VECTOR >

CANoe .Car2x

Table of contents

1 Introduction

Future generations of vehicles will be increasingly integrated into a comprehensive data infrastructure (ITS, or intelligent transport systems) which enables direct communication between vehicles (ITS vehicle station) on the one hand and infrastructure (ITS roadside station, or RSU) on the other – referred to as V2X (vehicle-to-everything) and Car2x (car-to-everything) communication.

The .Car2x option expands CANoe to include functions for the analysis, testing and stimulation of V2X-based ADAS functions for this. This domain-specific functionality enables direct analysis of both the Car2x-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) of the SAE J2735 Message Set in the US, for example. The respective security mechanisms according to ETSI and IEEE 1609.2 are also supported here.
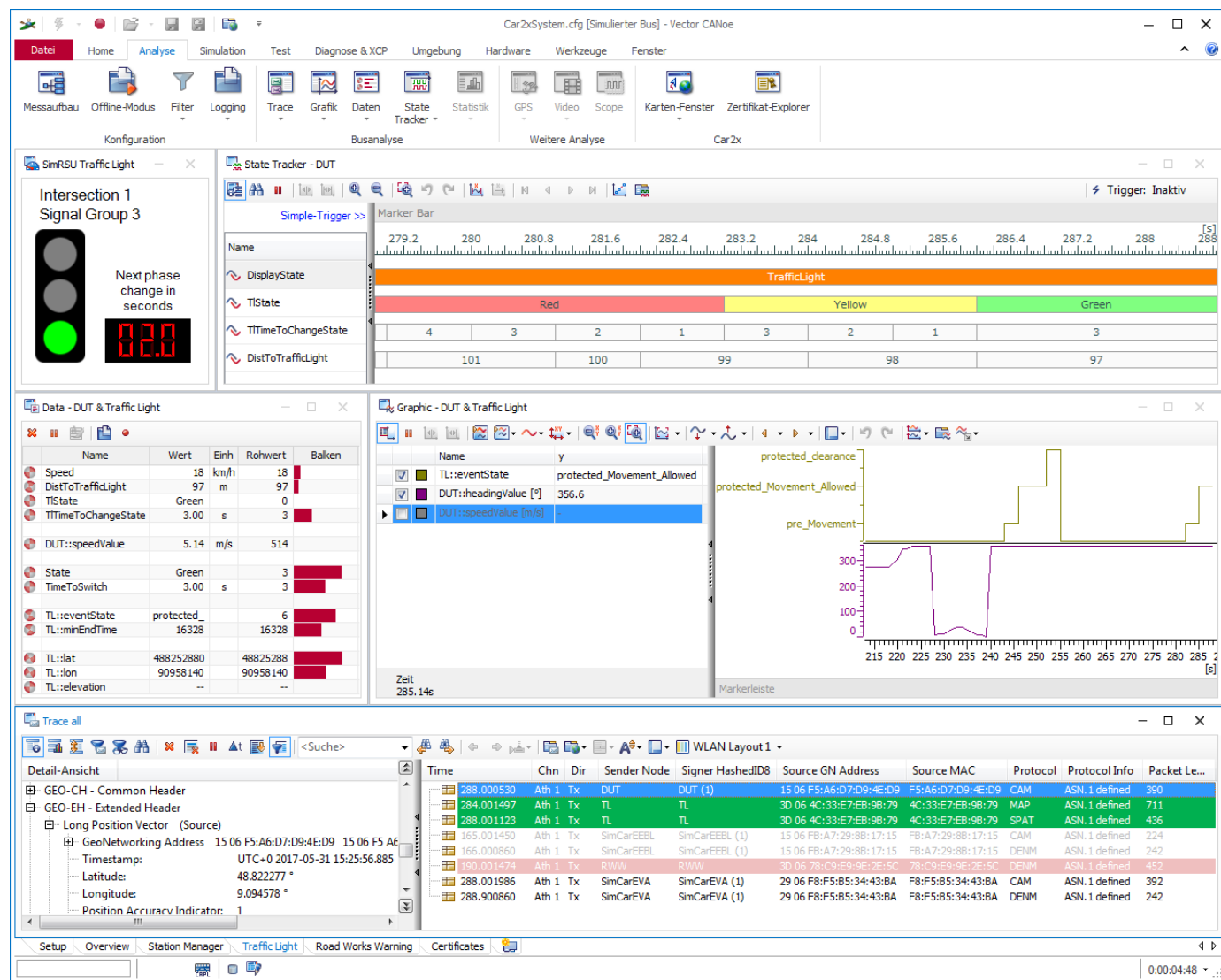

Figure 1: CANoe .Car2x simulates and visualizes Car2x traffic light scenarios with ITS vehicle stations. The measurement windows aid in the analysis of positions, content of application messages and in the monitoring of selected signals.

1.1 Benefits at a glance

> **Analysis**

>> Direct access to the WLAN packets according to IEEE 802.11p in conformance with ETSI ITS-G5 and IEEE 1609 WAVE for the display and analysis of communication

>> Interpretation of Car2x-specific EU and US communication protocols

>> Protocol analyzer for checking basic conformity of the network protocols

>> 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, the driving situation and the sequence

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

>> Management of certificates and private keys needed for the validity check of signed packets or generation of the security header (ETSI) or WSS layer (IEEE) including valid signatures for send packets

>> 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 GPS time as the measurement time

>> Logging and interpretation of received certificates

> **Simulation/Stimulation**

>> Easy creation and sending of correct and falsified WLAN packets for stimulation of the ECUs

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

>> Scenario Editor for creating geobased test cases – CANoe copies the application parameters and generates the associated V2X communication

>> Gateway functionality for measurements or data exchange between wireless networks and vehicle networks, such as CAN or 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 Car2x option is especially well-suited for application development of ECUs in vehicles which communicate using the following standards:

> IEEE 802.11p (physical layer)

> ETSI ITS standards

>> 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 (MAP)

- > Signal Phase and Timing (SPaT)

- > Infrastructure to Vehicle Information Message (IVIM)

> IEEE 1609 WAVE

- > 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)

- > Signal Phase and Time (SPaT)

- > Map Data Message (MAP)

To test the behavior of the application in various scenarios, environment simulations are necessary. The Car2x 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. (this requires the use of additional bus-specific CANoe options). All boundary conditions are thus present for testing the ECU and the ADAS applications connected to it.

For sending and receiving wireless frames, CANoe .Car2x supports both hardware from suppliers and the VN4610. In contrast to third-party hardware, this network interface – which is CE- and FCC-certified – makes it possible to reconfigure physical parameters like the channel number and transmission power directly in CANoe. Thus the transmission power can also be changed according to the test specifications at runtime in CAPL, for example.

During the analysis, the contents of the data packets and their physical packet properties like the wireless channel and reception strength are evaluated. Domain-specific measurement windows are available for this purpose. Logging of the WLAN 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.
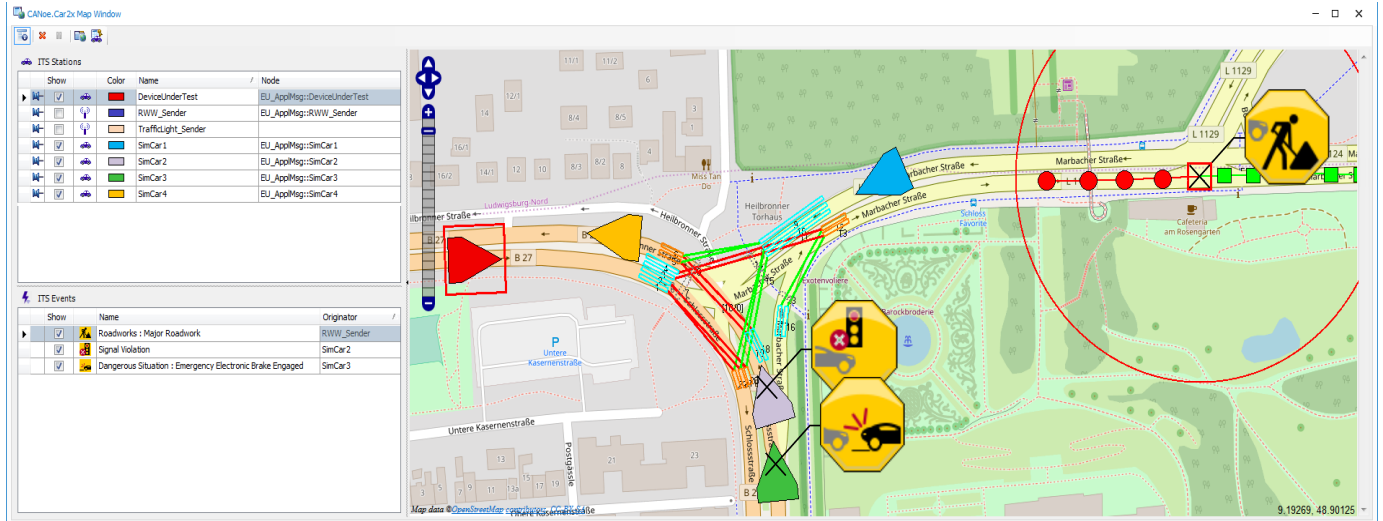
Figure 2: Map Window for geographic display of transferred vehicle and infrastructure information

You can perform comprehensive automated tests using the CANoe Test Feature Set. This allows, for example, very fast testing of interoperability. In addition, complex scenarios can be created, analyzed and reproduced in identical or modified form.

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 .Car2x option expands CANoe to include V2X-specific functions. WLAN channels are also supported in accordance with IEEE 802.11p. Configuration of up to 32 WLAN channels for simultaneous analysis and stimulation of control and service channels is possible.

2.1   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

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

> Generation of CAPL code for selected elements

> Configuration of application messages (encoding, protocol and Id/port)

> Configuration of node names and addresses

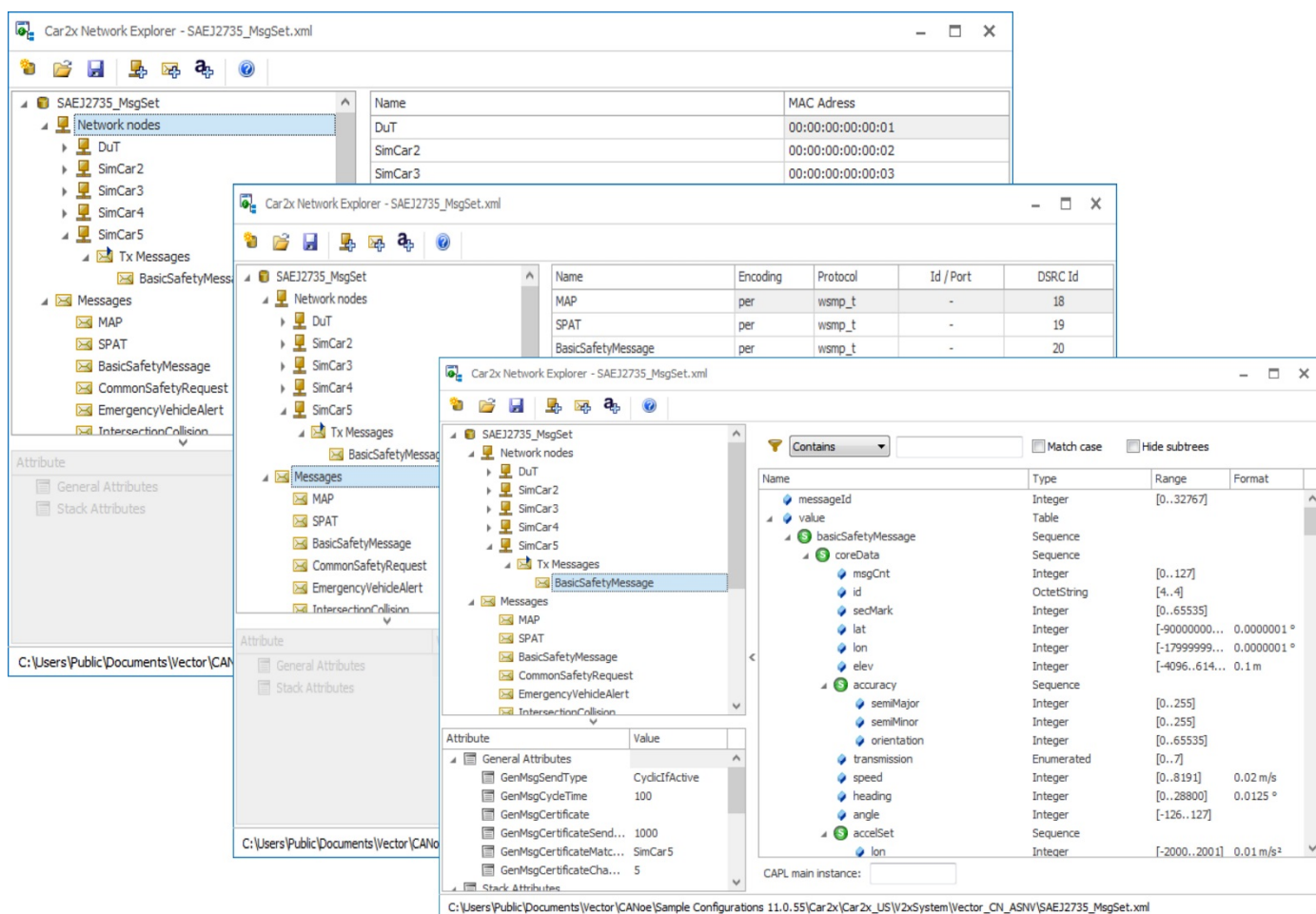> Configuration of the sending behavior of messages (for the interaction layer (IL))

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.

2.2   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 database 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

> Database 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 WLAN packets sent by the ITS stations in question in the Trace Window

> Saving and reloading of assignments of MAC addresses and Signer HashedId8 onto stations

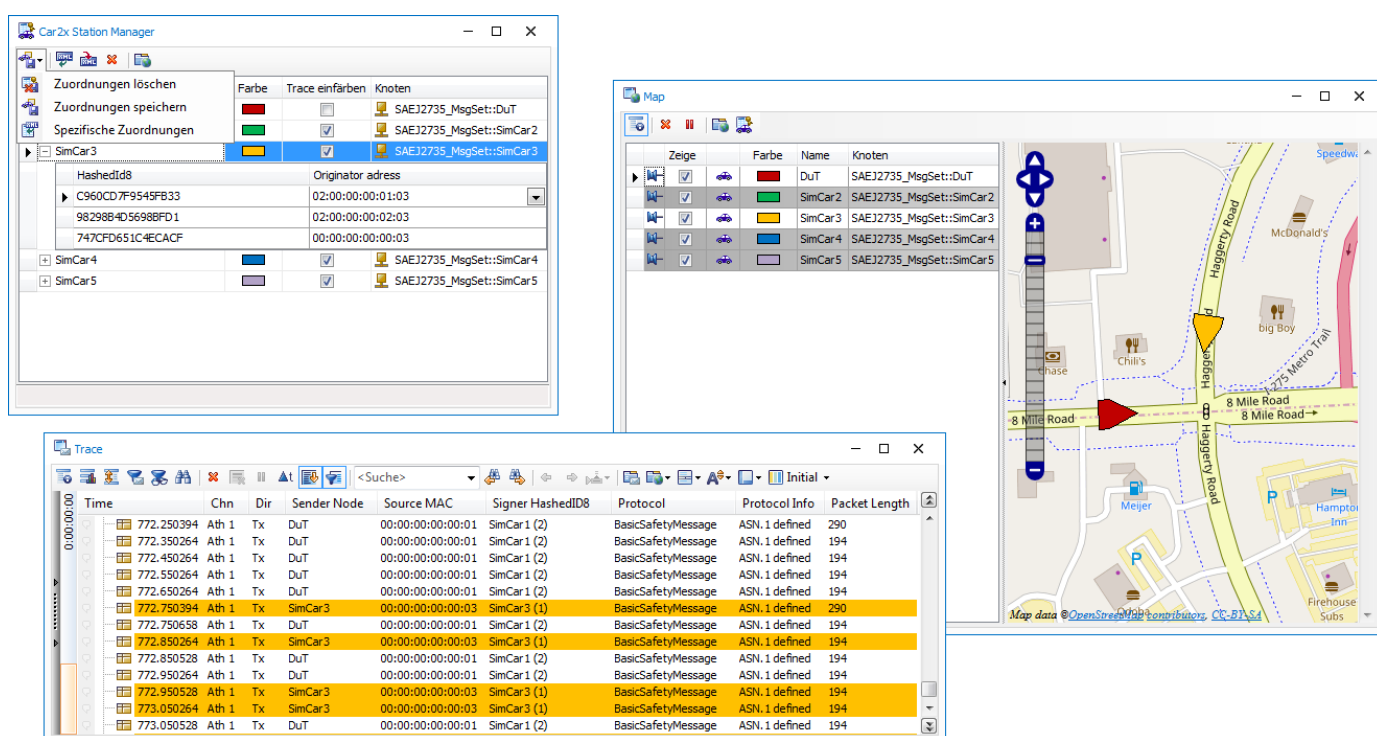> Specific handling of forwarded application messages with ETSI GeoNetworking (e.g. DENM)

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

2.3   Security Manager

The Security Manager administers the PKI (public key infrastructure), which is the basis for all security topics. The Security Manager administers all certificates (root, pseudonym cert etc.) required for validation.

> 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

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

> > Marking of certificates as trustworthy (typically the root certificate)

> > Assigning names for certificates to enable easy analysis

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

> Export of certificates, for example for use in other configurations

> Signing packets in the sending direction

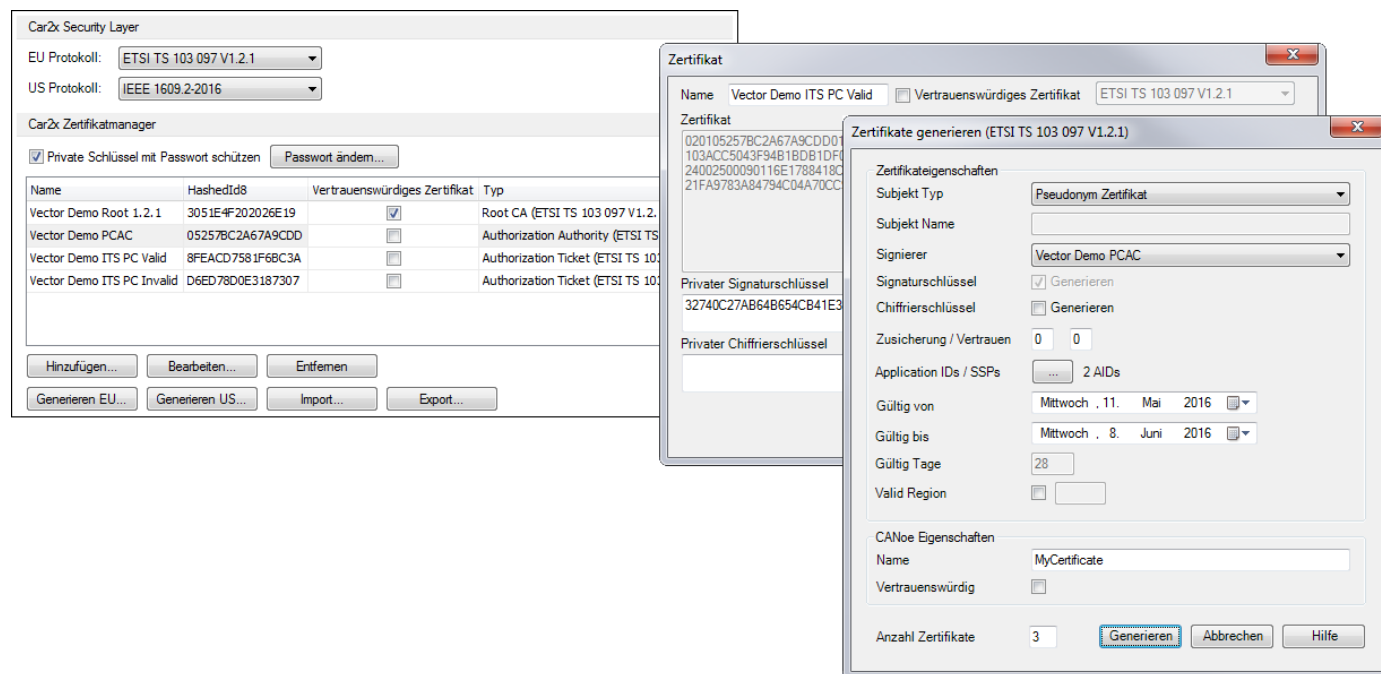> Function for creating certificates based on saved certificates

Figure 5: Provision of certificates and private keys and generating test certificates in the Car2x certificate manager

2.4   Analysis functions

CANoe .Car2x provides domain-specific measurement windows for the analysis of V2X communication (ETSI and IEEE 1609). The basis for this is the Car2x database, which contains the definition and detailed description of the application messages.

2.4.1   Expansions in the Trace Window

> Interpretation and presentation of detailed protocol header information

> Decoding of application messages (raw data **and** interpretation of the values) defined in ASN.1

> 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)

> Protocol analyzer: Basic protocol tests and validity test of signed packets (secured packets)

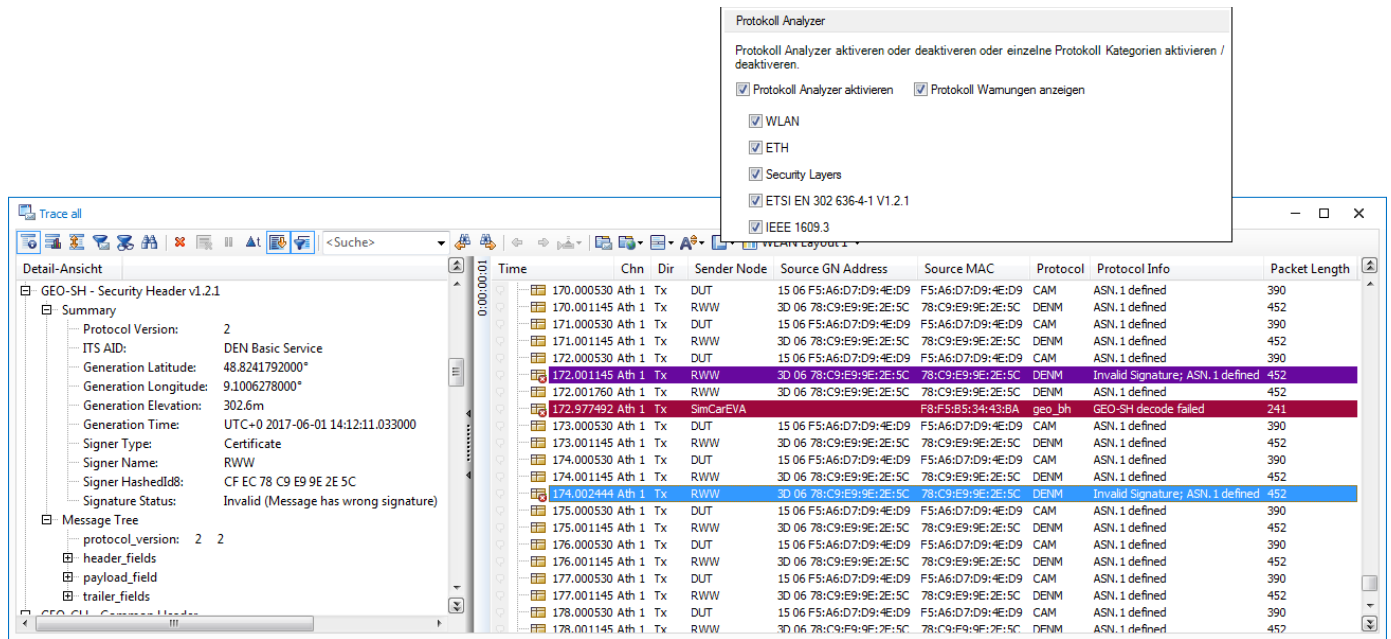> Configurable color marking of application messages, protocols and errors

Figure 6: The Trace Window displays packets with protocol errors and invalid signatures, among other things. The individual protocol fields are interpreted and other information (e.g. on errors and warnings to be detected) is output in the detail view.

2.4.2 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.

2.4.3 Map Window

In the Map Window, the display of multiple Car2x objects, like ITS vehicle stations and ITS roadside stations, on map material including synchronization with other windows for subsequent analysis is possible.
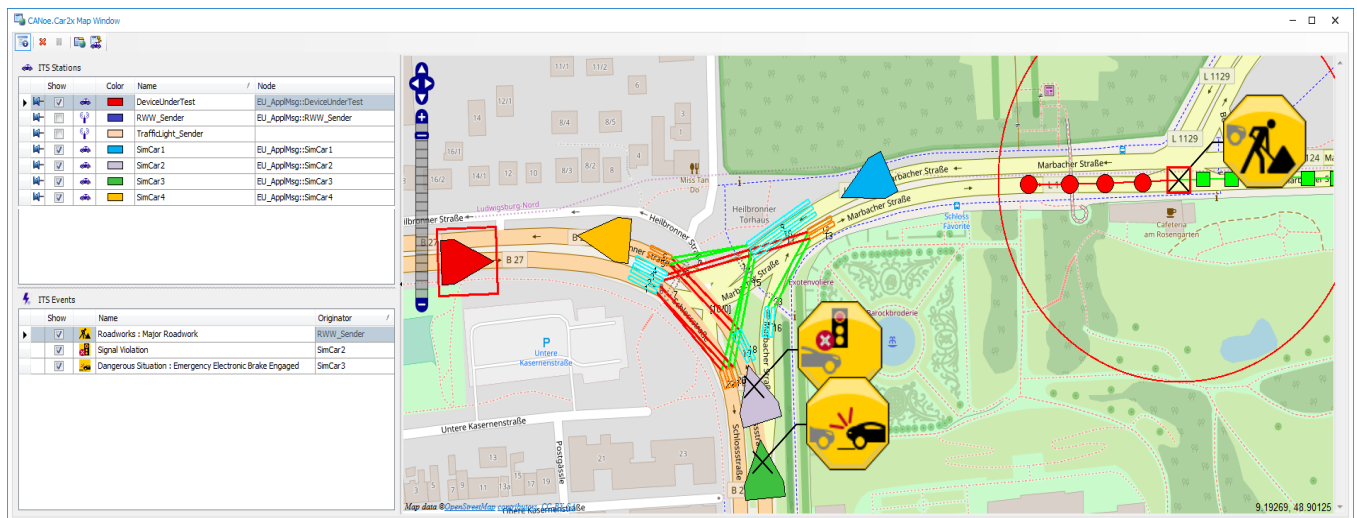

Figure 7: The Map Window automatically displays the ITS stations and events of the DENM and BSM. Additional individual information can be displayed using the CAPL MAP API. The window also shows the visualization of SPaT and MAP messages here.

> Automatic display of ITS stations and events

> Listing of detected stations and events in the "ITS stations" and "ITS events" list views

> 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.

2.4.4 Car2x Certificate Explorer

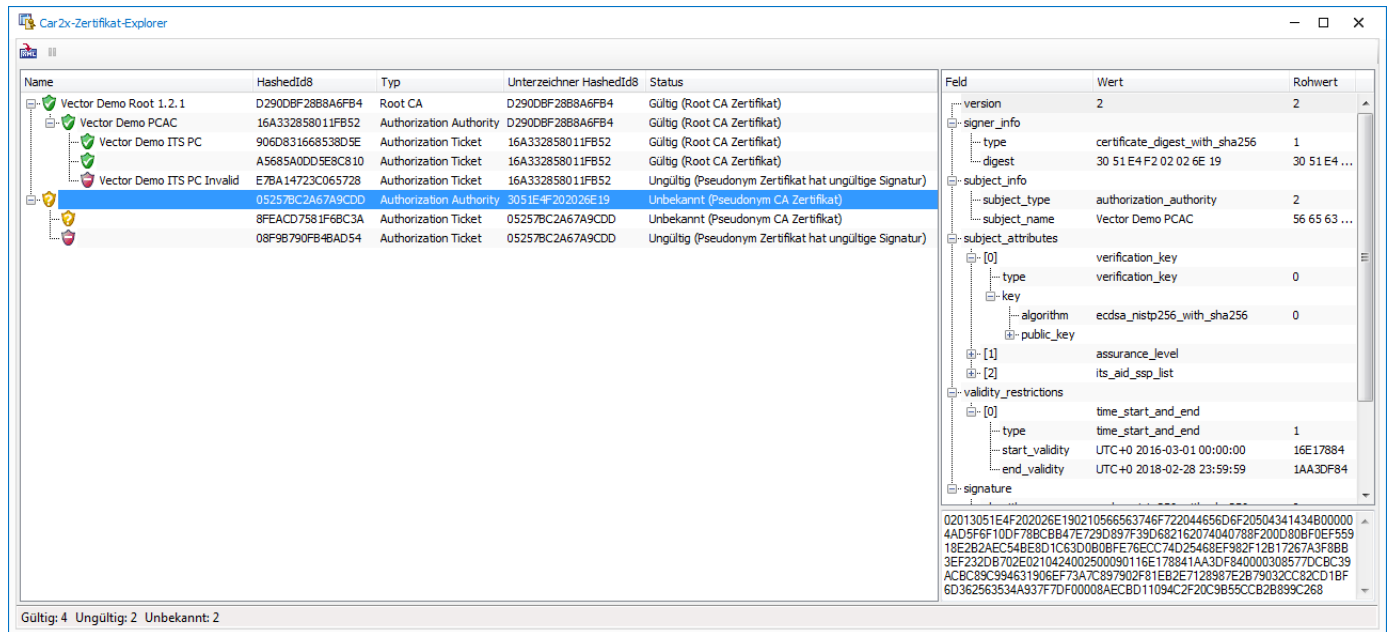The option .Car2x enables you to analyze and test the security mechanisms.

Figure 8: 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 or the certification path

> > Display of the signature hierarchy

> Display of the interpreted certificate contents

2.4.5 Expanded analysis with CAPL

The programming API makes it possible to access the contents of received WLAN 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

2.4.6 Logging and analysis

> If present, the GPS time of the WLAN device is displayed and logged with the WLAN packets. Measurement data from different vehicles can thus be put into their temporal context.

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

2.5 Simulation, stimulation and testing

CANoe .Car2x makes it possible to stimulate an ECU so that it can be tested. This includes environment simulation first and foremost, which ensures that an application to be tested on the ECU (DUT) is stimulated by an additional vehicle and/or a traffic light emulated by CANoe, for example. The application then sends 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.

2.5.1 V2X sending behavior – Using the Car2x interaction layer (IL)

> Car2x interaction layer (IL): cyclical sending of Car2x application messages incl. certificate selection and changing in accordance with the configuration in the Car2x database

> Programming API for sending and receiving Car2x application messages, including functions for setting the contents of the application messages and for influencing the configured sending behavior and security

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

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

> Simulations and test setups can be created in this way. The functions of the programming API can also be used in test units with WLAN channels.
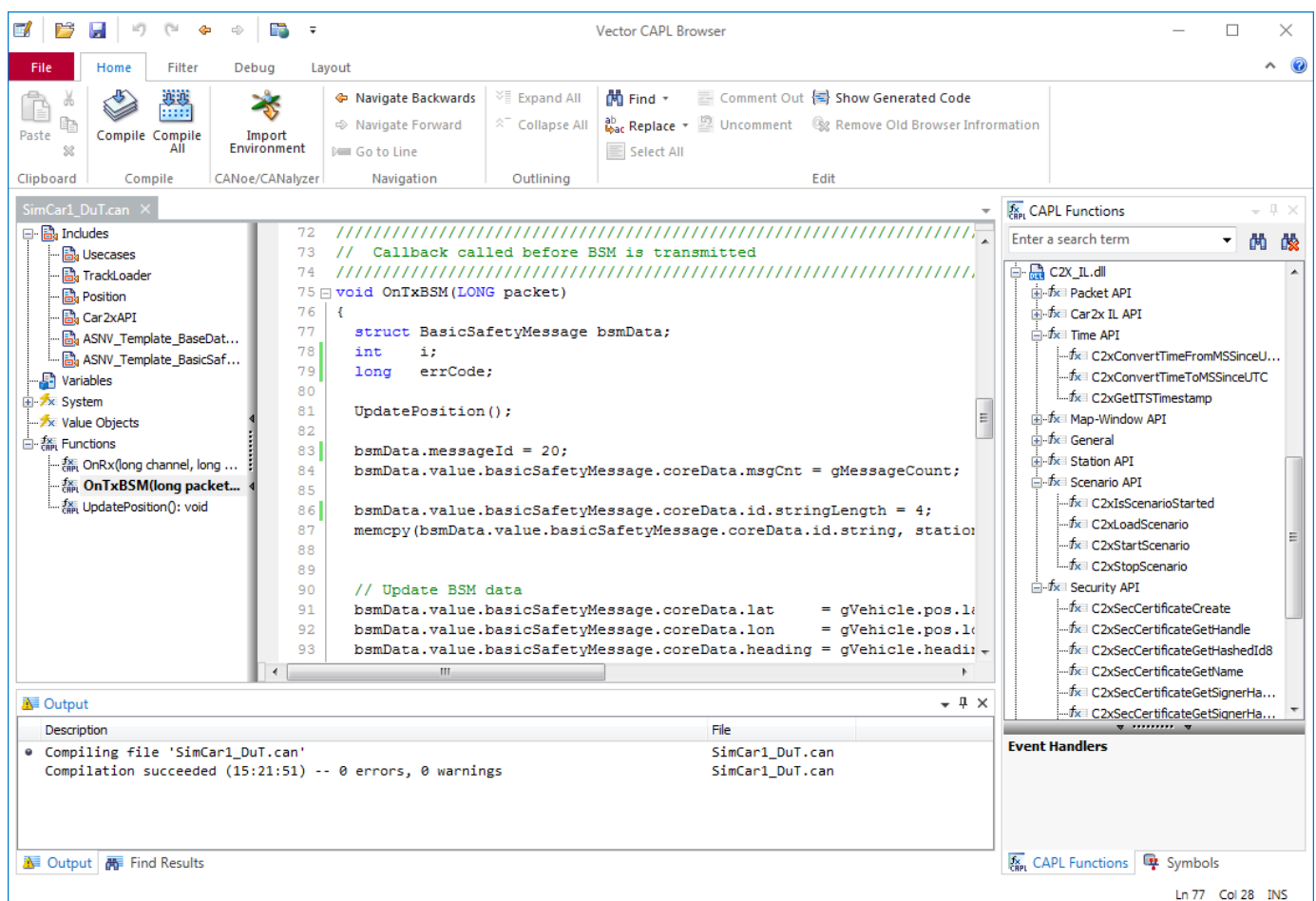

Figure 9: The CAPL browser shows the callback function for updating the data before sending an application message. Functions of the Car2x function library are displayed in the overview of CAPL functions.

2.5.2   Creating test scenarios

2.5.2.1   Car2x Scenario Editor

The Car2x 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. The Scenario Editor makes it possible to define a route, move vehicles along this route and thus simulate the particular ECU to be tested in just a few steps.
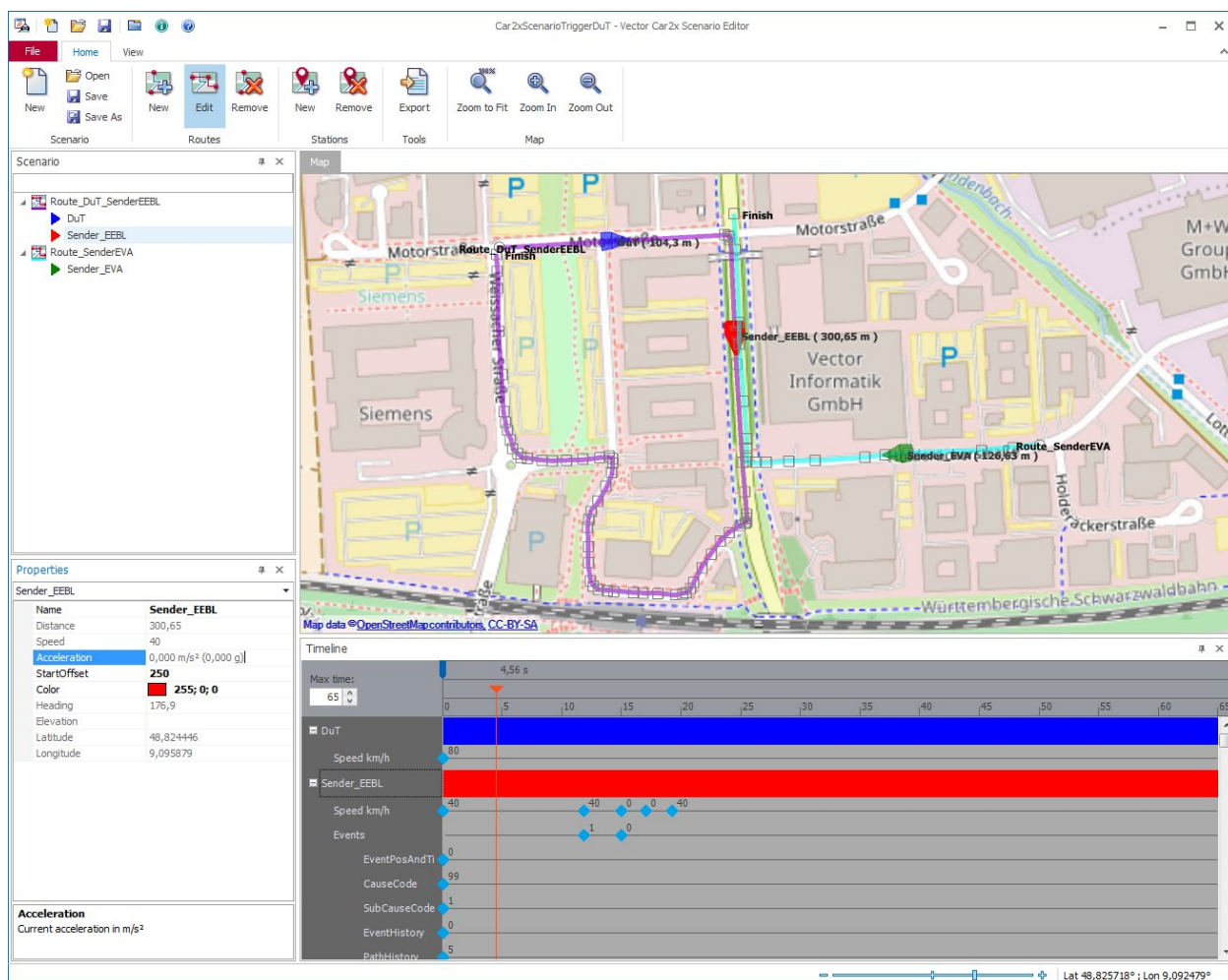

Figure 10: The Scenario Editor provides support in creating test scenarios for the ADAS test and offers specialized support for the creation of V2X-based test scenarios.

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

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. A scenario can thus be triggered manually during a test run, and the current position and direction are copied and serve as the starting point for the scenario.

2.5.2.2   Car2x Scenario Manager

The Scenario Manager ensures that the scenarios created in the Scenario Editor are loaded in CANoe. The Scenario Manager makes the loaded application data available to the Car2x interaction layer (IL) so that the application data is merged with the protocol headers of the frames and so that valid communication is generated when starting the stimulation.

3   Hardware

3.1   VN4610

Starting with version 11.0 SP3, CANoe .Car2x supports the 802.11p network interface VN4610.

> Boot time of the VN4610: approx. 5 seconds

> 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 stamp for CAN and 802.11p (time stamp precision: approx. 1 μs) and with additional Vector network interfaces

> The GNSS time of the VN4610 is copied as an absolute time, whereas the time stamps are synchronized to the GNSS

Figure 11: VN4610 - 802.11p network interface

3.2   Third-party hardware

CANoe .Car2x supports the MK4 wireless adapter and MK5 from the Cohda Wireless® company. Note that only certain specific firmware versions are supported here. Contact Vector regarding the firmware versions in question.

4   Training courses

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

For additional information on individual training courses and schedules, visit **www.vector-academy.com**

VECTOR >