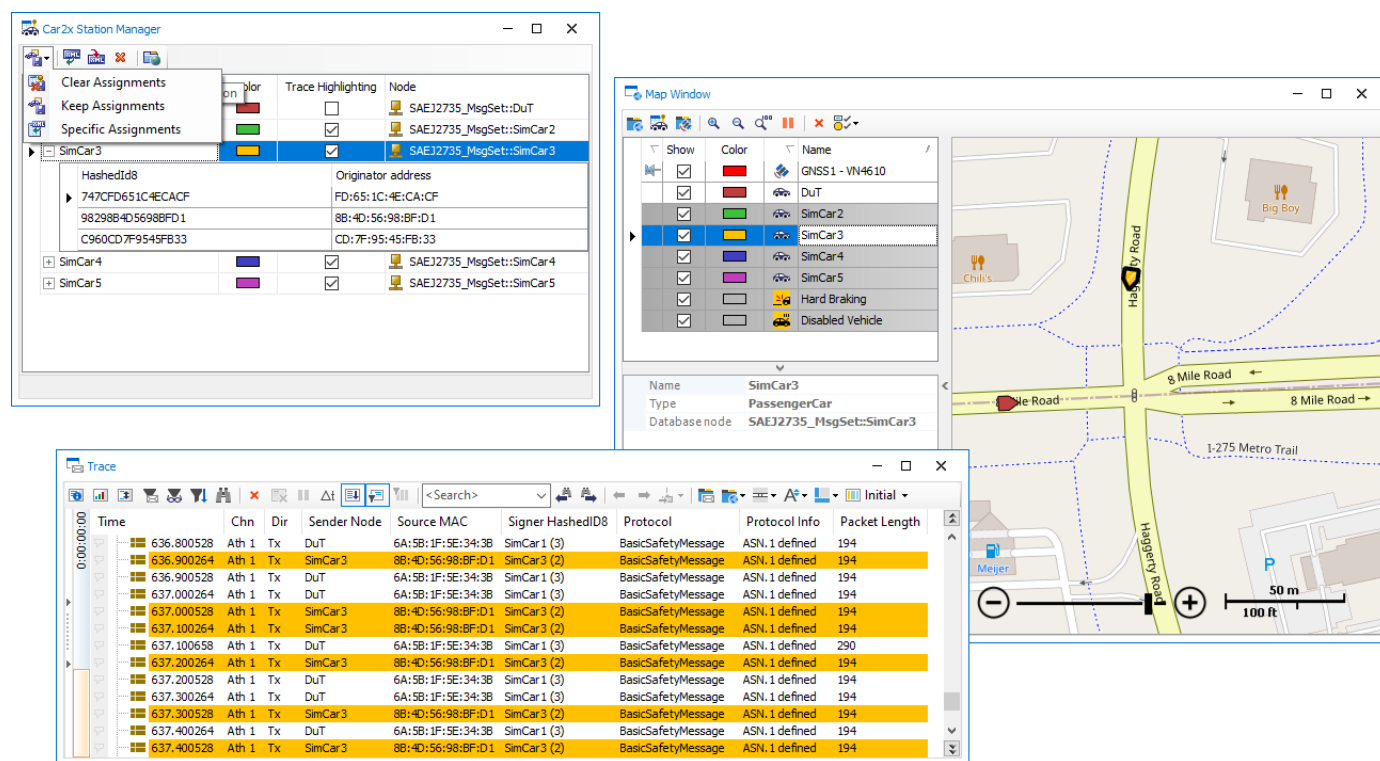> Specific handling of forwarded application messages with ETSI GeoNetworking (e.g. DENM)

Figure 4: In the Car2x Station Manager, colors are selected for ITS stations and the Trace Window coloring is activated for individual ITS stations.

2.1.3 Car2x Certificate Manager

The provision of certificates and private keys in the Car2x Certificate Manager forms the basis for the signature check of received packets and for generation of the Security Header including a valid signature for send packets by the Car2x Interaction Layer:

> Adding, importing, exporting and removing certificates and private keys

> Generating individual certificates and complete certificate chains, including private keys with suitable properties for defined test purposes

> Function for creating certificates based on saved certificates

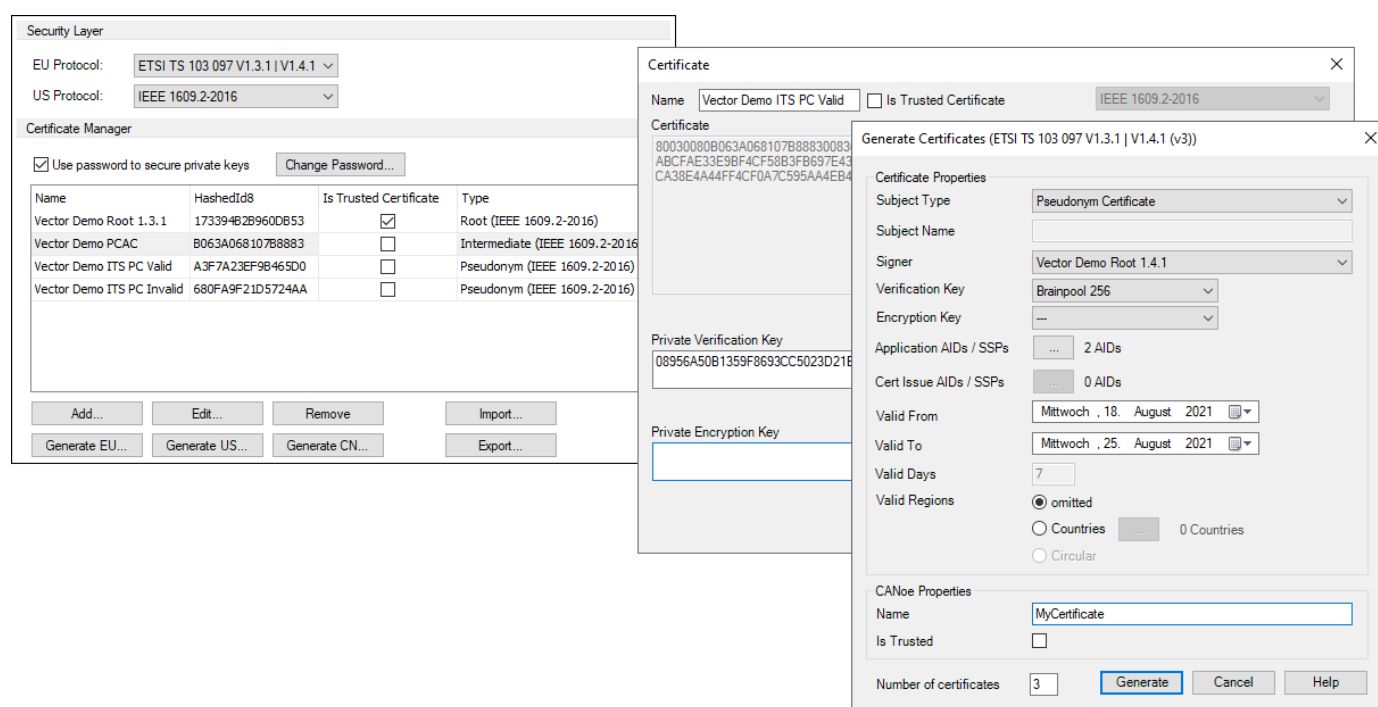> Password-protected storage of private keys for signature and encryption

Figure 5: Provision of certificates and private keys and generating test certificates in the Car2x Certificate Manager

2.2 Analysis Functions

CANoe.Car2x offers domain-specific measurement windows for the analysis of V2X communication. The basis for this is the Car2x database, which contains the definition and detailed description of the application messages.

2.2.1 Expansions in the Trace Window

> Interpretation and presentation of detailed protocol header information

> Decoding of application messages contained in the database (raw data and interpretation of the values)

> Specific columns for a quick overview of the most important parameters, such as the display of events in a column and the display of the transmission and reception power of frames (configurable)

> Signature check of "secured packets"

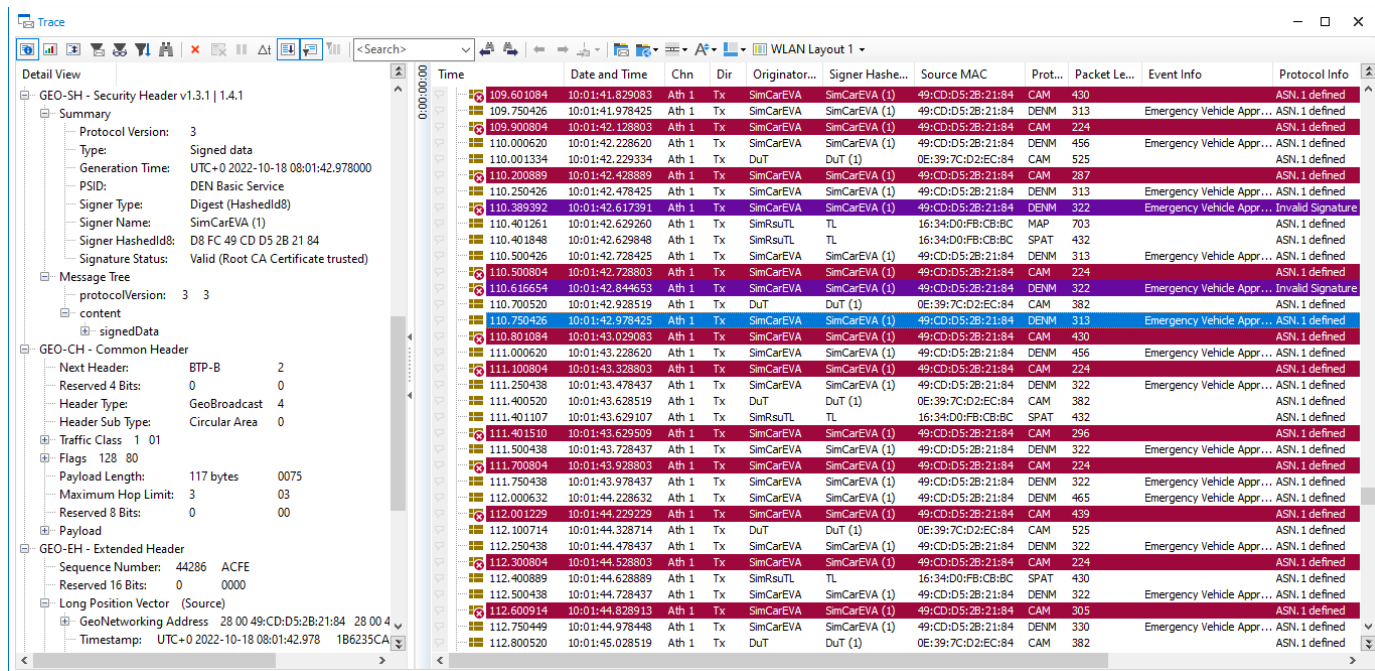> Configurable color marking of application messages, protocols and errors

Figure 6: The Trace Window displays packets with protocol errors and invalid signatures, among other things. The individual protocol fields are interpreted in the detail view.

2.2.2 Car2x Protocol Analyzer

The Car2x Protocol Analyzer can permanently perform checks in all protocol layers and application messages.
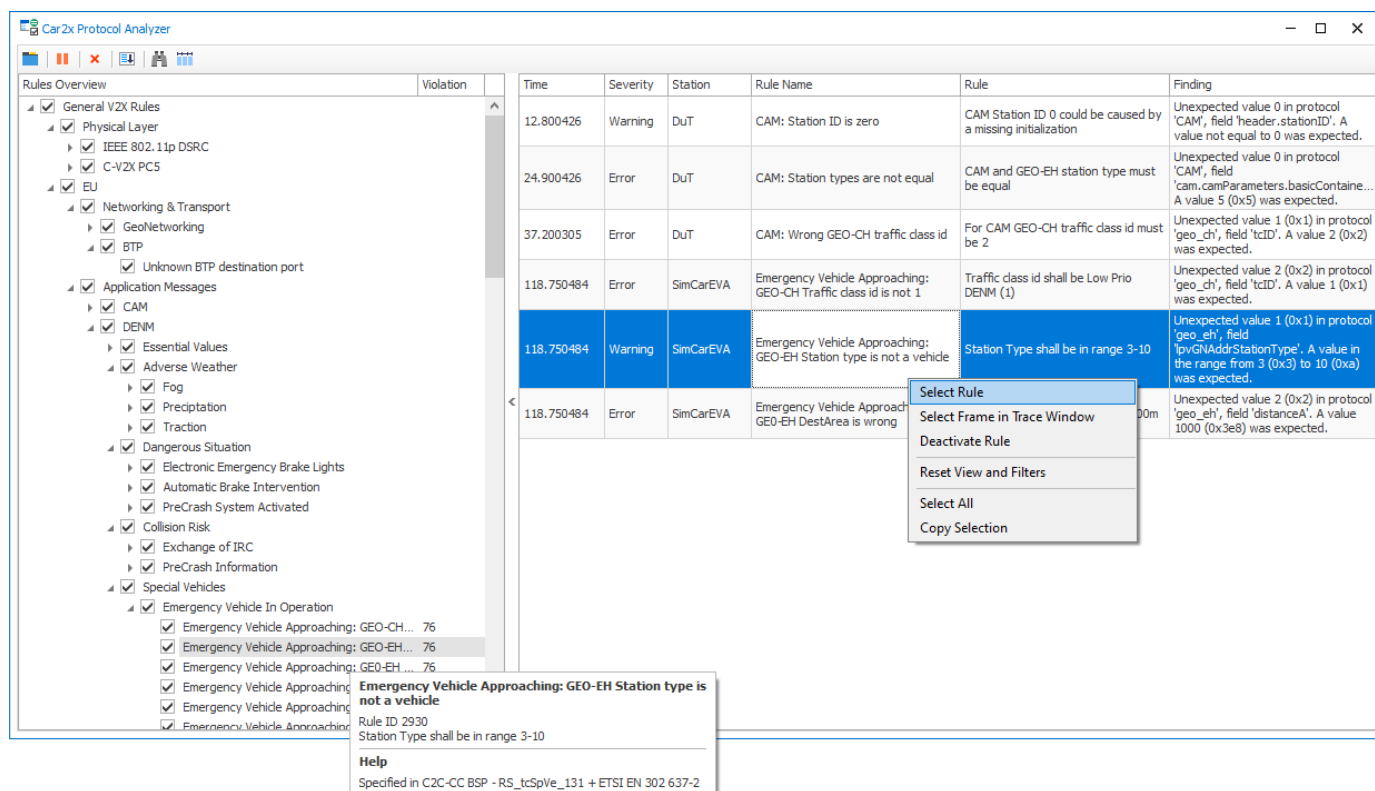

Figure 7: The Car2x Protocol Analyzer enables an efficient search for rule violations.

With its configuration options, the window offers the following advantages:

> Time-consuming creation and execution of corresponding test cases is no longer necessary, as the Car2x Protocol Analyzer automatically and permanently performs the existing checks.

> Available descriptions and references to standards and profiles enable a classification regarding relevance and importance.

> Various filter options simplify and shorten the search for relevant errors and warnings that concern your own ECU (DuT).

> A jump function to the Trace Window as well as the general window synchronization with other analysis windows support you in the detailed search for error causes.

2.2.3 State Tracker and Graphics & Data Windows

In the State Tracker and Graphics & Data Windows, it is possible to carry out a station-based signal analysis of application messages. The signals relevant to a test can be selected and monitored here.
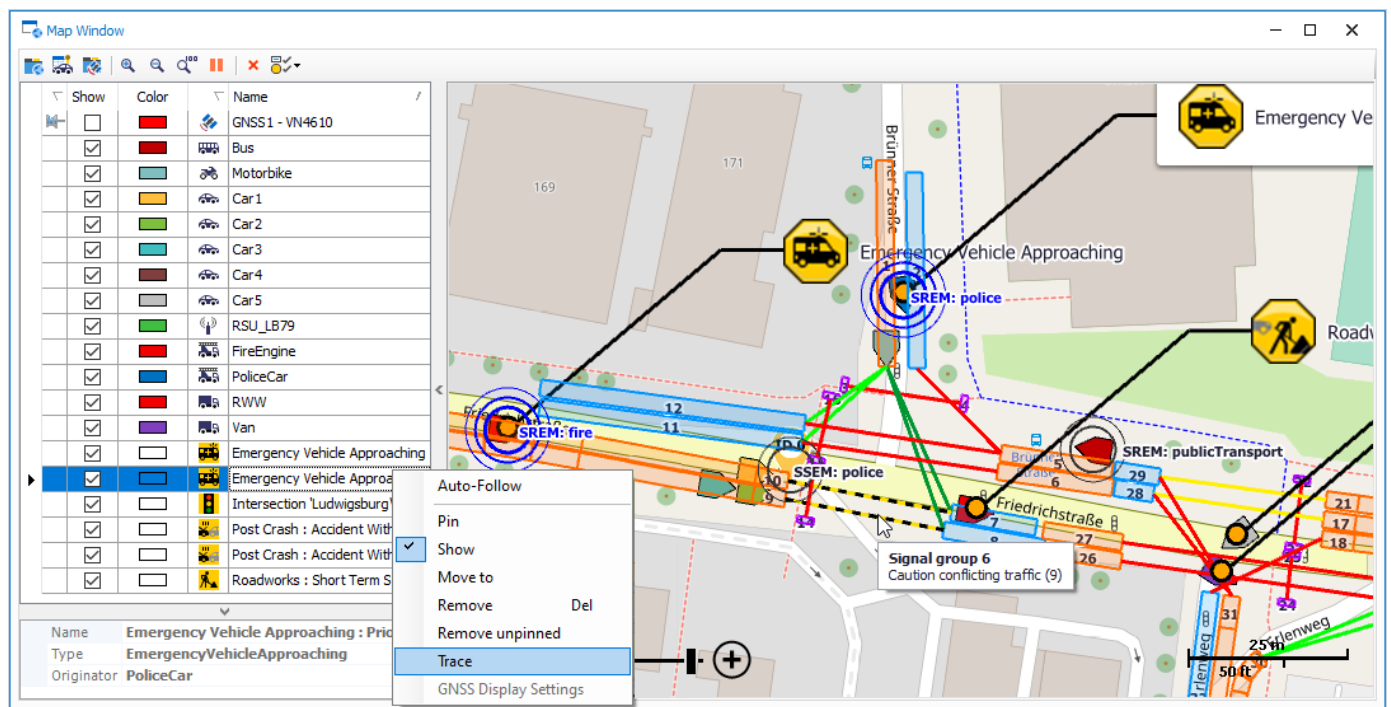
2.2.4 Map Window

Figure 8: The Map Window automatically displays the ITS stations and events of DENM and BSM. Using the MAP Window API, additional individual information items can also be displayed (e.g. blue light and data on SREM/SSEM). The window also shows the visualization of SPAT and MAP messages here.

In the Map Window, the display of multiple V2X objects, like ITS Vehicle Stations and ITS Roadside Stations, on map material including synchronization with other windows for subsequent analysis is possible.

> Automatic display of ITS stations and events

> Listing of detected stations and events in the list view

> Programming API for drawing in the Map Window: This allows, for example, the display of additional status information from ITS stations or test parameters from CAPL in the Map Window.

> Synchronization of Map Window and Trace Window. A specific test situation can thus be sought and precisely analyzed after stopping the measurement. By double-clicking an event, you can also jump to the corresponding point in the Trace Window.

> The following map material is currently supported:

– Open Street Map (hosted as Vector Tile Server)

– HERE

– Configurable user-defined tile provider

– Image (file format JPG, PNG, BMP, GIF and TIF)

2.2.5 Car2x Certificate Explorer

The Option Car2x enables you to analyze and test the security mechanisms.

Figure 9: Listing of received certificates in the Car2x Certificate Explorer, including display of the signature hierarchy and certificate contents

> Display of known certificates (stored in the Car2x Certificate Manager) and received certificates in the Car2x Certificate Explorer:

– Checking of the signature and the certification path

– Display of the signature hierarchy

– Display of the interpreted certificate contents

2.2.6 Expanded Analysis with CAPL

The programming API makes it possible to access the contents of received V2X messages.

> Callback functions for the evaluation of received packets

> Access to the fields of the various protocol layers

> Access to the signals/data of the application messages, such as CAM, DENM, BSM etc.

> Polling of the send node name of a received packet

> Time stamp checking

> Access to Security Header data

  – >Authentication and integrity checking of received packets

  – >Checking of certificate validity duration

2.2.7   Logging and Analysis

> If the GNSS time is available during measurement, the wireless packets are recorded and displayed with the corresponding time stamps. Measurement data from different vehicles (in different logging files) can therefore be put into their temporal context. With VN4610, the precision of the absolute time stamp compared to the GNSS time is approx. 1 ms.

> Logging of radio packets and playback, as well as offline analysis of logged measurement data

2.3   Simulation, Stimulation and Testing

CANoe.Car2x makes it possible to stimulate V2X-based ADAS applications so they can be tested. This includes environment simulation first and foremost, which ensures that an application to be tested on the real ECU (DUT) is stimulated by one or more additional vehicles and road side units (e.g. light signal systems) which can be emulated by CANoe with real radio messages. The application then responds with messages to the HMI or a central ADAS ECU, for example. These messages are checked by CANoe so that the test is initiated upon stimulation and so that functionality can then be checked using test methods.
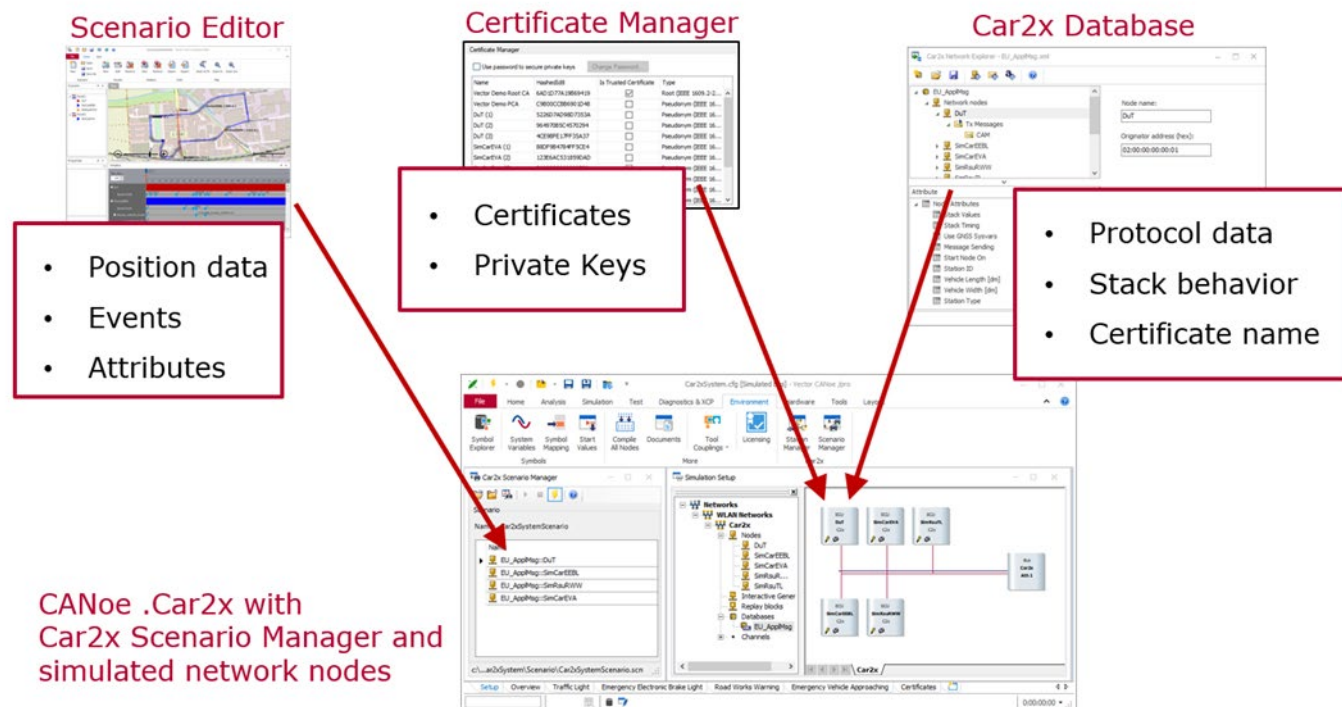

Figure 10: Interaction between the most important components when simulating a scenario with multiple ITS stations.

2.3.1   Scenario-based Stimulation

With scenario-based stimulation, tests based on predefined scenarios are carried out. The scenario, which can be created with the Scenario Editor for example, is first loaded by CANoe here. The V2X stack generates valid communication based on this data and under consideration of the corresponding protocol specifications (CN/EU/US) with which the ECU can be stimulated.

Predefined scenarios for the respective regions (CN/EU/US) are already included in the scope of delivery. These scenarios can be used as the basis for the creation of additional tests.

2.3.2   Packet-based Stimulation

To test a V2X application, it is also necessary to be able to send faulty packets or unrealistic data to the ECU, among other things. These tests can be implemented with the help of the programming library provided by the Car2x Interaction Layer (IL). The IL provides the option of generating individual packets here, including application messages, and to set/read the data fields across all protocol layers.

2.3.3   V2X Stack

The V2X stack generates essential data for protocol fields and signals like time stamps, schedules sending and takes a scenario with position data and signal sequences into account if present. If real GNSS data (e.g. from VN4610) is being used, an ITS Vehicle Station can be simulated without significant effort.

An independent V2X stack governs the communication behavior for each region (CN/EU/US). The V2X stack also supports Basic System Profile 1.5.2 for the EU protocol.

2.3.4   Car2x Interaction Layer

The Car2x Interaction Layer (IL) offers a comprehensive programming library for expanded analysis and stimulation. This can also be used as a supplement to the V2X stack. The functions include, among others:

> Functions for cyclical and manual sending of V2X application messages, including certificate selection and changing in accordance with the configuration in the Car2x database

> Functions for setting the content of the application messages and influencing the configured transmission behavior and security

> Functions for the creation and sending of individual packets, including faulty ones if necessary

> Callback functions enable the updating, cancellation and reconfiguration of the packet content immediately before sending

> Callback functions that inform about the reception of frames, thereby enabling expanded analysis

> Functions for loading, starting and stopping scenarios created with the Scenario Editor. The scenario can also be shifted to any desired coordinates here.

Simulations and test setups can be created in this way. The functions of the programming API and the V2X stack can also be used in test units and test modules.
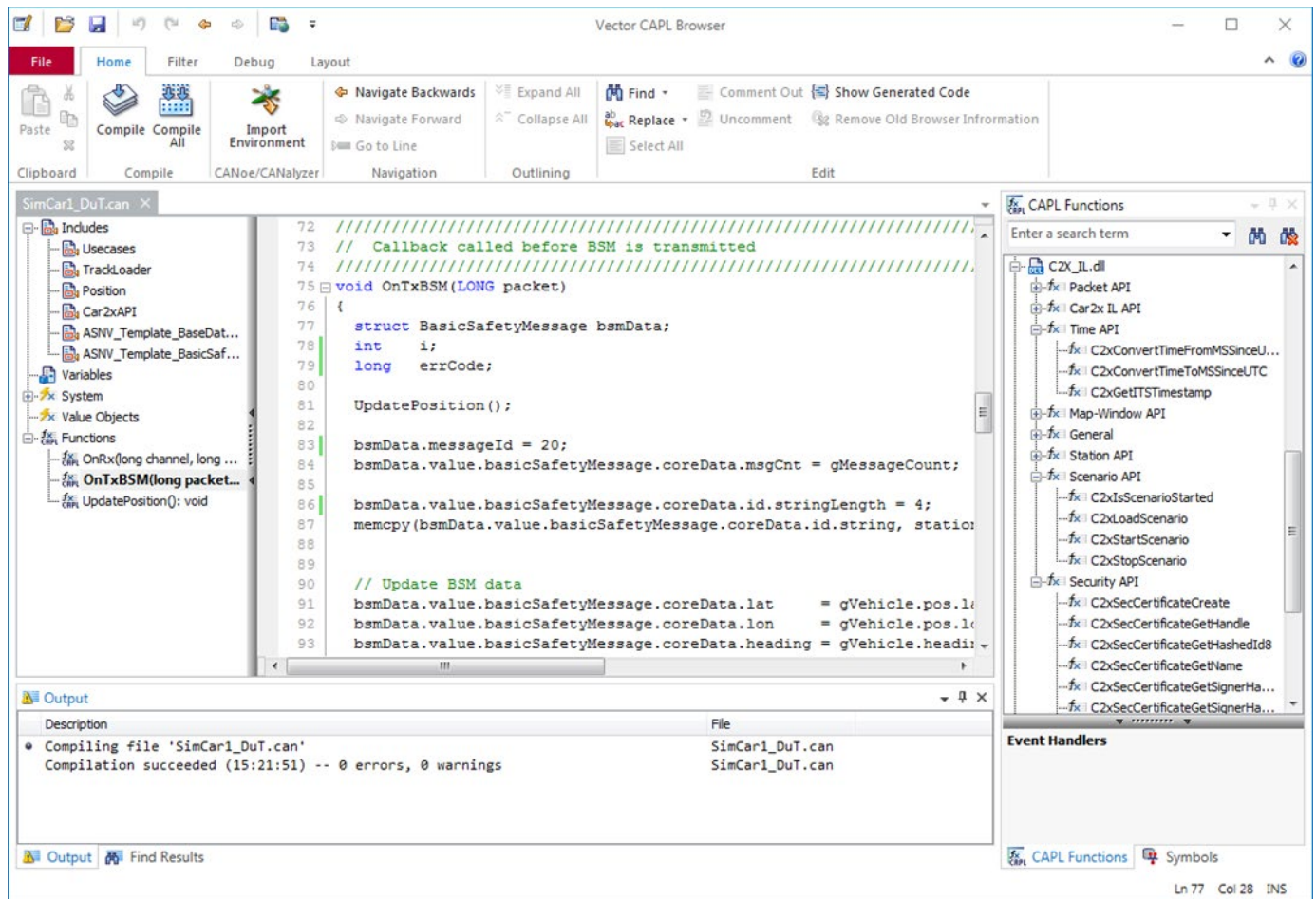
Figure 11: The CAPL browser shows the callback function for updating the data before sending an application message. Functions of the Car2x function library are displayed in the overview of CAPL functions.

2.3.5   Creating Test Scenarios

2.3.5.1   Scenario Editor

The Scenario Editor enables you to configure a route-based environment simulation. An intersection collision situation, braking vehicle, tail end of a traffic jam etc. can be designed in a map-based GUI here. A route is defined in just a few steps. It is also possible to import a previously recorded route (supported file formats: KML, GPX and NMEA). The driving behavior and events to be sent by the vehicles can be configured using a timeline on this route.

The behavior of the traffic scenario can be configured based on the time using attributes in the timeline. Attributes define statuses, properties and behaviors of the vehicles and can be mapped as constant or interpolated values. Parameters such as the acceleration behavior of vehicles and the statuses of turn signals, windshield wipers and traffic lights can therefore be configured according to the test in scenarios. Using attributes, special situations such as construction sites and approaching commercial vehicles can be described.

The Scenario Editor offers the option of selecting V2X events defined in the standards. The attributes required for this are then automatically integrated and can be adjusted if necessary.

The created scenarios do not necessarily need to be executed at the configured absolute coordinates. The scenario can be ported to other coordinates "relatively" as desired. This means that a scenario can be triggered manually during a test drive. The current position and direction are copied and serve as the starting point for the scenario.
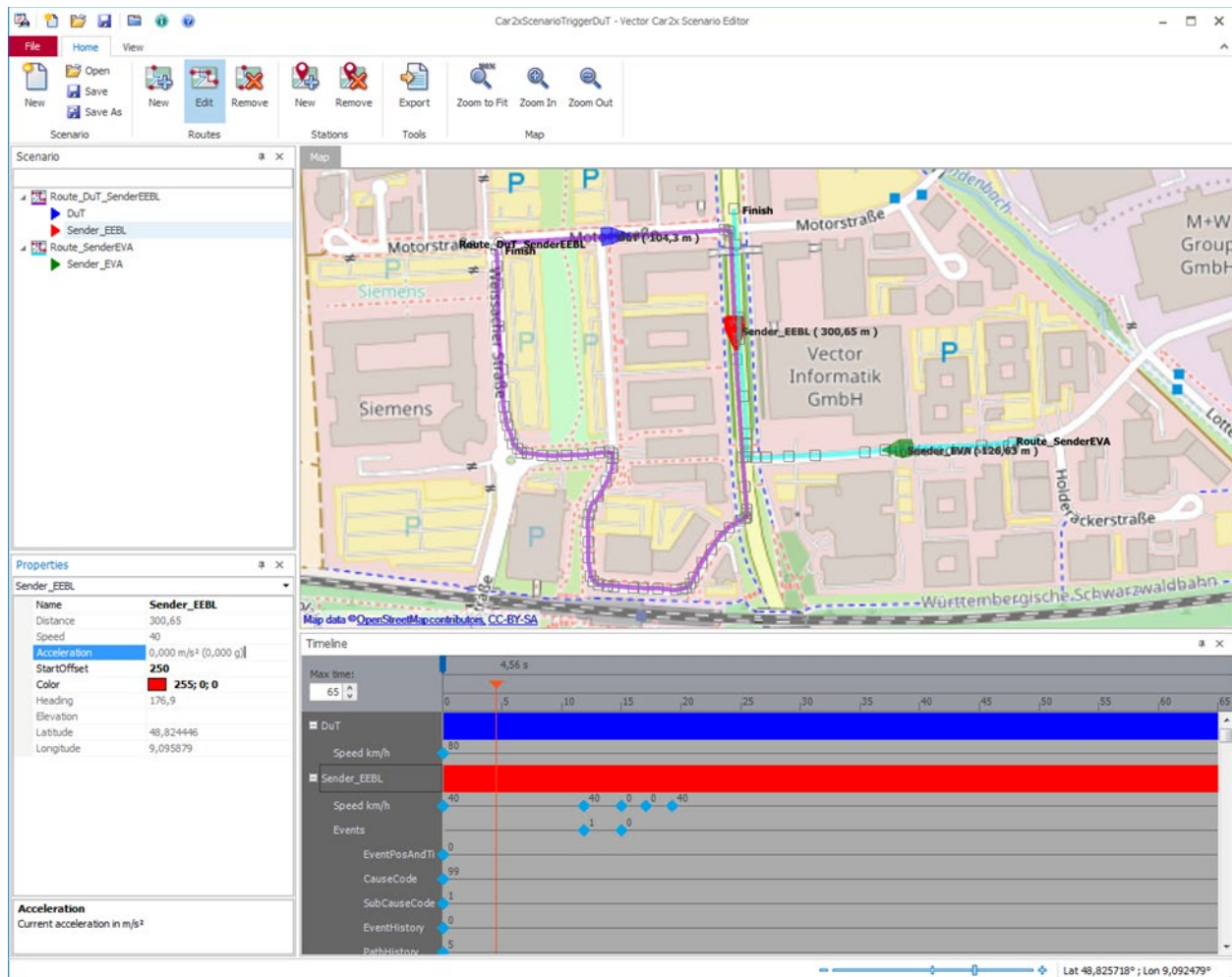
Figure 12: The Scenario Editor provides support in creating test scenarios for the ADAS test and offers specialized support for the creation of V2X-based test scenarios.

2.3.5.2 Scenario Manager

The Scenario Manager ensures that the scenarios created in the Scenario Editor are loaded in CANoe.Car2x. The Scenario Manager makes the loaded application data available to the V2X stack or Car2x Interaction Layer (IL) so that the application data is merged with the protocol headers of the frames and so that valid communication for the defined scenario is generated when starting the stimulation.

2.3.6 Test Feature Set

Within the scope of the Test Feature Set, the Option Car2x makes a domain-specific Test Service Library available. These functions enable an automatic test run where, for example, the reception of a V2X packet can be awaited as the response to a simulation without blocking the entire system. The test functions, together with the programming library of the Car2x Interaction Layer and the V2X stack, thereby enable stimulation and testing. vTESTstudio can provide supplemental support in the creation of the test environment here.

3   Hardware

Depending on the physical layer in use, different network interfaces are used.

3.1   VN4610 (IEEE 802.11p)

VN4610 offers two IEEE 802.11p channels, two CAN channels and a GNSS receiver. In addition to the specific properties of a dedicated measurement interface, VN4610 offers other advantages in CANoe.Car2x. Overview of the most important aspects:

> Easy configuration of the WLAN channels, transmission power, protocol layout etc. used, without requiring a reboot

> The channel parameters and transmission power can be reconfigured via CAPL at runtime (during the measurement).

> Synchronized time stamps for CAN and IEEE 802.11p (relative time stamp precision: approx. 1 µs) and with additional Vector network interfaces (via the hardware sync cable or the Precision Time Protocol via Ethernet)

> The GNSS time of the VN4610 is used as an absolute time in CANoe. The time stamps are synchronized to the GNSS (approx. 1 ms).

> The GNSS data can be used directly for simulation (especially useful in HiL systems or real driving tests, for example).

Figure 13: VN4610 - 802.11p network interface

Additional information on VN4610 can be found on the Internet at **Products/VN4610**.

3.2   Hardware for C-V2X PC5

3.2.1   Generic Interface

Various third-party devices can be connected as a network interface over generic UDP/IP communication for PC5 wireless frames. The data can be transferred over a UDP connection and fed into CANoe using specific functions here. This makes it possible to interpret external data and process it in CAPL. Of course, generated V2X frames can also be transferred to the third-party device and further processed by it.

3.2.2   R&S CMW500

The CMW500 network simulator from the Rohde & Schwarz company can be connected to CANoe.Car2x. A sample configuration which simplifies this connection, thereby ensuring a quick start, is available here.

3.2.3   Autotalks Craton2 EVK

Autotalks Craton2 EVK enables C-V2X PC5 communication and can be used as a third-party network interface with CANoe. For this purpose, the device requires special firmware from Vector so that CANoe identifies the device during a network scan and so that an application channel can be assigned.
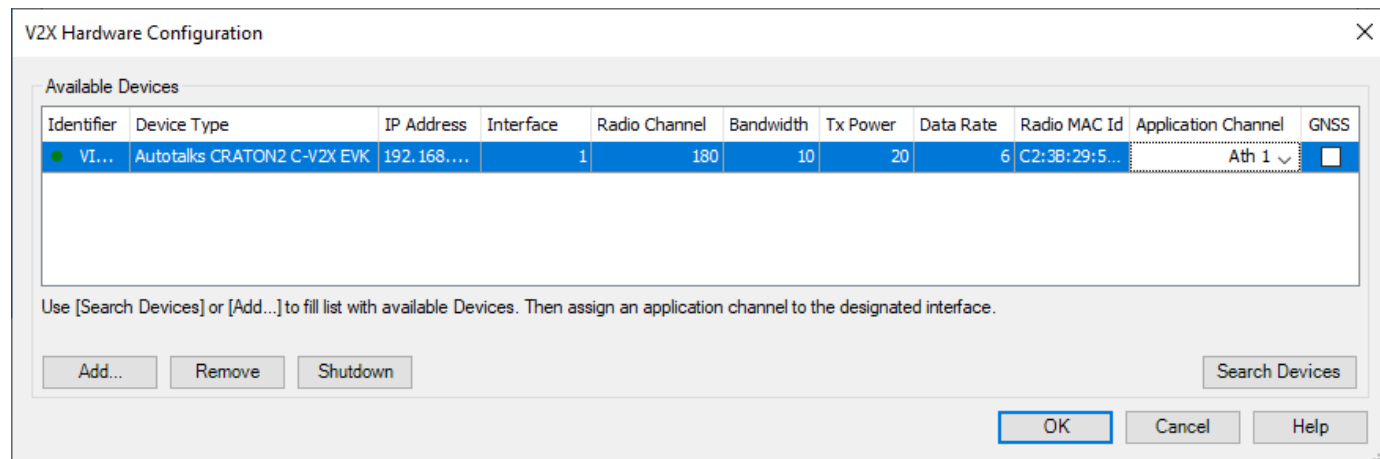

Figure 14: Configuration dialog for supported third-party V2X network interfaces

4   Training Courses

Our training offer for CANoe includes various training courses and workshops at our training facility and at the customer's facility.

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