VECTOR >

CANoe and CANalyzer as Diagnostic Tools
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Abstract	This application gives an introduction into working with diagnostics in CANoe/CANalyzer. It presents the basic technical aspects and possibilities with the Diagnostic Feature Set, complements the help file of CANoe/CANalyzer and may be used as a tutorial.

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1.0 Overview

1.1 Introduction

Diagnostics is used to configure, maintain, support, control and extend an ECU before or after it is installed in a system, e.g. a vehicle. Diagnostics is usually performed in a request – response scheme: a tester (client) sends a request to an ECU (or even more than one ECU) and the ECU (server) responds by sending a "positive response message" containing the requested information, or a "negative response" indicating the reason for the negative response.

The purpose of this application note is to give a general introduction into working with diagnostics in the Vector tools CANoe and CANalyzer. The basic technical aspects and possibilities ("first steps") with the Diagnostic Feature Set will be presented. Examples are used to get the test engineer started with testing diagnostics in CANoe/CANalyzer.

This document is a complement to the online help in CANoe/CANalyzer and should be used as a tutorial to learn the "first steps" of the Diagnostic Feature Set. For more detailed information about the Diagnostic Feature Set, please refer to the CANoe/CANalyzer help file demo applications, both of which come with a standard CANoe/CANalyzer installation.

Note
The functionality described below refers to CANoe and CANalyzer version 10.0 (unless otherwise noted – please see the general limitations of CANalyzer in chapter 2.0). The term "CANoe/CANalyzer" stands for both applications, while the term "CANoe" describes functionality only available with CANoe.

For older program versions application notes can be requested from the Vector support (cf. chapter 10.0).

1.2 Diagnostic components

The following table lists the names of the components relevant for diagnostics in CANoe/CANalyzer, how to activate them and where to find more information.

Component	Description	Activation	More Information
Transport Protocol (TP) DLLs	Implementation of the respective Transport Protocol for CANoe simulation nodes	See chapter 2.1	Regarding CAN in folder "User Assistance | Documents": CanTP_Manual.PDF
ISO TP Observer	Displays TP information in the trace window for the CAN messages used by the ISO TP	Menu: "Configuration-> Diagnostics/ISO TP configuration", page "ISO TP Observer"	Online help: "Diagnostics/ISO TP Configuration: ISO TP Observer"
KWP 2000 Observer	Extension of the ISO TP Observer that interprets the transported data according to Keyword Protocol 2000	Like ISO TP Observer, check box "Interpretation according to KWP2000"	Online help: "Diagnostics/ISO TP Configuration: ISO TP Observer"
Diagnostics Observer	Extension of the ISO TP Observer, interpret the transported data according to the available diagnostic specification(s)	Menu: "Configuration-> Diagnostics/ISO TP configuration", corresponding network in which Diagnostic Descriptions can be loaded	Online help: "Diag. / ISO TP Obs.: Diagnostic Descriptions"
Interactive Diagnostic Console	Direct sending of requests defined in a Diagnostic Description, display of responses	By assigning a Diagnostic Description to any of the available networks (see Diagnostics interpreter above) a corresponding Diagnostic Console window is made available, and can be accessed via the "View" menu	Online help: "Diagnostic Console: Overview"
Fault Memory window	Direct access to an ECU's fault memory	By assigning Diagnostic Descriptions to any of the available networks (see Diagnostics interpreter above) a corresponding Fault Memory window is made available, and can be accessed via the "View" menu	Online help: "Fault Memory window: Overview"
Diagnostic Session Control window	Easy switching of the session state (e.g. Default, Extended, Programming),helpful especially in combination with services protected by security access	By assigning a Diagnostic Description to any of the available networks (see Diagnostics interpreter above) a corresponding Diagnostic Session Control window is made available, and can be accessed via the "View"	Online help: "Diagnostic Session Control: Overview"

Component	Description	Activation	More Information
		menu	
OBD II window	Support of on-board diagnostics	By choosing the addressing mode (11 bit Normal or 29 bit NormalFixed) at the page "OBD-II Functionality" (Menu: "Configuration-> Diagnostics/ISO TP configuration")	Online help: "Diagnostics Description Settings: OBD-II Functionality"
CAPL extensions for diagnostics	Specialized CAPL functions to access diagnostics objects specified via Diagnostic Description(s)	The extended CAPL API is available after assigning at least one Diagnostic Description to the CANoe configuration	Online help: "Diagnostics: Expanded Functions in CAPL"
CAPL Callback Interface reference implementation	Handles the communication between Diagnostic Layer and TransportProtocol Layer in CANoe	Add the include file for the respective TP into the simulation or tester node	Application Note AN-IND-1-012

1.3 "Built-in" diagnostic channel vs. TP DLL and CAPL Callback Interface

While CANalyzer only provides the "built-in" diagnostic channel for diagnostic communication, CANoe offers an additional alternative: The so-called CAPL Callback Interface (CCI) in combination with the corresponding Transport Protocol (TP) DLL. The CCI acts as a kind of interconnection between diagnostic layer and TP layer in CANoe.

The diagnostic windows (Diagnostic Console, Fault memory, Session Control and OBD-II window) are always using the built-in diagnostic channel. Test Modules and Test Units are able to use both ways alternatively. While CANoe versions up to 9.0 SPx mandatorily need the CCI for simulating ECU diagnostics, CANoe 10.0 and higher also offers the built-in diagnostic channel for simulation nodes:
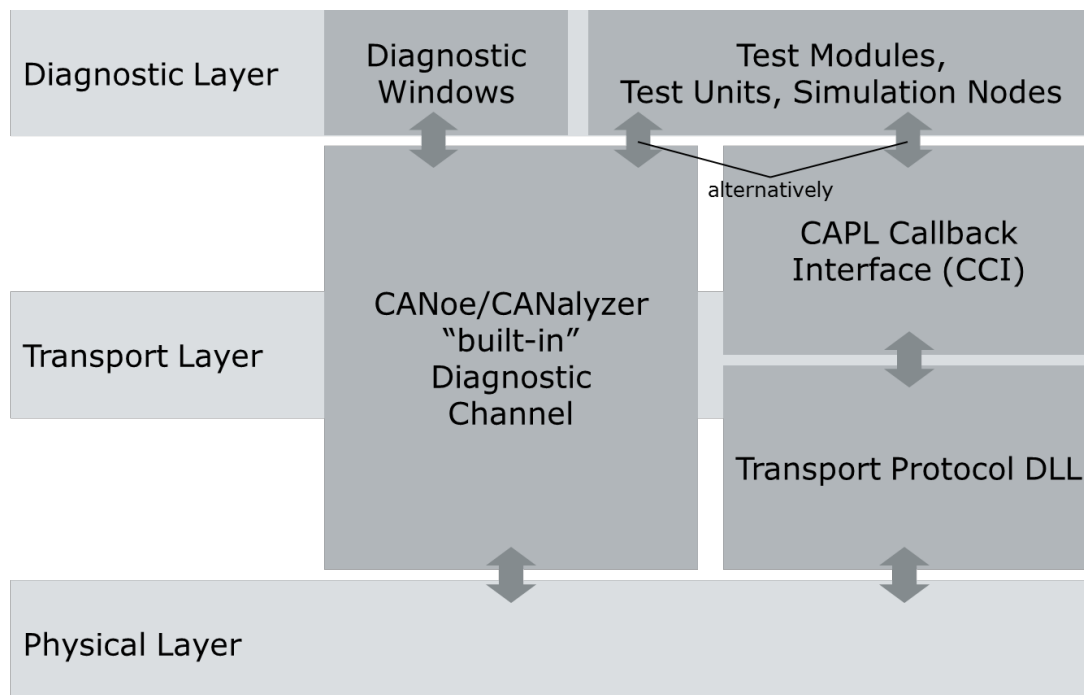
Figure 1: Layer model of CANoe

Before setting up a diagnostics configuration in CANoe, you should therefore make up your mind about the intended use cases. In the majority of cases, the built-in diagnostic channel will be sufficient. The CCI is only needed if your CANoe configuration needs to be compatible with older CANoe versions or if you intend to implement some fault injection functionality on TP layer. For more information on the CCI, refer to the application note **AN-IND-1-012**.

2.0 Diagnostics in CANoe and CANalyzer

CANoe and CANalyzer can be used in all steps of developing ECUs and performing diagnostics on them. The following table summarizes the main use cases, the corresponding diagnostic features and the differences between CANoe and CANalyzer:

Use case	Feature	CANalyzer	CANoe
Analysis of real ECU communication	ISO TP, KWP2000 and Diagnostics Observer	✓	✓
Perform diagnostics with ECUs using integrated tester functionality	Diagnostic Console	✓	✓
Error search	Fault Memory window	✓	✓
Security access and session control	Session Control window	✓	✓
On-board diagnostics	OBD II window	✓	✓
Design of the diagnostic functionality	System / remaining bus simulation		✓
Implementation of diagnostic functionality in a simulated ECU	TP DLLs, ECU simulation and CAPL extensions		✓
Specification-/Integration-/Regression tests including fault injection on TP level	TP DLLs (only necessary if TP fault injection requested), CAPL extensions, Test Feature Set (TFS)		✓

2.1 Transport Protocol support

CANoe/CANalyzer supports several automotive protocols. For most of them, a node layer Transport Protocol (TP) DLL and a corresponding CCI reference implementation exists in CANoe:

Network	Protocol	Interpretation	TP DLL (Node layer)	CCI reference implementation
CAN	ISO/DIS 15765-2 DoCAN (OSEK TP)	ISO TP observer	osek_tp.dll	CCI_CanTP.cin
LIN	ISO 17987-2 (LIN TP)	(with option LIN)	LINtp.dll	CCI_LINTP.cin
K-Line	ISO 14230-2 DoK-Line	K-Line observer	- (not necessary)	CCI_KLine.cin (+KLine_Utilities.cin)
FlexRay	ISO 10681-2 Transport Protocol STD Version 2.2 2008-11-28	FlexRay TP observer (with option Flexray)	FlexRayTPISO.DLL	CCI_FrISOTP.cin (+CCI_FrCommon.cin)
	AUTOSAR Transport Layer V2.1.1 R2.1 Rev 0014	FlexRay TP observer (with option Flexray)	AutosarFlexRayTP3.dll	CCI_FrAsrTP.cin (+CCI_FrCommon.cin)

Ethernet	ISO 13400-2 DoIP (on UDP + TCP)	DoIP Packet Events observer	DoIP.DLL	CCI_DoIP.cin
	HSFZ (on UDP + TCP)	HSFZ message observer	DoIP.DLL	CCI_DoIP.cin
	SoAd (on TCP)	(with option Ethernet)	DoIP.DLL	-

The interpretation is typically performed by the TP observer for the respective network. The TP observer interprets messages sent over the network according to this TP and displays the results in the Trace window in clear text.

It also includes an implementation of the transport protocol that enables easy sending and receiving of diagnostic objects. This implementation is realized by a node layer DLL that comes with every CANoe standard installation and takes care of transport protocol specific functions such as segmentation, flow control etc. For further explanation on CAN TP and the corresponding osek_tp.dll, refer to [1].

To enable transport layer interpretation it is needed to activate the ISO TP Observer. Please refer to the online help in CANoe/CANalyzer on how to activate the observer.

To enable the TP functionality for a simulated node, please refer to paragraph 4.2.

2.2 Diagnostic Descriptions

To work on diagnostics layer in CANoe/CANalyzer, Diagnostic Descriptions have to be assigned to the configuration. Simple diagnostic descriptions can be defined using CANoe/CANalyzer's Basic Diagnostic Editor. If you want to take advantage of the Fault Memory or the Session Control window, Diagnostic Descriptions in the shape of **CDD**, **ODX** (PDX) or **MDX** files are necessary. All of these types are referred to as "Diagnostic Descriptions" in this application note. It is possible to mix those file types within one CANoe/CANalyzer configuration.

2.2.1 CDD – CANdela Diagnostic Description

CANdela Diagnostic Descriptions (CDD) files are databases for diagnostic data, comparable to the .dbc-file used for CAN messages and signals. The CDD files are created in the Vector tool CANdelaStudio and can be used in CANoe/CANalyzer for symbolic access and interpretation of diagnostic services and parameters.

2.2.2 ODX – Open Diagnostic Data Exchange

ODX files (Open Diagnostic Data Exchange) also carry diagnostic data. This data can be divided into several ODX files and stored in PDX files (ODX archives). Since a single ODX file does not contain enough information for a diagnostic tester, Vector recommends to use PDX (packed ODX) files instead which contain all relevant single ODX files. The usage of PDX files is similar to the usage of CDD files.

2.2.3 MDX – Multiplex Diagnostic Data Exchange

MDX files (Multiplex Diagnostic Exchange) is an OEM-specific format carrying diagnostic data as well. The usage of MDX files is similar to the usage of ODX archive files.

2.2.4 Basic Diagnostic Description (UDS or KWP)

Basic Diagnostic Descriptions are created using CANoe/CANalyzer's Basic Diagnostic Editor and therefore can be customized by the user. They are stored as part of the CANoe/CANalyzer configuration, can be exported and then imported into another CANoe/CANalyzer configuration. Compared to the above Diagnostic Description formats, they only have limited functionality: since Basic Diagnostic Descriptions do not contain a fault memory model and also no session model, the Fault Memory and the Session Control Window is not available when using them. Physical network requests (chapter 2.5.10), variants, different languages, target groups and security access using a Seed&Key DLL are also not available. However, it is possible to describe simple diagnostic services (UDS & KWP) and afterwards send/receive the defined requests/responses on CAN, LIN, FlexRay, K-

Line and via DoIP using the Diagnostic Console, CAPL, CAPL test modules/ test case libraries and test units. Additionally, CANoe/CANalyzer supports symbolic interpretation of the Basic Diagnostics services and their parameters in the Trace window. Basic Diagnostic Descriptions can also be used as "additional descriptions", see chapter 2.3.

For simple applications, Basic Diagnostics thus represents an extension to the process-oriented approach with CANdela Diagnostic Descriptions.

In order to use Basic Diagnostics, you need to add a "Basic Diagnostic Description" (KWP or UDS) to the CANoe/CANalyzer configuration using the "Diagnostics/ISO TP…" configuration dialog. While measurement is stopped, you can define/modify the diagnostic services in the Basic Diagnostics Editor and commit them to the Diagnostic Console. Saving the CANoe/CANalyzer configuration also commits these changes.

On the same network, you are able to work with ECUs configured using Diagnostic Description files as well as with multiple Basic Diagnostic Descriptions at the same time. The TP parameters of these control units must be different though.

2.2.5   Standard Diagnostic Description

A Standard Diagnostic Description only contains services defined in the ISO standards "Unified Diagnostic Services" (UDS, ISO 14229) or "Keyword Protocol 2000" (KWP2000, ISO 14230). It is based on the CDD format, does not contain any OEM-specific services and cannot be customized. Parameter values can only be chosen based on those defined in the respective standard.

UDS and KWP2000 are standard diagnostic protocols used by many OEMs. Please note that most manufacturers use diagnostics specifications that differ from these standards!

Three "Generic CDDs" are provided. They describe diagnostics on the level of the standards. This has the following advantages:

> All mechanisms implemented for concrete Diagnostic Descriptions can be applied for the standard CDDs, though certain restrictions apply, e.g. the parameter definitions cannot be as precise as for concrete Diagnostic Descriptions.
> It is possible to set the communication parameters in the configuration dialog, removing the need to enter them in a database or code them into a CAPL program.
> The Diagnostic Console can be used to get fast access to ECUs.
> The interpretation of the transmitted data can also be parameterized with the Diagnostic Description(s).

You can also look at the standard definitions by opening the generic CDDs [2] with the CANdelaStudio Viewer application provided with CANoe/CANalyzer.

Note
The below mentioned features can only be used after including a Diagnostic Description into the CANoe/CANalyzer configuration.

2.3   Additional Descriptions

Diagnostic Descriptions are sometimes provided by an OEM to his suppliers and the supplier either is not allowed to or does not want to modify it since this file is the reference for testing. However, especially during development, it is helpful to be able to use services which are not defined in the original ("Master-") Diagnostic Description.

For such cases, it is possible to add so-called "Additional Descriptions" to a "Master" Diagnostic Description. Each "Additional Description" will take over the communication parameters from its "Master" Description and provide a dedicated Diagnostic Console, in case of CDD, PDX or MDX descriptions additionally a Fault Memory Window and Session Control Window. Based on the order defined in the "Diagnostics/ISO TP" configuration dialog, the Diagnostic Observer will use the Additional Descriptions to interpret diagnostic messages in the Trace Window, trying to apply the

descriptions in top-down order. The order can be changed in the "Diagnostics/ISO TP" configuration dialog via drag & drop. Also in CAPL programs, these Additional Descriptions can be used as diagnostic targets.

2.4   Trace window

A Diagnostic Description allows tracing diagnostic services (requests/responses) and their parameters in a symbolic fashion. You can expand the requests/responses in the same way as with ordinary bus messages:
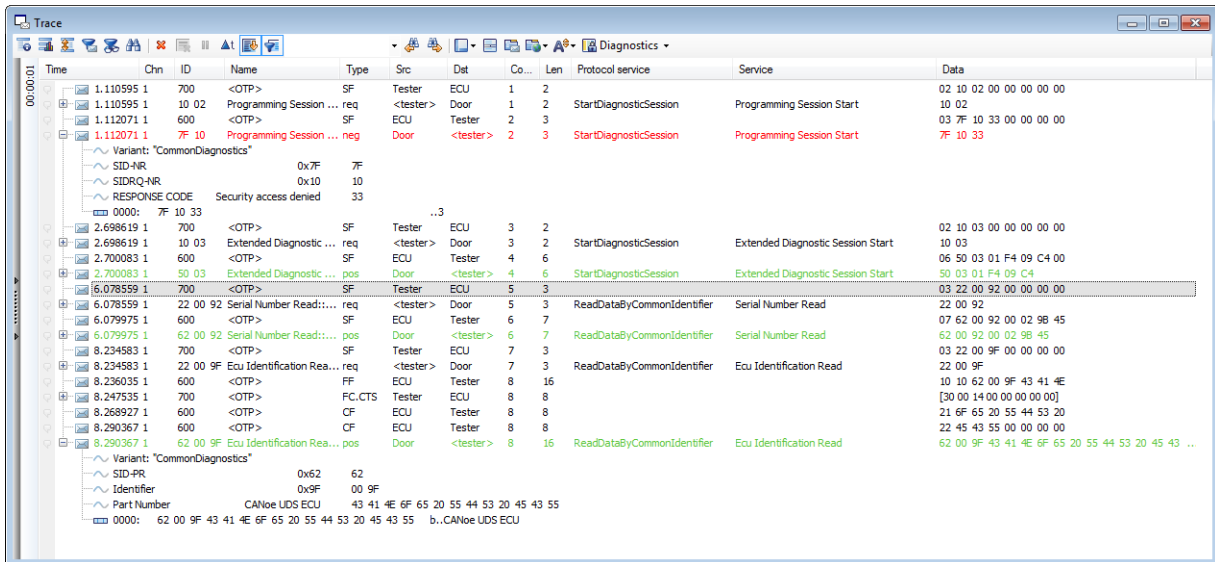
Figure 2: Trace window

Using the predefined filters of the trace window, you can reduce the amount of displayed data to the information you are interested in. You can easily e.g. filter out Tester Present messages to a specific ECU by unchecking the corresponding filter setting:
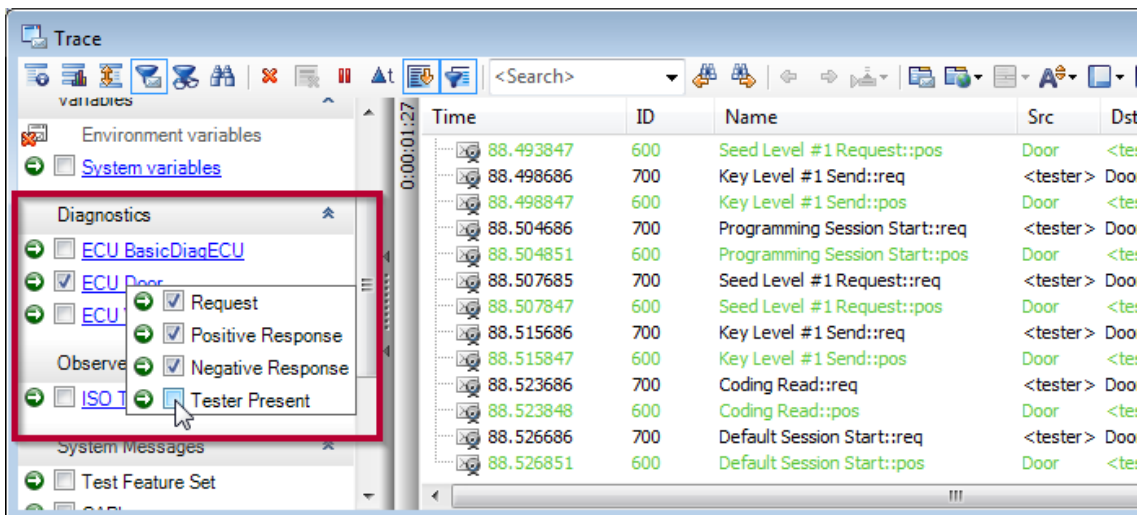
Figure 3: Predefined filters for diagnostics

Using the analysis filters and column filters of the trace window, you can either filter out a specific service (stop filter) or only keep a specific service visible in the trace (pass filter). To add such a filter, just pause the trace and configure the service by drag & drop of a diagnostic observer event to the filter on the left. By right-clicking on "Stop filter" or "Pass filter", you can also add a service from the Symbol Explorer (menu "Add condition… | Add Diagnostic Service…"). Right-clicking on an already configured service, you can modify the filter conditions (menu "Edit condition…") in order to filter only requests or only responses. Additionally, you may use the column filters to show only specific patterns in the trace:
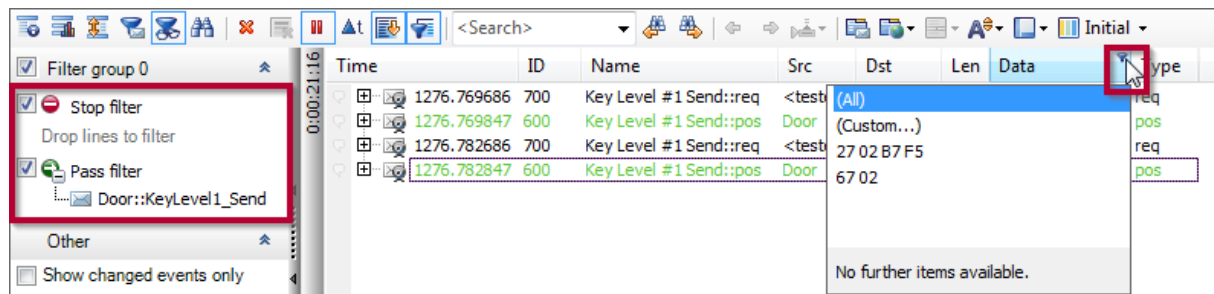
Figure 4: Using the column filters of the trace window

2.5 Diagnostic Feature Set

The Vector Diagnostic Feature Set includes several functions that are necessary for development, test and application of ECUs with/via diagnostics.

Based on the Diagnostic Description, the Diagnostic Console provides interactive access to all diagnostic services. Diagnostic requests can be selected, parameterised and displayed with their dedicated response.

The Fault Memory Console provides quick and easy access to the fault memory of an ECU.

With the Session Control window, you can easily change the active session. In combination with a configured Security DLL, restricted security levels can easily be accessed.

Finally, the OBD-II window allows you to perform On-Board Diagnostics (OBD) according to the SAE J1979 standard.

Apart from CANoe/CANalyzer the Diagnostic Features Set is also included in the Vector products CANape MC+D and CANdito. Thereby the complete development process is supported identically.

2.5.1 Interactive Diagnostic Console window

The Interactive Diagnostic Console fetches its information from the Diagnostic Description and presents an easy way to select a diagnostic request, manipulate its parameters and to send the request. The response received is presented together with its parameters.
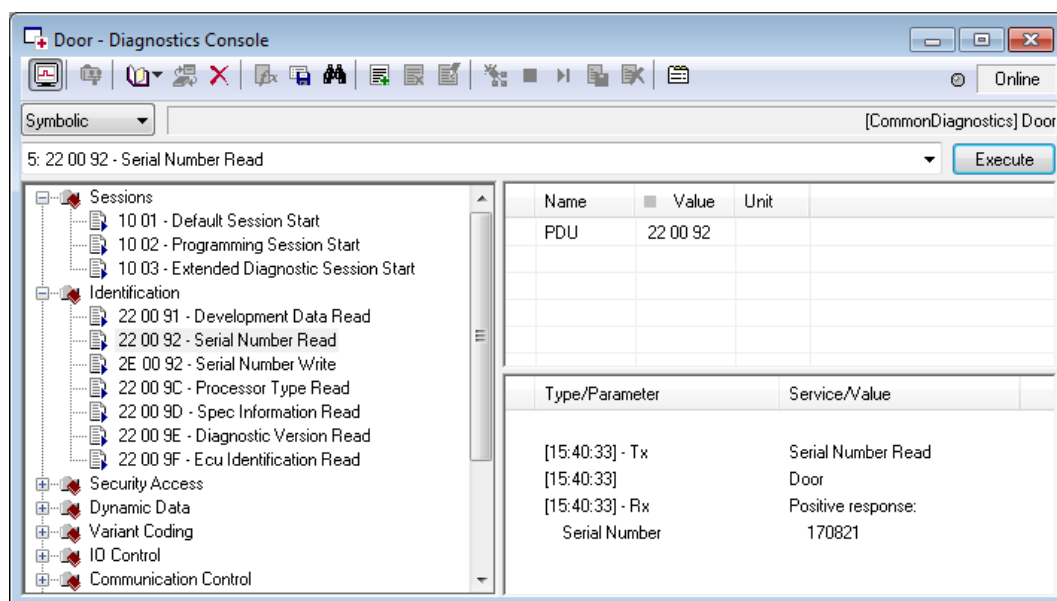
Figure 5: Interactive Diagnostic Console window

2.5.2 Fault Memory window

The Fault Memory window presents a possibility to read out the fault memory list of an ECU once or cyclically.

> **Note**
> Although with Standard Diagnostic Descriptions ("generic CDDs") and Basic Diagnostic Descriptions no Fault Memory Window is available, it is possible to access the fault memory of an ECU via the Diagnostic Console and via CAPL.
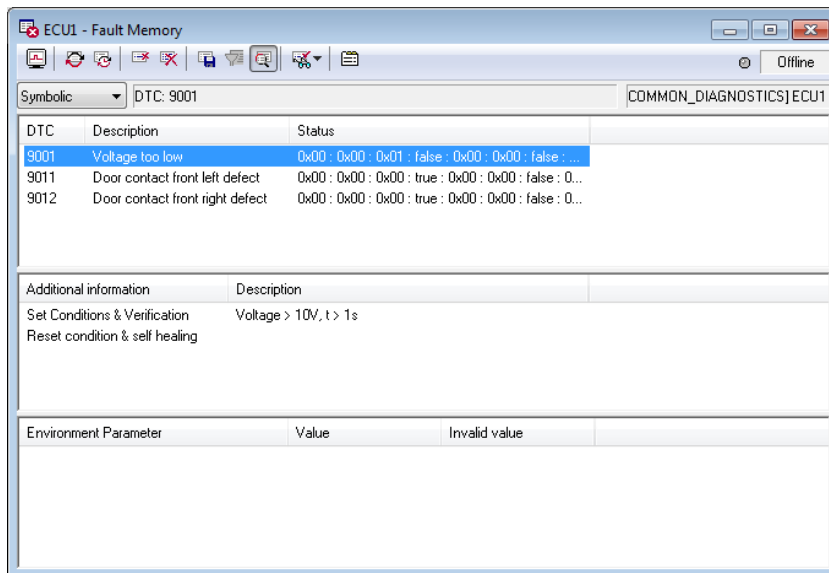
Figure 6: Fault Memory window

2.5.3 Diagnostic Session Control window

With the Diagnostic Session Control window, the user can easily switch between different session states like Default, Extended, or Programming session.

In combination with a security DLL assigned to the corresponding Diagnostic Description (see chapter 2.8 for details), it is possible to switch the session state without having to care about the computation and exchange of security keys. After switching the session state via the Diagnostic Session Control window, the user can easily execute diagnostic services from the Diagnostic Console which are only accessible within sessions protected by a certain security level.
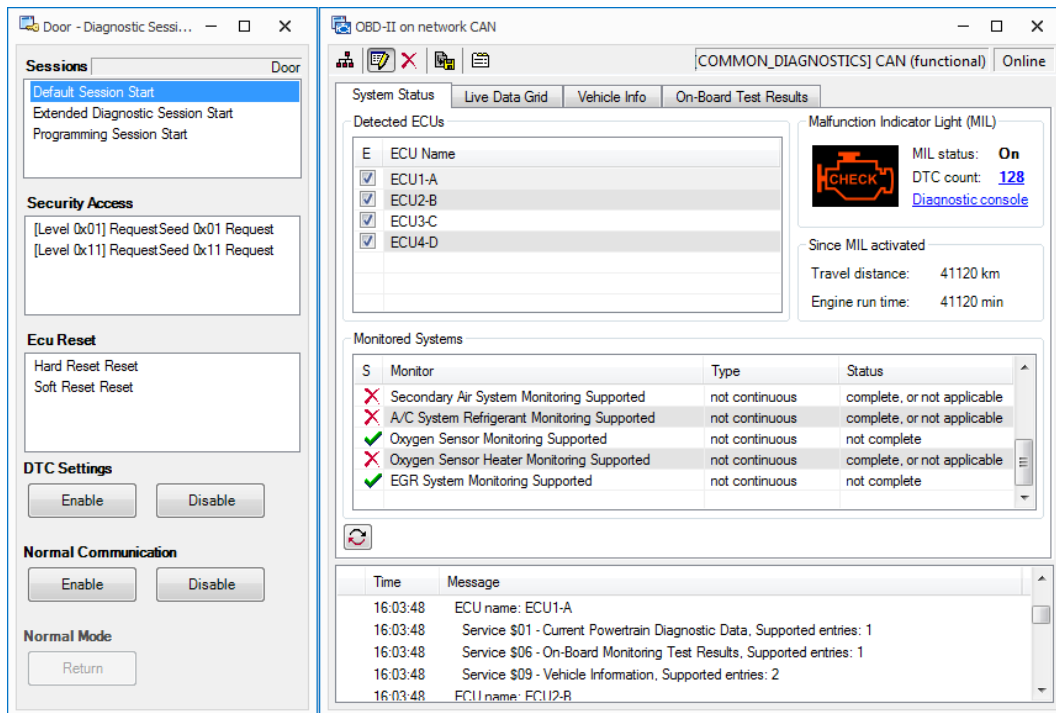
Figure 7: Diagnostic Session Control (left) and OBD-II window (right)

2.5.4 OBD-II window

On-Board Diagnostics, or OBD, in an automotive context, is a generic term referring to a vehicle's self-diagnostic and reporting capability. OBD systems give the vehicle owner or a repair technician access to state of health information for various vehicle sub-systems.

OBD implementations use a standardized fast digital communications port to provide real-time data in addition to a standardized series of diagnostic trouble codes (DTCs), which allow to rapidly identify and remedy malfunctions within the vehicle.

After configuring 11bit or 29bit Addressing in the "Diagnostics/ISO TP…" configuration dialog for a network, the OBD-II window plus the corresponding Diagnostic Console and Fault Memory window will open. Using the OBD-II window by, you can manually start a network scan, so that a request is sent to all ECUs that will answer with the corresponding responses when they are supported. Based on the responses the module calculates all available ECUs and the requests supported by them, updating the corresponding pages "System Status", "Live Data Grid", "Vehicle Info" and "On-Board Test Results". Additionally, you can send requests using the corresponding Diagnostic Console window as well as reading the OBD-II related fault memory using the Fault Memory Window for OBD-II.

2.5.5 ECU, gateway or tester simulations using CAPL

CAPL can be used to simulate an ECU, gateway or a diagnostic tester even if no real ECU, gateway or tester is present. The diagnostics commands in CAPL enable access to the diagnostics services and data using symbolic names that were defined in the Diagnostic Description. The simulation has to react on the requests or responses from its counterpart (real or simulated by CANoe) that are received and processed in appropriate event procedures. It is even possible to implement interactive tester applications where the user accesses the diagnostic functionality via a GUI (panel). Regarding gateway simulations, there is a dedicated Application Note on that topic (see chapter 9.0).

> **Note**
> CANalyzer provides only limited simulation possibilities. However, for simple use cases, it is possible to access the diagnostics services and data using symbolic names like in CANoe and use them in CAPL code.

2.5.6 Test modules using CAPL (CANoe only)

In CANoe, it is possible to implement automated tests that run without user interaction and perform a sequence of sending requests and processing of responses. The result of such a test can be written to a report file (in XML/HTML format).

2.5.7 Test Units (CANoe only)

With the Vector application vTESTstudio, you can create tests on a very high level, using many different ways of describing your tests (with Test Tables, in C++/C#/CAPL or even graphically). From such a test description, you can generate so-called test units in vTESTstudio which can be executed directly in CANoe. vTESTstudio offers several high-level commands for diagnostics, making it very easy e.g. to check the contents of the fault memory of an ECU.

2.5.8 Symbol Explorer for diagnostics objects and parameters

In order to simplify the specification of diagnostics qualifiers for requests, responses and parameters, these parameters and diagnostic objects - defined in Diagnostic Descriptions - can be inserted into CAPL code via drag & drop from the Symbol Explorer into the CAPL browser. Simply drag the object named with the diagnostics primitive, service, parameter or target qualifier and drop it at the current cursor location into the CAPL program.
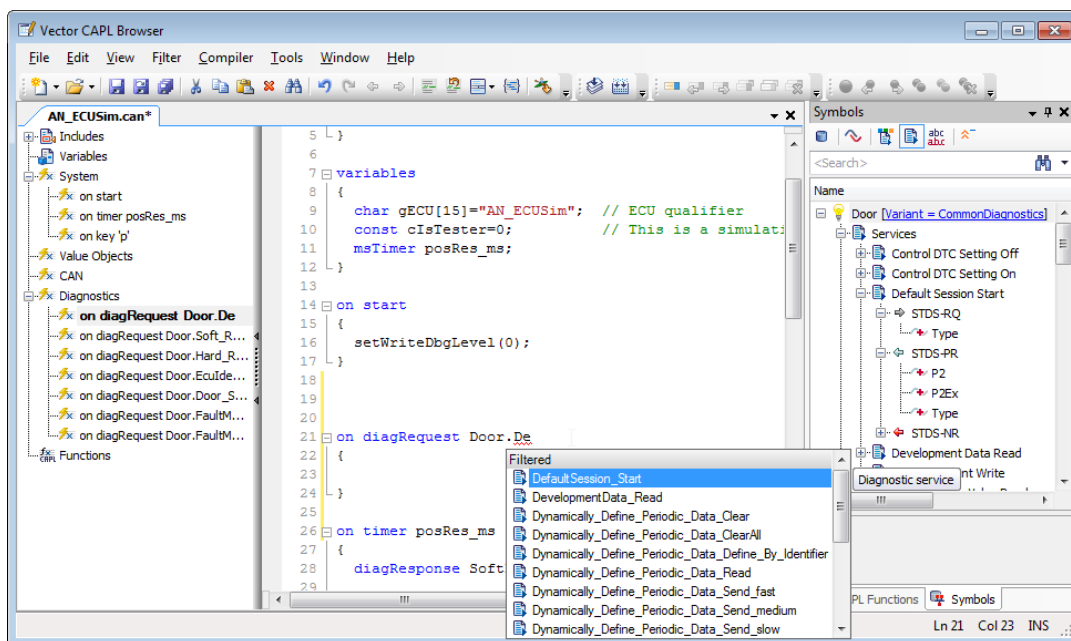
Figure 8: Autocomplete Input Assistance and symbolic selection of diagnostic objects and parameters in CAPL Browser

You can switch the display of diagnostic symbols between Diagnostic Classes and Diagnostic Services. When the "Diagnostic Classes" is chosen, the Symbol Selector will additionally show the class of a Service, its Primitives and Parameters. This is especially helpful, if an "`on diagRequest`" or "`on diagResponse`" handler shall handle multiple Requests of the same Class:

Example wildcard handler:
```
on diagRequest Door.EcuReset::*
{
  // Handle all Requests dealing with ECUReset (Hard- and Soft-Reset)
}
```

Additionally, it is possible to switch the display between the names (ODX: "LONGNAME") of the diagnostic object and its qualifier (ODX: "SHORTNAME"). Note that if several variants exist in the Diagnostic Description, the displayed content will depend on the variant chosen in the Symbol Explorer. The dialog in Figure 8 is also used to select diagnostics parameters to be displayed in data and graphics windows.

2.5.9 Autocomplete Input Assistance for diagnostics

When using the syntax with ECU Qualifier in DiagRequest/Response Objects (see chapter 4.1.1 for details), it is possible to use Autocomplete Input Assistance to get some suggestions for valid diagnostics identifiers. The Input Assistance can be opened automatically by entering text in the source code or via the key combination <Ctrl>+<Space>.

2.5.10 Physical Network Request and Network Diagnostic Description

For CAN networks, it is possible to specify within a network one Diagnostic Description as a "Network Diagnostic Description". This Diagnostic Description is then used to physically address all nodes in the same network that are selected in the PNR column, one after the other. The sent services only differ on the Identifiers, corresponding to the "Settings" of the respective ECU. For this purpose, the Diagnostic Description used as "Network Diagnostic Description" needs to be configured to have "Physical Network Requests" as its Diagnostics Tester usage. The "Network Diagnostic Description" can then be selected as target in CAPL programs, and when a request is sent, it will be sent as a physical request to each selected ECU. The responses received from the ECUs will then be processed individually in the tester, and the interpretation will be based on the concrete Diagnostic Description for each ECU.

Figure 9: Configuring Physical Network Requests

It is also possible to open the Diagnostic Console, the session control window and the fault memory window for the Network Diagnostic Description, offering a simple interface to send a request to every ECU on the CAN bus. The responses will be displayed in the console's trace window, while the DTCs reported will be listed in the fault memory window with their originating ECU. DTCs can then be deleted individually, or all fault memories can be deleted with the press of one button. This functionality is especially helpful if Functional Group Requests (see below) are not available.

2.5.11 Functional Group Requests

Similar to Physical Network Requests, selecting "Functional Group Requests" as the Diagnostic Tester usage of a Diagnostic Description, the diagnostic requests for it will be sent using the transport protocol parameters for functional requests so that all ECUs which react on this functional request will send responses. The responses received from the ECUs will be processed individually in the tester, and the interpretation will be based on the concrete Diagnostic Description for each ECU.
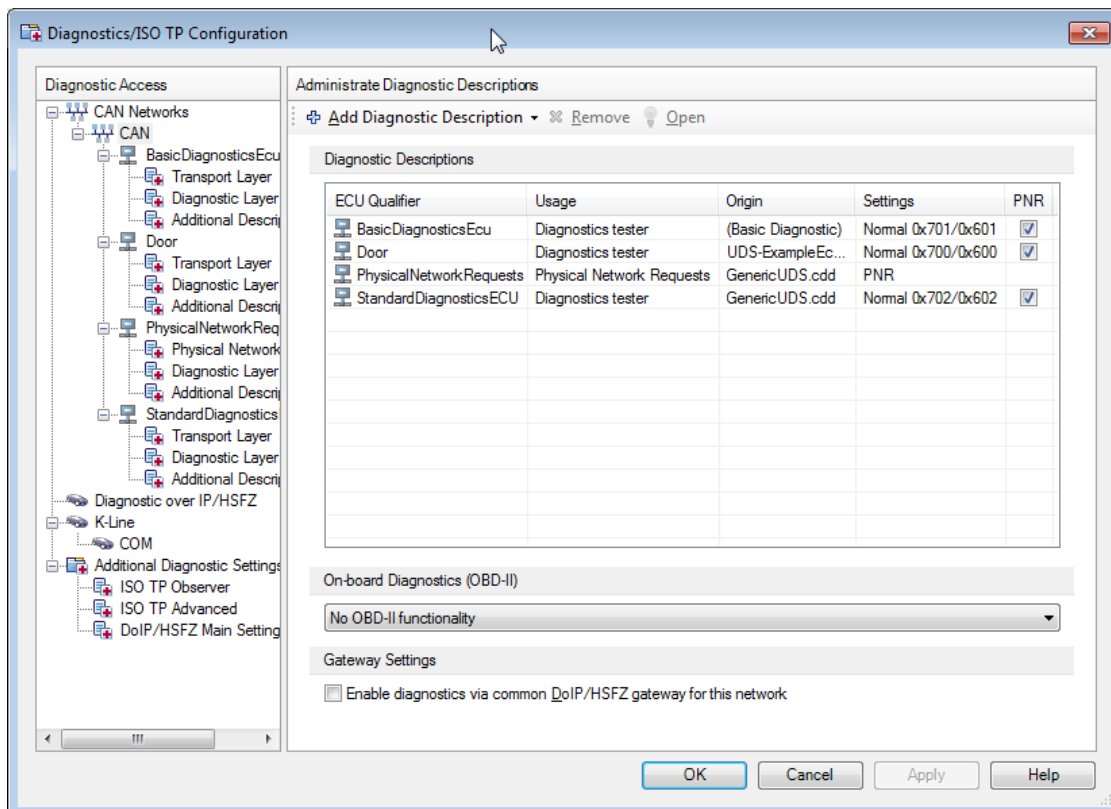
Like for Physical Network Requests, it is possible to open the Diagnostic Console and the fault memory window with a Diagnostic Description configured for Functional Group Requests. The responses will be displayed in the console's trace window, while the DTCs reported will be listed in the fault memory window with their originating ECU.

2.6 Access to diagnostics features via COM

The COM server has an additional interface that allows external application written in VisualBasic, VisualBasicScript etc. to access diagnostics features in CANoe/CANalyzer. This allows the simple implementation of special functionality, e.g. a manufacturer dependent process. More information can be found in the Technical Reference on the COM interface included in the CANoe/CANalyzer online help.

2.7 Basic Diagnostic Editor

Using the Basic Diagnostic Editor, you can describe simple diagnostic services (UDS & KWP) for control units on CAN, LIN, FlexRay, Ethernet (DoIP/HSFZ) and K-Line.

After adding a Basic Diagnostic Description to the diagnostic configuration in the "Diagnostics/ISO TP…" configuration dialog, the Basic Diagnostic Editor opens automatically for this Diagnostic Description. You can then also open the editor in CANoe/CANalyzer via the Diagnostics & XCP ribbon "Configuration | Basic Diagnostic".

If you finished editing your Basic Diagnostic Description, you either need to press the "Commit" button on the Basic Diagnostic Editor or save the CANoe/CANalyzer configuration in order to activate the editing result e.g. for usage in the Diagnostic Console window.

While the measurement is in progress, editor functions for editing Basic Diagnostic Descriptions are disabled.

2.8 Security Access handling

In order to execute locked diagnostic functions in the control unit (ECU), the tester requires a key to unlock the ECU. The key is calculated from a seed which is received from the ECU in a diagnostic response. The algorithm used to calculate the key can be implemented as a DLL (Security DLL).

Several CAPL functions encapsulate the concrete implementation of the key algorithm in the provider-dependent Security DLL. The Security DLL must be configured in the "Diagnostics / ISO TP…" configuration dialog (Path: <Network> | <Diagnostic Description> | Diagnostic Layer | Security Access | Seed & Key DLL) for each diagnostics description that shall be used with those CAPL functions:
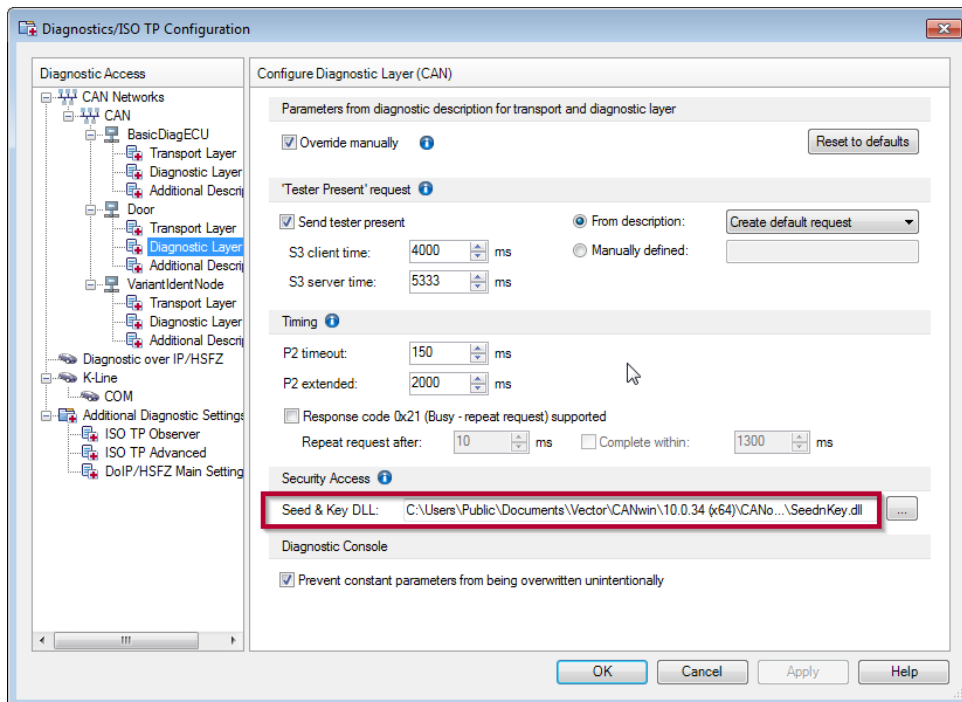
Figure 10: Configuring the Security Access

For information on requirements on the Security DLL, the corresponding CAPL functions as well as on usage in older versions, please consult the online help in CANoe/CANalyzer (search for "Seed & Key DLL / Security Access").

3.0 First steps

The diagnostic features in CANoe/CANalyzer may be used for either tracing diagnostic communication on the bus or for acting as a diagnostic tester (via the Diagnostic Console or via CAPL). Furthermore they provide capabilities for simulating the diagnostic services of an ECU in CANoe.

All these use cases demand that a Diagnostic Description (a diagnostic database) is used, and it may be necessary to use a Transport Protocol DLL (e.g. osek_tp.dll) to transfer data.

3.1 Usage of Diagnostic Descriptions

3.1.1 Add a Diagnostic Description

Diagnostic Descriptions describe the diagnostic data (services and parameters), i.e. they are diagnostic databases. Diagnostic Descriptions are added to the CANoe/CANalyzer configuration in the "Diagnostics/ISO TP Configuration…" dialog.

After adding a Diagnostic Description to the CANoe/CANalyzer configuration, there will be additional event handlers in the CAPL Browser: on diagRequest, on diagResponse and on diagRequestSent:
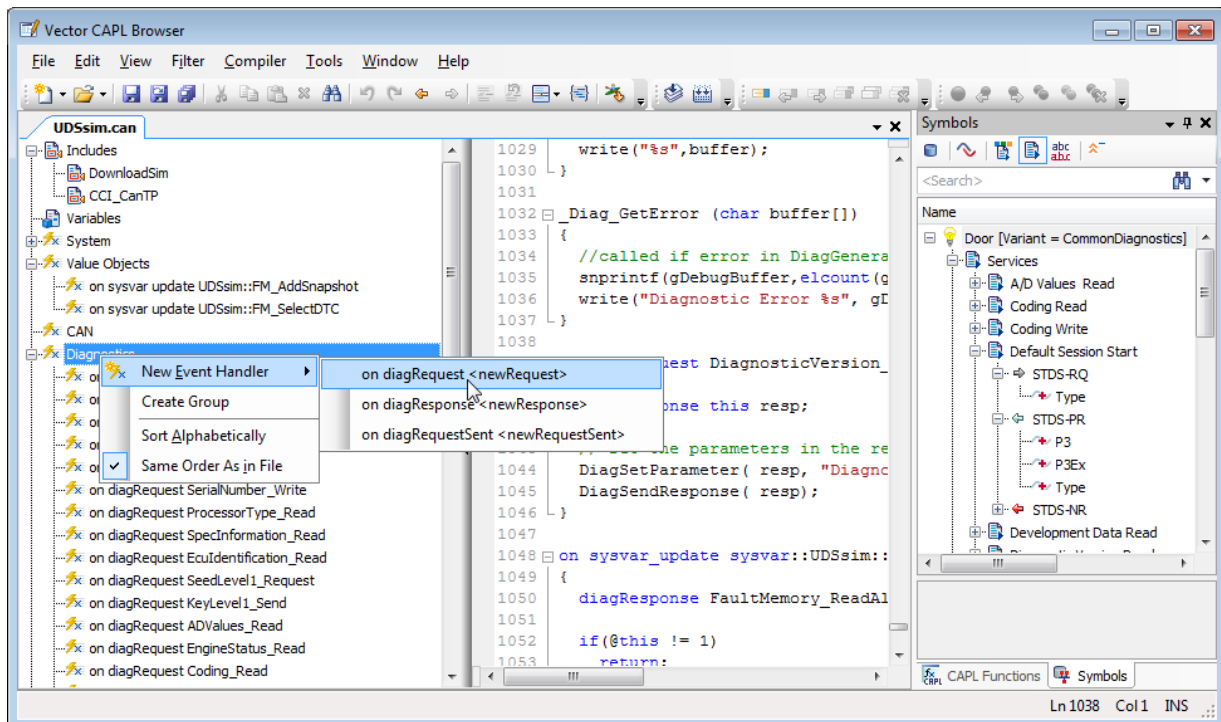
Figure 11: Adding an "on diagRequest" handler

If CANoe/CANalyzer is connected to a real vehicle with ongoing diagnostic communication it will now be possible to have symbolic interpretation in the trace window.

When a Diagnostic Description is added to the CANoe/CANalyzer configuration, the Diagnostic Console, Fault Memory and Session Control windows will appear (they can also be accessed via the View menu). This makes it possible to select a service in the Diagnostic Console, send the request, receive the response, and inspect certain parameters.

> **Note**
> For Basic Diagnostic Descriptions and Standard Diagnostic Descriptions, no Session Control Window and no Fault Memory window is available since those Diagnostic Descriptions do not contain a fault memory model and also no session model.

3.1.2 Configure the Diagnostic Description

After adding a Diagnostic Description to a network in the "Diagnostics/ISO TP" configuration dialog and selecting the Diagnostic Description or one of its sub-components (e.g. Transport Layer, Diagnostic layer), you can change the settings for this particular Diagnostic Description.

At first, especially for Basic and Standard Diagnostic Descriptions, you may change the ECU qualifier of the Diagnostic Description. The ECU qualifier is used as a unique identifier in order to reference this Diagnostic Description e.g. in a CAPL test module.

Second, you need to choose the "Interface" for this Diagnostic Description. Such a diagnostic interface contains the communication parameters for a specific network. There may be even more than one appropriate diagnostic interface for a specific network type defined in a diagnostic description (e.g. for the network type CAN: "Normal 11bit" and "Extended 29bit free" addressing). On the other hand, an appropriate diagnostic interface for the chosen network type might be missing in your diagnostic description. In such a case, CANoe/CANalyzer will generate appropriate default interfaces for this diagnostic description, indicated by the prefix "{generated}". For such a generated interface, you need to define important communication parameters like timeout values or transport protocol parameters in the "Diagnostics/ISO TP" configuration dialog manually by you own.

For Standard Diagnostic Descriptions or file based Diagnostic Descriptions like CDD, ODX/PDX or MDX, there are additional settings:

> "Variant" can be modified if the Diagnostic Description contains several different variants and determines the default variant to be used for interpretation in the trace. CANoe distinguishes between the "default" variant and the "active" variant. The "active" variant can be dynamically changed during an active measurement while the "default" variant becomes active at measurement start. This setting will determine the set of services you see in the Diagnostic Console, e.g. if the "Common" variant is chosen, the user might not find services that are only present for other variants.
> "Language" determines the language used for interpretation of the diagnostic services, provided that the Diagnostic Description contains such information.
> "Target group" additionally restricts the set of services which can be accessed by the user to those services intended for a specific user group, based on the definition in the Diagnostic Description. If it is set to "(Display all services)", there is no limitation.
> "Usage" defines how the diagnostic description is intended to be used. By default, the Diagnostic Description is used for interpretation in the trace. If you select "Diagnostics Tester", you can additionally choose how the requests should be sent by the tester (to a single ECU via physical addressing or to multiple ECUs as Physical Network Requests (CAN only) or as Functional Group Requests; the latter two possibilities require that all ECUs on the network implement the contents of the Diagnostic Description as a common subset). Selecting "Simulation by:" (only available for CANoe) will let you choose the node implementing the simulation code for this Diagnostic Description and enable the simplified simulation for it, i.e. CANoe will send positive responses for requests defined in this Diagnostic Description, as long as there are no "on diagRequest" handlers in this node covering those requests.

Selecting an interface here will determine which TP parameters are available for configuration:

> The "Interface" combo box shows the interfaces defined in the Diagnostic Description. Each interface defines an addressing mode and address parameters that are used as default. Note that the addressing mode of an interface cannot be changed – chose a different interface instead.
> For a Network Diagnostic Description, i.e. if you defined "Physical Network Requests" as its usage, no TP parameters have to be set since the TP parameters of the individual ECUs will be used.
> If the "VAG Addons packet" (version 1.10 or later) is installed, it is possible to select the interface called "VWTP 2.0 (CANoe)". You then have to enter the correct TP parameters on the page "Transport Layer (VW TP 2.0)".
> If the Diagnostic description was added to an Eth network, the corresponding parameters can be defined on the page "DoIP/HSFZ Settings" or "Socket Adaptor Settings", depending on the chosen diagnostic interface (DoIP or AUTOSAR Socket Adaptor).
> If a node from a LIN database file is selected, the corresponding parameters can be defined on the page "LIN settings".
> If a node from a FlexRay database is selected, the FlexRay TP parameters can be defined in the page "FrTP Parameter".
> Since for MOST ECUs, only interpretation of the diagnosis messages is possible, there are no dedicated MOST TP parameters for MOST nodes.

For further details of the configuration dialog please refer to the online help.

3.2 Usage of Diagnostic Console, Session Control and Fault Memory window

When you add a Diagnostic Description to your CANoe/CANalyzer configuration and choose "OK", the available Diagnostic Windows for that Diagnostic Description will automatically become visible.

> **Note**
> For Basic Diagnostic Descriptions and Standard Diagnostic Descriptions, no Session Control Window and no Fault Memory window is available since those Diagnostic Descriptions do not contain a fault memory model and also no session model.

3.2.1 Send a diagnostic request and receive a response

You can easily send a request by selecting it in the Diagnostic Console "Explorer-like" tree structure. The parameters in the request can also be selected in an easy manner by choosing a value in a drop-down menu or writing a value (e.g. a part number of an ECU). The response will be presented accordingly in this window.

If you do not have a real ECU with implemented diagnostics, you may create a simulated node in CANoe and implement relevant functionality in CAPL (please see paragraph 4.2).

3.2.2 Read fault memory

With the Fault Memory Window you can easily read out the fault memory of an ECU. Depending on the Diagnostic Description, a KWP2000 standard request ($18 02) or a UDS request ($19 02) is used to read out the trouble codes. Additionally, the services specified in the Diagnostic Description can be used if the manufacturer scheme can be recognized by CANoe/CANalyzer (via the qualifier paths). It is also possible to specify the requests explicitly.

3.2.3 Physical Network Requests and Functional Group Requests

It is also possible to send physical requests to all ECUs defined on a network (CAN only) or Functional Group Requests from the Diagnostic Console and the Fault Memory Window. If a Diagnostic Description is configured to be a "network description", i.e. if you defined "Physical Network Requests" as its tester usage in the configuration dialog, both windows will open for that Diagnostic Description. In analogy to the "Physical Network Requests", you are able to configure "Functional Group Requests" as the tester usage of a Diagnostic Description; this will result in sending a functional request ("broadcast") to all ECUs defined on a network.

3.2.4 Change the session and security level

With the Session Control window, both switching the session and the security level is possible. In order to be able to use this functionality, you need a diagnostic description which contains the available sessions and the allowed transitions between them (the "session model"). For switching the security level, you additionally need to add a Security DLL (sometimes referred to as "Seed & Key DLL") to the diagnostics configuration (see chapter 2.8 for details). To change the session or the security level, simply double-click on the session or security level in the Session Control window. In case of switching the security level, CANoe/CANalyzer will request the Seed from the ECU, use the configured Security DLL to compute the key and send the key to the ECU in order to unlock it.

3.3 Display diagnostic data

An important use case is to display data contained in diagnostic requests or responses, e.g. the value of an ECU's voltage signal. As a precondition to display this data, the request or response with this signal value must be received by CANoe/CANalyzer (or generated in case of a CANoe simulation). In case of a response parameter, this typically implies that the corresponding diagnostic request has to be sent cyclically. This can be done creating a user-defined message with a specified cycle time in the Diagnostic Console Window or by using a timer in CAPL. The following example defines a timer which sends the diagnostic request "DID_Voltage_Read" to the ECU "Door".

Example cyclic diagnostic request:

```
Variables
{
  mstimer tVoltageRead;
}

on start
{
```

```
        setTimerCyclic(tVoltageRead, 500);
}

on timer tVoltageRead
{
  diagRequest Door.DID_Voltage_Read req;

  diagSendRequest(req);
}
```

3.3.1 Diagnostic data in State Tracker, Data and Graphics window

Once the diagnostic requests or responses with the parameters to be displayed are recognized and displayed in the Trace Window, you can add these diagnostic parameters to be displayed in the Data or Graphics Window by Drag & Drop. The same procedure can be used to display diagnostic parameters in the State Tracker Window. In Data and Graphics Window, you alternatively can add the parameters using the Context Menu (right-click and select "Add Diagnostics Parameters…").
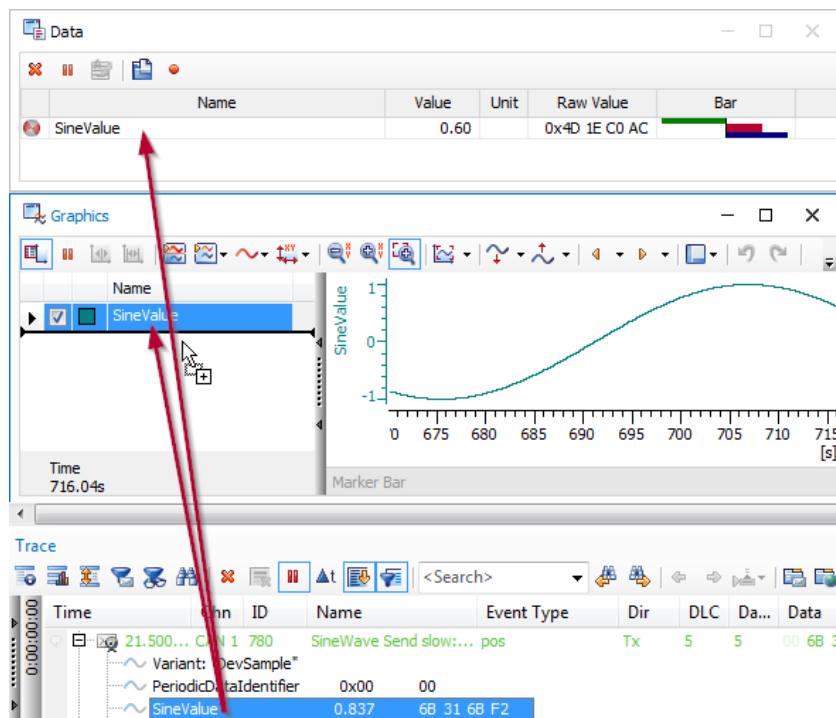
Figure 12: Choosing diagnostic parameters for display in data and graphic window using drag & drop

3.3.2 Diagnostic data in panels

In order to display parameters in a panel, you first need to add an appropriate control to the panel, e.g. an input/output box. Next, you need to attach a diagnostic parameter to this control by clicking on "Attach Diagnostic Parameter" in the Panel Editor and selecting the parameter using the symbol selector:
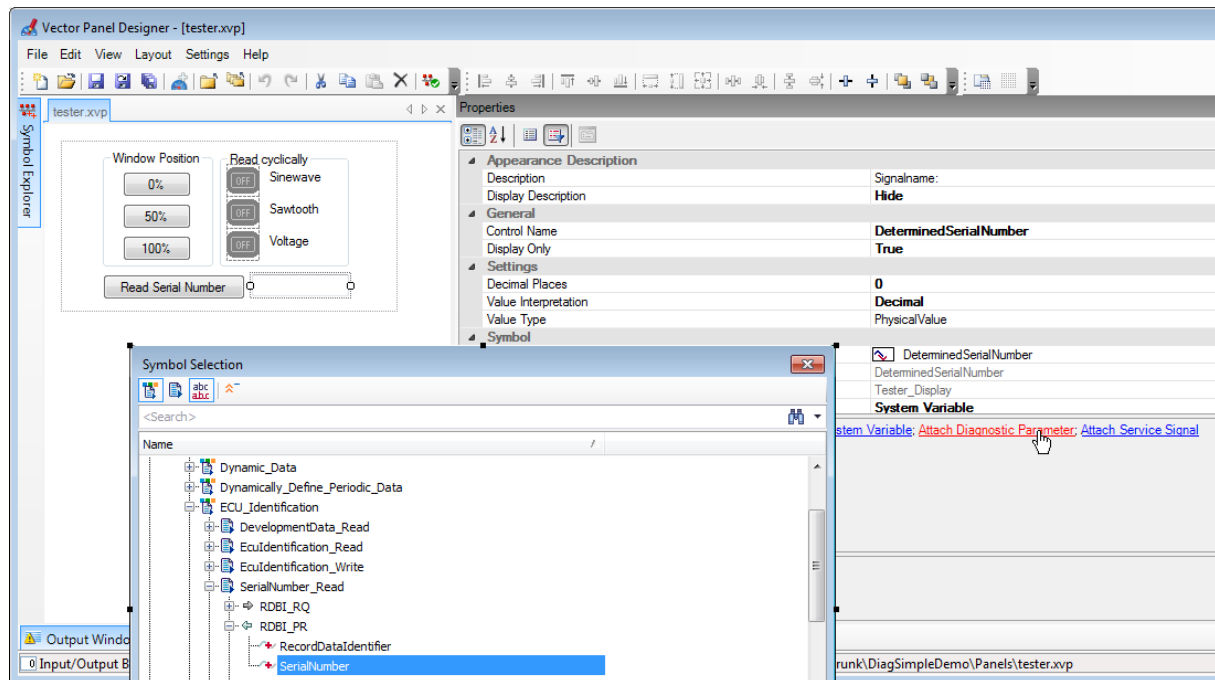
Figure 13: Attaching a diagnostic parameter to a panel control

Depending on the desired data format and the used control, it might be necessary to convert the diagnostic parameter value into a system variable in a "on diagResponse" CAPL handler and attach this system variable to the control instead.

4.0 Using CAPL for Diagnostics

4.1 Common techniques for Simulation and Tester

4.1.1   Usage of the CAPL Browser

Three additional event handlers are present after adding a Diagnostic Description to the CANoe/CANalyzer configuration: "on diagRequest", "on diagResponse" and "on diagRequestSent", see Figure 14.
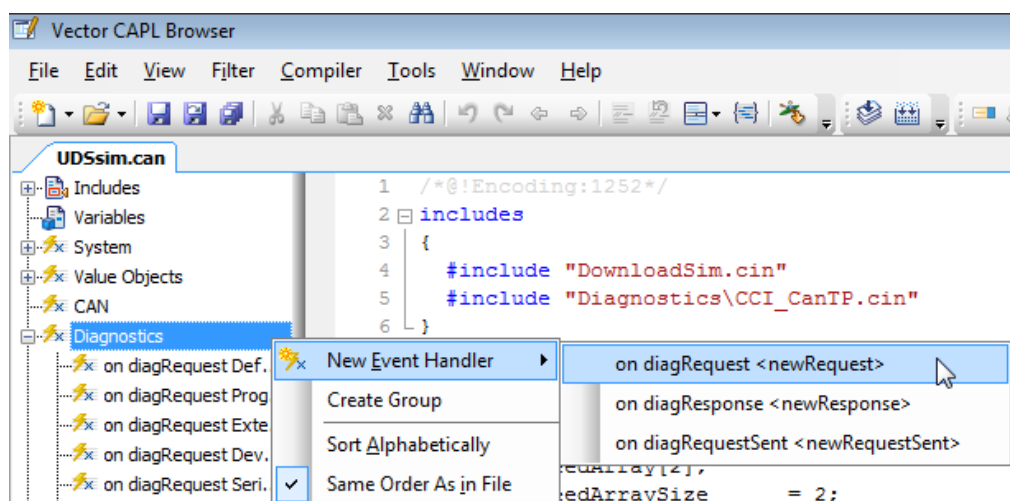
Figure 14: Diagnostics Event Handlers

The actual request and response objects as well as their event handlers are accessed through their service qualifier as described in the Diagnostic Description. There are two alternative ways to declare diagnostic objects and event handlers, the deprecated syntax and the syntax with ECU Qualifier in DiagRequest/Response Objects ("new syntax").

Example (deprecated syntax):
```
// Request object
diagRequest StartSession request;
```

Example (new syntax):
```
diagRequest Door.StartSession request;
```

Both code snippets initialize the object/variable "request" using the service qualifier "StartSession" as a request to start the default diagnostic session. Using the deprecated syntax, you need to make sure to call diagSetTarget("Door"); or diagInitEcuSimulation("Door"); before using this object (see chapter 4.3.1). On the other hand, these functions will have no effect on objects declared using the new syntax.

> **Note**
> Mixing both, the deprecated and the new syntax is not recommended by Vector.

> **Note**
> In older CANoe/CANalyzer versions, requests and responses were accessed via their qualifier paths with the syntax <class>::< instance>::<service> which is still working as well. However, this kind of definition is no longer recommended by Vector.

4.1.2   Work with parameters

The parameters of a diagnostic request or response can be accessed (read and written) symbolically as they are described in the Diagnostic Description.

Diagnostic parameters are divided into two groups; simple and complex parameters. The two groups have corresponding Set- and Get- functions. Simple parameters are parameters that have fixed offsets in the diagnostic object. Complex parameters are parameters that have varying offsets since they are contained within container parameters, e.g. a list of DTCs (Diagnostic Trouble Codes).

There are three different access modes to access a parameter – by default "physical" is used. The column "Example" in the following table contains the values returned by DiagGetParameter() for a parameter which is defined as 4 byte linear data type with IEEE Float (single) encoding and the conversion formula "phys = 1 / 100 * data":

Access mode	Explanation	Example
numerical	Access to the transmitted numerical value.	100.0
physical	Access to the value calculated from the transmitted numerical value (is also displayed symbolical as text).	1.0
coded	Immediate transformation into a numeric type (up to 32 bit), i.e. floating point values will also be provided in their internal description (bit form).	1120403456.0 (= 0x42C80000)

Below is an example of a simple parameter that has the *name* (ODX: "longname") "Voltage Terminal 15" (note the blank characters!) in the Diagnostic Description. Since the names are language dependent, the *qualifier* (ODX: "shortname") has to be used (accessible via the symbol explorer, see chapter 2.5.8) in CAPL, i.e. "Voltage_Terminal_15".

Example simple parameter:
```
on diagRequest ECU.InputOutput_Read
{
  const cNumerical=0;
  diagResponse this resp;
  // Set simple parameters in response to 0
```

```
DiagSetParameter ( resp, "Voltage_Terminal_15", 0 ); // Default: set physical value
DiagSetParameter ( resp, cNumerical, "Interior_Temperature", 0 ); // set numerical value
DiagSendResponse ( resp );
}
```

Below is an example on how to work with a complex parameter, e.g. a list of DTCs. The DTCs together with their status masks are grouped in a list called "List of DTC" in the Diagnostic Description.

First of all, some memory has to be reserved for the DTCs. The response object is created with an iteration counter of 0, i.e. indicating that no DTCs will follow. As a first step, the response object has to be enlarged, i.e. the iteration counter has to be set to the number of DTCs that should be returned. Since CANoe/CANalyzer 5.2 this will automatically reserve the requested space, i.e. it is not necessary to resize the object.
Note that sometimes no iteration counter is specified. In these cases the number of DTCs to follow would be determined by the actual length of the response; here the total length in bytes has to be specified for the resize operation.

After enough memory is available, the DTCs can be initialized step by step, i.e. the ECU simulation sets the parameter for the DTCs it wants to report to the tester.

Example complex parameter:
```
on diagRequest Door.FaultMemory_ReadAllIdentified
{
  diagResponse this resp;
  // Set the number of DTCs returned
  DiagSetParameter( resp, "NUMBER_OF_DTC", 2);
  // Create memory to hold the DTCs
  DiagResize( resp);      // Note: NOT necessary anymore since CANoe/CANalyzer 5.2!
  // Set complex parameters in response
  // Set the first DTC to a hex value
  DiagSetComplexParameter ( resp, "List_of_DTC", 0, "DTC", 0xFAFAF );
  // Set the status mask of the DTC to true
  DiagSetComplexParameter ( resp, "List_of_DTC", 0, "DtcStatusDataType.ConfirmedDTC", 1 );
  // Set next DTC
  DiagSetComplexParameter ( resp, "List_of_DTC", 1, "DTC", 0xCFCFC );
  DiagSetComplexParameter ( resp, "List_of_DTC", 1, "DtcStatusDataType.ConfirmedDTC", 1 );
  …
  DiagSendResponse ( resp );
}
```

The following example shows how to set the size of the response if the actual Diagnostic Description does not contain the parameter "NUMBER_OF_DTC". In CANoe/CANalyzer versions older than 8.5, you need to count the amount of needed data bytes this case and fill in this value directly.

Example 2 complex parameter:
```
on diagRequest Door.FaultMemory_ReadAllIdentified
{
  diagResponse this resp;
  // Set the number of DTCs returned
  DiagResize( resp, 9);  // NOT necessary anymore since CANoe/CANalyzer 8.5!
  // in this example 9 bytes are needed to transfer the response
  DiagSetComplexParameter ( resp, "List_of_DTC", 0, "DTC", 0xFAFAF );
  …
}
```

4.2 ECU diagnostics simulation

4.2.1 Necessary preparations

> **Note**
> This chapter only applies to CANoe.

> **Note**
> Since CANoe 10.0, including certain callback functions (referenced as the CAPL Callback Interface, CCI) is no longer necessary to simulate an ECU or a Diagnostic Tester in CAPL. However, if your configuration needs to run on older CANoe versions, you need to execute tests including fault injection on TP level, or you need to deal with more complex ECU simulations like e.g. diagnostics gateways between different networks, using the CCI still is necessary. Refer to the application note **AN-IND-1-012** for details.

Before you start, it makes sense to analyze the requirements regarding the diagnostics functionality of the simulated node.

For LIN and FlexRay ECUs, adding a database (*.ldf, FIBEX) is mandatory. After adding a diagnostics description, for simple diagnostic simulations it is sufficient to activate the usage "Simulation" for this Diagnostic Description and assign – in case of LIN and FlexRay – the database node of the ECU to it or – in case of the other networks – the simulation node.

If the requirements regarding the simulated functionality are more complex, e.g. if you want to perform fault injection or need to simulate gateway functionality, a CAPL Callback Interface (CCI) implementation is necessary. In case of simple ECU node, the reference implementation provided with CANoe might be sufficient, but for even more complex use cases, e.g. the implementation of a gateway, you need to customize this CCI to your needs. If you are using a CCI implementation, you need to make sure that the corresponding transport protocol nodelayer DLL (TP DLL) is configured as component to your simulation node. This already might have happened automatically by adding the database, otherwise you need to add it manually. The following picture illustrates the workflow.
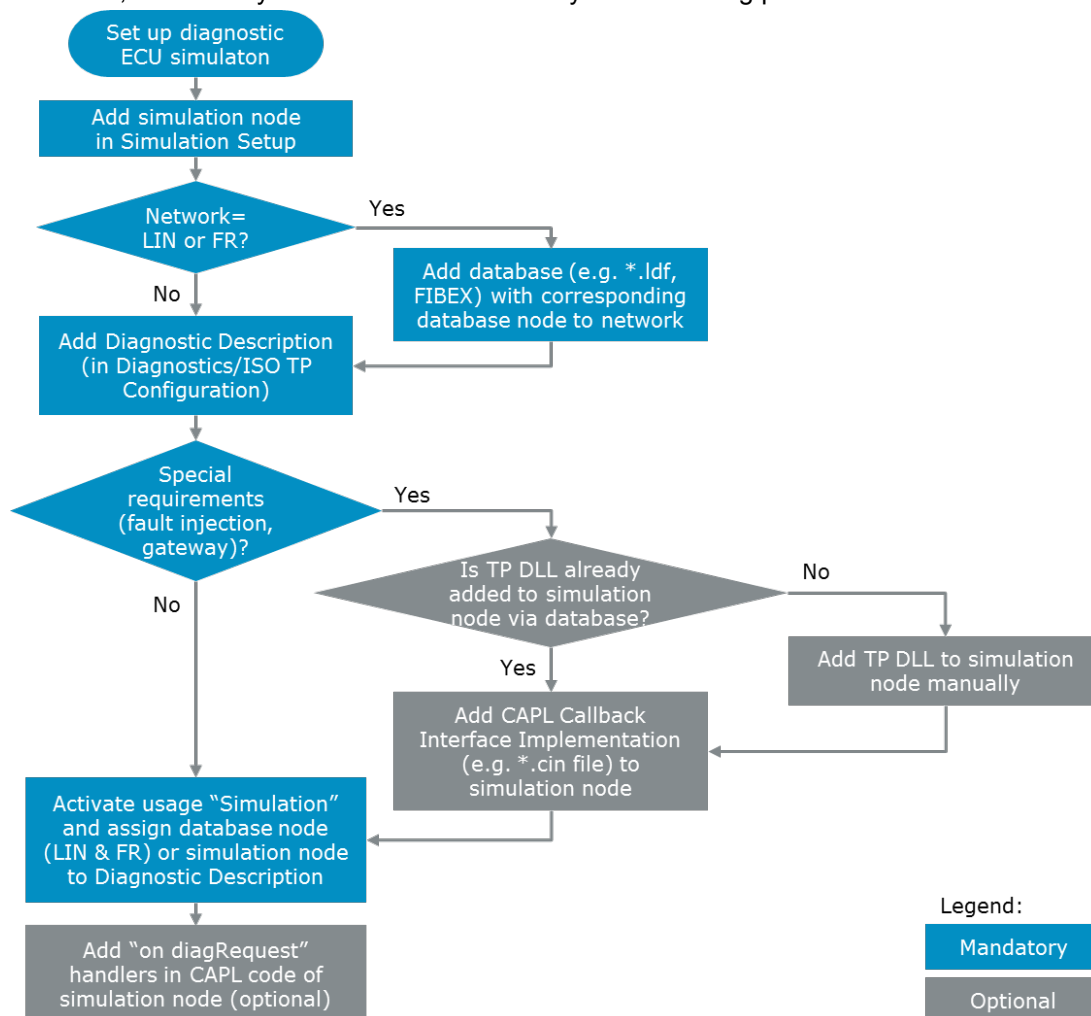

Figure 15: Workflow when setting up a diagnostics ECU simulation

4.2.2   Add a Network Node to the Simulation Setup

As a first step, you need to add a Network Node to the Simulation Setup. In order to do this, right-click on the bus line in the Simulation Setup window and choose the context menu "Insert Network Node".

4.2.3   Add a database in case of LIN and FlexRay

For LIN and FlexRay, a database (e.g. *.ldf or FIBEX) containing the corresponding Network Node must be available for the respective network. Without this network node, it is not possible to add a Diagnostic Description to a LIN or FlexRay network. If necessary, you may add it using the CANdb++ editor.

4.2.4   Add a Diagnostic Description and assign it to the network node

Next, you should add a diagnostic description. To do so, select the menu "Diagnostics & XCP | Configuration | Diagnostics/ISO-TP Configuration…" and add the diagnostic description to the desired network. Afterwards, you need to check "Simulation by" and select the Network Node from the database or the simulation node you defined in the first and/or the second step (see sections 4.2.2 and 4.2.3 for details):
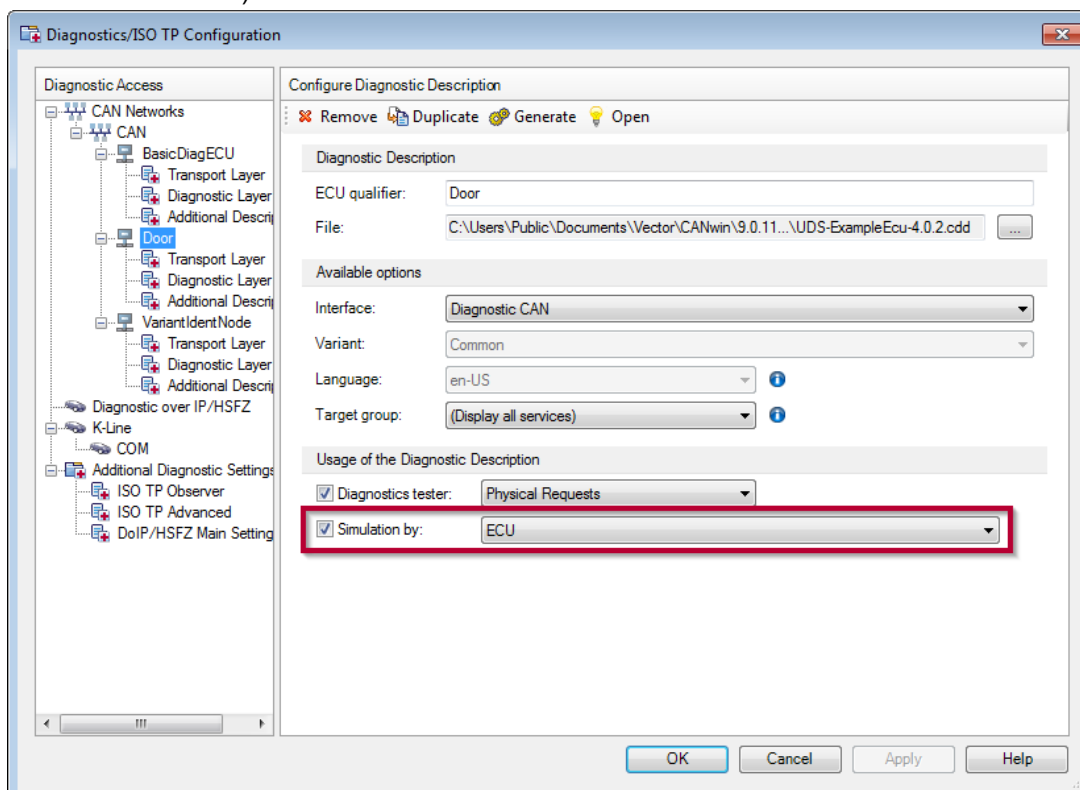
Figure 16: Configuring a Diagnostic Description for simulation

4.2.5   Configure the Network Node in Simulation Setup

If you want to add a CAPL Callback Interface (CCI) implementation, at first you need to make sure that the appropriate TP DLL is added as a component to the Network Node just added to the Simulation Setup. To do this, perform the following two steps:

1. [If you did not add a database to the network as described in in chapter 4.2.3, you may skip this step] In the Node Configuration dialog of the Network Node just added to the Simulation Setup, set the "Network node" to the corresponding node defined in the database and confirm the dialog

with "OK":
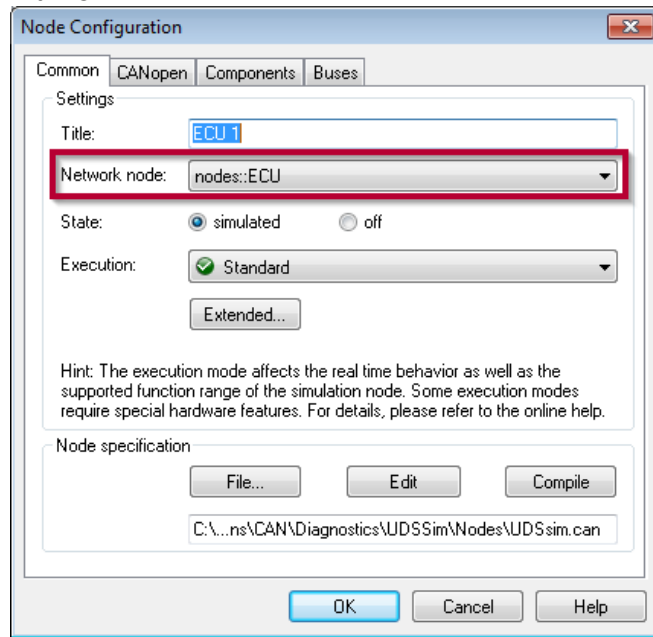
2. Open the Node Configuration dialog of the Network Node again and make sure that in its "Components" tab, the corresponding TP DLL is configured as a component. If it is not already configured, add it manually (you can find the TP DLLs in the Exec32 directory of your CANoe installation):
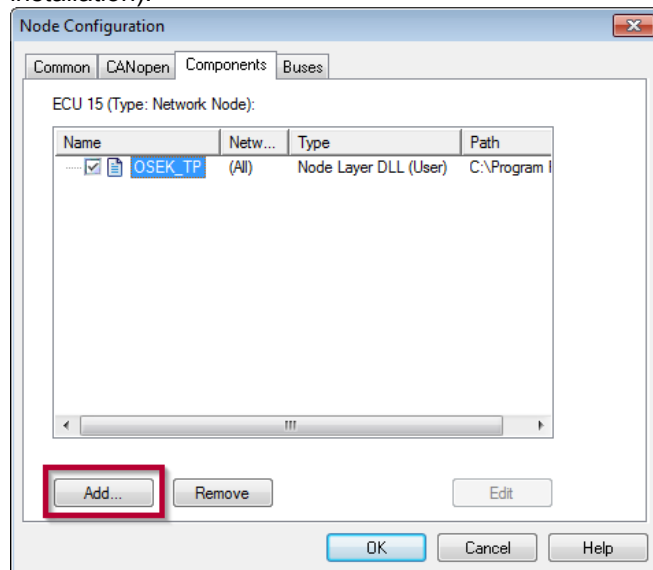
Using the TP DLLs (overview of TP DLLs see chapter 2.1), it is possible to work with diagnostic objects in CAPL even if these objects exceed the size of one frame. E.g. a diagnostic response with 24 data bytes is still treated as one object - the diagnostic response. E.g. the OSEK transport protocol is implemented in a dynamic link library (DLL) named "osek_tp.dll". In order to use this DLL, you need to add it as a component to the network node as described above.

> **Note**
> The TP DLLs use several callback functions - the so-called CAPL Callback Interface (CCI) - which need to be implemented in the network node (see section 4.2.6 for details).

4.2.6 Add the CAPL Callback Interface

If you want to use the CAPL Callback Interface, you additionally need to provide certain callback functions (referenced as the CAPL Callback Interface, CCI) in your CAPL code. For all relevant automotive networks, reference CCI implementations are available as CAPL include files (*.cin) in the folder "Reusable\CAPL_Includes\Diagnostics" which is located in the same folder as the Sample Configurations (see the list of supported TPs and the corresponding DLL and *.cin files in chapter 2.1). These include files implement the CCI for simple ECU simulations, i.e. they need to be adapted in case of more complex simulations like e.g. gateways. Refer to the application note **AN-IND-1-012** for details.

4.2.7 Debug level

If using the CCI reference implementations, the amount of errors and warnings written to the Write Window e.g. by the ISO TP functions can be controlled by a parameter to the function setWriteDbgLevel(). To set the debug level to verbose use setWriteDbgLevel(1) or to set the debug level to quiet use setWriteDbgLevel(0).

Example:
```
on start
{
   setWriteDbgLevel(0);
}
```

4.2.8 Add a diagnostics request event handler

In order to add an event procedure for a specific diagnostic request (e.g. in a simulated ECU), right-click on "Diagnostics" and select the respective handler under "New event handler | Diagnostics | on diagRequest <new request>". This code will be created:

```
on diagRequest NewRequest
{
}
```

Use the diagnostics symbol explorer (see chapter 2.5.8) to enter the qualifier path via drag and drop or type the ECU qualifier and Service qualifier separated by ".", taking advantage of the Autocomplete Input Assistance of the CAPL Browser.

Example:
```
on diagRequest Door.DefaultSession_Start
{
}
```

4.2.9 Create a diagnostic response

> **Note**
> This paragraph only applies to ECU simulations.

Usually a response is sent on reception of the event „diagRequest", i.e. when the specific request arrives. By using the keyword „this" the response object will reflect the request object by referring to the actual qualifier. Note how the diagnostic response is treated as an object rather than one or several CAN message(s). Due to the TP functionality a response can be sent in one function call even if the response object should be segmented (i.e. distributed over several subsequent messages).

Example:
```
on diagRequest Door.DefaultSession_Start
{
  // Create a response to this request
  diagResponse this resp;
  // Send a positive response
  DiagSendResponse( resp);
  // For negative responses, use
  // DiagSendNegativeResponse(resp, NRC)
}
```

4.3 CANoe/CANalyzer as Diagnostic Tester

4.3.1 Set the diagnostic target

> **Note**
> The function DiagSetTarget() is deprecated. Vector recommends using the syntax with ECU Qualifier in DiagRequest/Response Objects (see chapter 4.1.1 for details) instead. Additionally, this paragraph only applies to tester simulations. In an ECU simulation node, either the new syntax (see above) or DiagInitEcuSimulation() should be used.

If you simulate a diagnostic tester that should send requests and receive responses from a specific (simulated or real) ECU, you must set the target name in the tester CAPL code – either in the diagRequest object itself or using the deprecated DiagSetTarget() function. DiagSetTarget() is usually set in the "on start"-handler of the CAPL code, but may be changed later.

Example:
```
on start
{
  if( 0 != DiagSetTarget( "ECU" )) write( "Error setting target!" ); // deprecated syntax
}
```

The string "ECU" should be changed to the actual ECU qualifier contained in the Diagnostic Description. Note that you can edit this ECU identifier in the "Diagnostics/ISO TP Configuration" dialog.

4.3.2 Create a diagnostic request

To create a request that should be sent (e.g. from a Diagnostic Tester) you can create a function where you create and send a request.

Example:
```
StartSession()
{
  diagRequest Door.DefaultSession_Start req;
  // Send the request as a complete object (TP takes care of segmentation)
  DiagSendRequest ( req );
}
```

4.3.3 Add a diagnostics response event handler

In order to add an event procedure for a specific diagnostic response (e.g. in a simulated Tester), right-click on "Diagnostics" and select the respective handler under "New event handler | Diagnostics | on diagResponse <new response>". This code will be created:

```
on diagResponse NewResponse
{
}
```

Use the diagnostics symbol explorer (see chapter 2.5.8) to enter the qualifier path via drag and drop or type the ECU qualifier and Service qualifier separated by ".", taking advantage of the Autocomplete Input Assistance of the CAPL Browser.

4.3.4 Negative Response handling

A request sometimes results in a negative response e.g. if the request cannot be performed by the ECU. This section describes how to implement a handling for this kind of situation.

The service of the request can be specified exactly, but the service of the response is not clear. To handle the ambiguity of negative responses, it is suggested to implement an "all-handler".

Example:
```
on diagResponse ECU.*
{
  // Handle the ambiguity of neg responses by treating them as '*'
```

```
  if( DiagIsNegativeResponse ( this ) )
  {
    write( "Received negative response for service 0x%x, code 0x%x",
     (long) DiagGetParameter( this, "SIDRQ_NR" ),
     (long) DiagGetParameter( this, "NRC" ) );
  }
}
```

A special case of negative response is a response with a code that indicates "I'm busy, I'll respond later". This means that a (hopefully) positive response that should be mapped against the actual request will follow later. On tester side of CANoe (i.e. using e.g. the Diagnostic Console or when implementing a Test Module in CAPL), this behaviour is handled automatically. To simulate this special kind of negative response from a simulated ECU, it is suggested to implement a timer in the ECU. The simulated ECU first sends a negative response, then starts a timer where the positive response is sent.

Example:
```
on diagRequest Door.FaultMemory_ReadAllIdentified
{
  // Send neg response with code 0x78 (requestCorrectlyReceived-ResponsePending)
  DiagSendNegativeResponse(this, 0x78);
  // Optionally set a timer to respond with a positive response later
  setTimer(posReq, 1);
  // pos resp after 1s
}
```

4.4 Combine Test Feature Set and Diagnostic Feature Set

Note
This chapter only applies to CANoe.

This document does not cover the Test Feature Set in detail. For details on Test Feature Set please refer to the online help in CANoe.

A very common diagnostic sequence is to send a request and to wait for a response before continuing with the next request.

Tester   ECU

Send diag request

    …   → Receive request

Wait for response   Process request

    …   Respond to request

Receive response ←
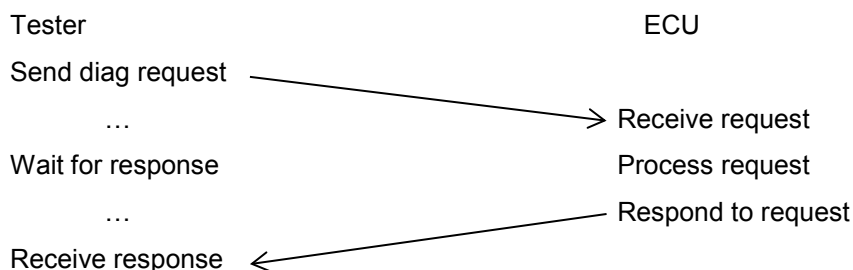
To be able to use the Test Feature Set in combination with the Diagnostic Feature Set, you can create a *CAPL Test Module* instead of an ordinary ECU, and use it as a Diagnostic Tester. In this way you can use the built-in test functions like TestWaitForDiagnosticResponse() to get a smoother handling of the request/response scheme.

4.4.1 Timeout handling

The timeout on a diagnostic request can be recognized automatically via the return value of TestWaitForDiagResponse() function.

Example:
```
TestWaitForDiagResponse( req, 5000 );  // wait 5s for a response on this request
```

4.4.2 Automated diagnostic tests with CANoe

Diagnostics tests in CAPL

Create a test case in the TestControl section, e.g. tc_StartSession(), and call this test case from MainTest(). In tc_StartSession() create a diagnostic request and wait for response until timeout.

Example Diagnostic Tester:

```
void MainTest ()
{
  tc_StartSession ();
}
testcase tc_StartSession ()
{
  // Create a request with correct qualifier
  diagRequest Door.DefaultSession_Start req;
  // Send the request
  DiagSendRequest ( req );
  // Wait until request has been sent completely (important especially in case of
  // segmented messages)
  TestWaitForDiagRequestSent( req, 1000)
  // Wait 5s for response and evaluate
  // Return values of Test Feature Set functions are defined in the help file
  if( 1 != TestWaitForDiagResponse ( req, 5000) )
  {
    // Response not received
    TestStepFail( "Start Default Session", "No response received!");
  } else
  {
    // evaluation of response data here
  }
}
```

To produce a response to your Diagnostic Tester it is a good idea to configure a simulated ECU as long as no real HW is available. Simply add a simulation node to the Simulation Setup, activate the "Simulation by" setting in the "Diagnostics/ISO TP" configuration dialog and select the simulation node you just created (see chapter 4.2.4).

In the newly created simulation node you can define answers to diagnostic requests like this:

Example simulated ECU:

```
on diagRequest Door.DefaultSession_Start
{
  // Create a response to this request
  DiagResponse this resp;
  // Send the response
  DiagSendResponse( resp);
}
```

Diagnostics tests created in vTESTstudio

With vTESTstudio, it is possible to define automated tests using CAPL, C#, Test Tables (see Figure 17) or even graphically and generate so-called Test Units from these tests.

CANoe and vTESTstudio are perfectly matching each other. You can import CANoe's project settings including the assigned Diagnostic Descriptions into vTESTstudio and CANoe can execute test units created in vTESTstudio.

Such Test Units can be executed in the same way like CAPL test modules and will generate Test Reports as shown below.

With vTESTstudio, checking of e.g. the fault memory contents becomes very easy by just using drag & drop when creating the tests, reducing the effort for diagnostic test creation tremendously compared to test creation using CAPL.
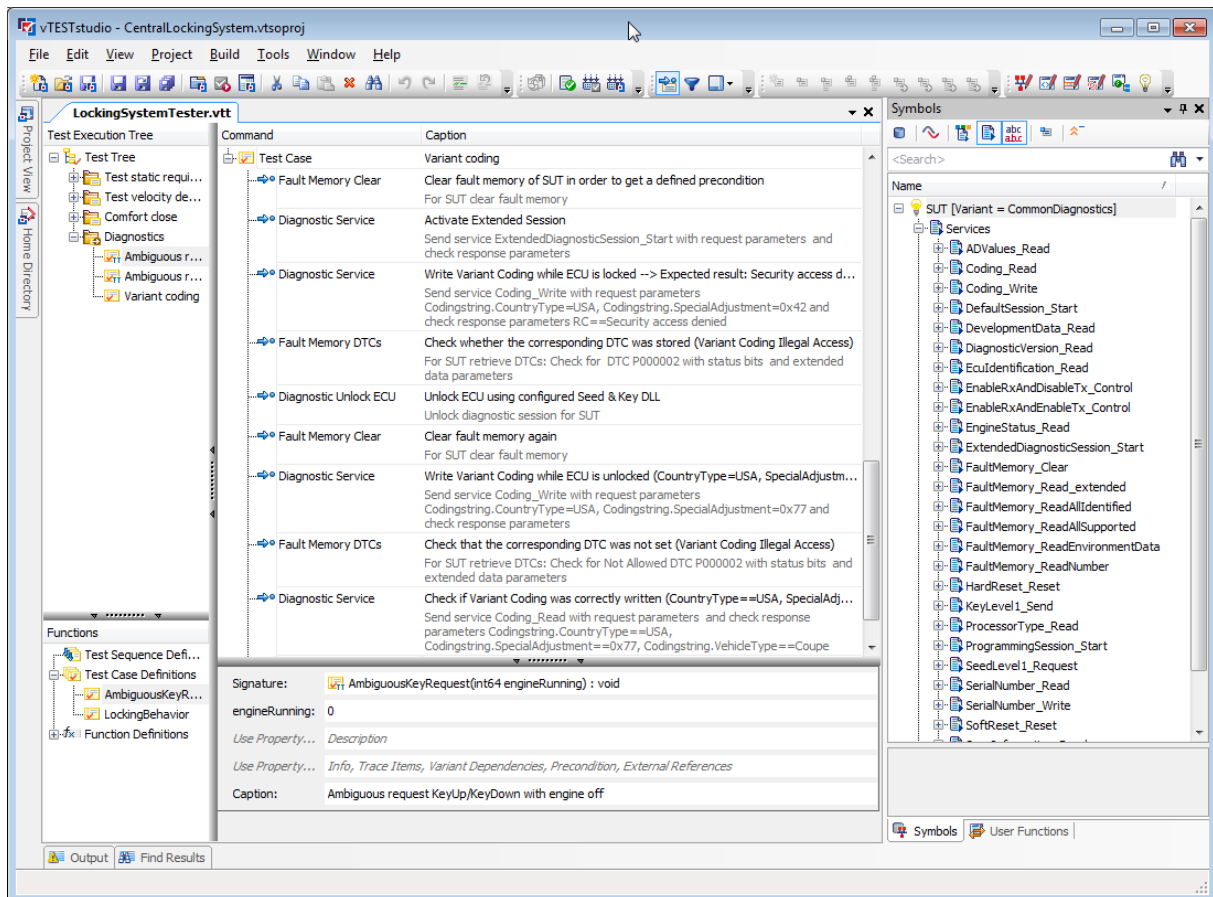
Figure 17: Defining diagnostics tests in a vTESTstudio Test Table

The test case above will result in the following test report (extract):

Main Part of Test Case

Timestamp	Test Step	Description	Result
1. Clear fault memory of SUT in order to get a defined precondition: Passed			
1.614395	Query fault memory	Clearing fault memory of target Diagnostic ECU 'SUT'	-
1.618371		DTCs cleared successfully	pass
2. Activate Extended Session: Passed			
1.618371		Set P2 to 150ms, P2ex to 2000ms	-
1.618371		Sending request '//Beispiel_Steuergeraet/CommonDiagnostics/ExtendedDiagnostic Session_Start/STDS_RQ' ...	-
1.619907	Resume reason	Resumed on Diagnostics request sent to 'SUT' Elapsed time=1.536ms (max=10000ms)	-
1.619907		Request sent successfully	pass

1.619907		Receiving diagnostic response	-
1.621395	Resume reason	Resumed on Diagnostics response from 'SUT' Elapsed time=1.48801ms (max=10000ms)	-
1.621395		Positive response received.	pass

3. Write Variant Coding while ECU is locked --> Expected result: Security access denied: Passed			
1.621395		Sending request '//Beispiel_Steuergeraet/CommonDiagnostics/Coding_Read/RDBI_RQ' ...	-
1.623859	Resume reason	Resumed on Diagnostics request sent to 'SUT' Elapsed time=2.46399ms (max=10000ms)	-
1.623859		Request sent successfully	pass
1.623859		Receiving diagnostic response	-
1.625287	Resume reason	Resumed on Diagnostics response from 'SUT' Elapsed time=1.42801ms (max=10000ms)	-
1.625287		Response received successfully	pass
1.625287		Set P2 to 150ms, P2ex to 2000ms	-
1.625287		Sending request '//Beispiel_Steuergeraet/CommonDiagnostics/Coding_Write/WDBI_RQ' ...	-
1.626811	Resume reason	Resumed on Diagnostics request sent to 'SUT' Elapsed time=1.524ms (max=10000ms)	-
1.626811		Request sent successfully	pass
1.626811		Receiving diagnostic response	-
1.628287	Resume reason	Resumed on Diagnostics response from 'SUT' Elapsed time=1.47601ms (max=10000ms)	-
1.628287		Negative response received.	pass
1.628287		Received primitive can be interpreted as Diagnostic primitive 'WDBI_NR'.	pass
1.628287	Evaluate Response	[-] Check of expected values	pass

Symbol	Op.	Reference Value	Actual	Result
Diagnostic parameter 'RC'	==	51 (Security access denied)	51	pass

4. Check whether the corresponding DTC was stored (Variant Coding Illegal Access): Passed

1.628287	Query fault memory	Reading DTCs from Diagnostic ECU 'SUT'	-
1.629859	Sent at 1.629859	[+] //Beispiel_Steuergeraet/CommonDiagnostics/FaultMemory_ReadA⁻ _RDTCBSM_RQ	
1.631287	Sent at 1.631287	[+] //Beispiel_Steuergeraet/CommonDiagnostics/FaultMemory_ReadA⁻ _RDTCBSM_PR	
1.631287		Mandatory DTC 0x2 (Diagnostic trouble code 'P000002') found with matching status.	pass

4.5 Using CAPL in the measurement setup

The "on diagRequest" and "on diagResponse" handlers described in chapter 4.2.8 and 4.3.3 as well as the "on diagRequestSent" handler can also be used in program nodes in the measurement setup. This is especially helpful when programmatically analysing large log files in offline mode. Note that in the measurement setup, it is necessary to add the line "output(this);" in order to forward the event to subsequent elements, e.g. the trace window. Otherwise the respective event – in the following example a specific diagnostic response of the Door ECU - is filtered out.

Example:
```
on diagResponse Door.SerialNumber_Read
{
  long serialNo;

  serialNo=DiagGetParameter(this, "SerialNumber");
  write("Diagnostic response with serial number %d received from Door ECU!", serialNo);

  output(this);
}
```

5.0 Advanced examples

5.1 ECU simulation of "Response Pending"

If an ECU is not able to respond to a request immediately, it can send a negative response with the response code "requestCorrectlyReceived-ResponsePending" (RCR-RP, 0x78) to indicate that it will delay the final response. To simulate this behavior in CAPL, the following code pattern can be used:

Example:
```
variables
{
  // ...
  BYTE gDelayedResponse[ 500];        // global buffer for one delayed response
  dword gDelayedResponseLen = 0;      // length of the response stored, or 0 if none
  msTimer gDelayTimer;   // timer for delayed response
}

on diagRequest ECU.Action1
{
  diagResponse this resp;
  // Set the parameters in the response.
  DiagSetParameter( resp, "Param1", 1);
  DiagSetParameter( resp, "Param2", 2);
  // Copy the response data into the global buffer for sending later.
  gDelayedResponseLen =
    DiagGetPrimitiveData( resp, gDelayedResponse, elcount( gDelayedResponse));
  // Send "response pending"
  DiagSendNegativeResponse( resp, 0x78);
  // Start the timer that will initiate the actual sending of the response.
  settimer( gDelayTimer, 100);
}
```

```
on timer gDelayTimer
{
  diagResponse ECU.ActionX dummy;
  if( gDelayedResponseLen > 0)
  {
    DiagResize( dummy, gDelayedResponseLen);
    DiagSetPrimitiveData( dummy, gDelayedResponse, gDelayedResponseLen);
    // The diagnostics object may now have changed its "type"!
    DiagSendResponse( dummy);
    gDelayedResponseLen = 0;
  }
}
```

Note that the "type" of the response object in the "on timer gDelayTimer" handler can differ from the one it is initialized with, depending on the content of the data that is written into the object.

5.2 Modifying the length of a diagnostic object

The length of a diagnostic object, e.g. a diagnostic response, can be resized. This is typically useful for sending diagnostic responses containing DTCs from a simulated ECU because this kind of diagnostic response can be of very different length depending on the number of DTCs.

If there is a parameter that specifies the number of simple parameter sequences that follow (e.g. "NumberOfDTC"), set that parameter to the value you need:

Example:
```
DiagResponse this resp;
DiagSetParameter( resp, "NumberOfDTC", 12); // 12 sequences follow
DiagResize( resp); // Note: Not necessary anymore since CANoe 5.2
```

The example above will make room for 12 parameter sequences.

If no such parameter exists, you have to specify the number of bytes to reserve.

Example:
```
DiagResize( resp, 20); // resize the response to 20 bytes
```

5.3 Fill diagnostic content

A diagnostic parameter can be set directly via raw bytes instead of using symbolic values. This can also be useful for simulating errors in e.g. diagnostic responses.

Example:
```
  char ECUpartNo[25] = "030821111A";
  byte inbuffer[25];
  // Convert from char array to byte array
  for(i=0;i<25;i++) inBuffer[i] = ECUpartNo[i];
  // Set the parameter's raw byte representation in the response.
  DiagSetParameterRaw(resp, "Partnumber_for_ECU", inBuffer, 25);
```

5.4 Fault injection

To verify how the ECU reacts on e.g. an incorrect diagnostic request the parameters of the request can be manipulated by using the function `DiagSetPrimitiveData()`. This function can also be used to patch the content directly to simulate an error in the ECU implementation.

You can declare an object with

  diagRequest Door.SineWave_Send_once req;

and it will hold a buffer with the whole "bus message" (i.e. what will be transported over the bus as data, including service and subfuction IDs). If you put different data into the object with DiagSetPrimitiveData, it might no longer belong to the class "STORED_DATA", but may be any other "type" of response, or even something unspecified.

5.4.1 Make request length illegal

```
// Set length of request object to an incorrect value to check ECU action
```

```
// Length differs from Diagnostic Description
DiagResize( req, 2);
```

If this request is sent, the transport layer will operate correctly, i.e. the data will be transferred correctly.

5.4.2   Introduce errors on transport protocol level

It is possible to test the ECU's capacity to cope with errors on the transport layer when using the CAPL Callback Interface (CCI).

Example:
The tester claims to send the full data (e.g. 10 bytes), but stops sending after the first frame, i.e. the Consecutive Frames are not sent:

```
_Diag_DataRequest( BYTE data[], DWORD count, long furtherSegments) {
   if( gAbortAfterFF) {  // Using a flag to trigger fault injection
      CanTpFI_Enable( gHandle);        // Activate fault injection functionality
        // gHandle contains the handle of the TP connection
      CanTpFI_SendXByte( gHandle, 1, 8, -1); // Send only 1 byte but fill First Frame to DLC 8
      gAbortAfterFF = 0; // Do this only once
   }
   CanTpSendData(gHandle, data, count);
}
```

For more details on the fault injection feature of the OSEK_TP.DLL, please cf. [1], chapter "Fault Injection"; for more information on the CCI, refer to the application note **AN-IND-1-012** for details.

5.5   Access a node via a gateway simulation

> In order to access a node using the diagnostics features of CANoe, it is possible to introduce a simple TP-level gateway simulation in the setup. The diagnostics description file can be configured to use standard ISO TP data transfer on CAN. Assign the Diagnostic Description to the CAN bus the gateway is attached to, *not* to the gateway node itself.
> In the simulation setup, configure the gateway node to use the ISO TP DLL for CAN (OSEK_TP.DLL) and the TP DLL for the corresponding network (e.g. LINtp.DLL for LIN), i.e. load these DLLs under "modules" or configure a database.
> The gateway simulation has to receive requests sent on the CAN bus (by the Diagnostic Console or fault memory window, real nodes, simulated nodes, test modules, etc.), and send the data on the LIN bus. The same approach has to be used for responses from the LIN to CAN.
> Note that the "bus context" is set to the bus where the data has been received on, and that the context has to be switched to the other bus before forwarding the data.
> In case of LIN, the gateway simulation has to act as the LIN master node.

The following implementation of a TP-level gateway simulation can be used as an example (the settings in "on start" have to be adapted in most cases).

```
variables
{
  char gECU[10] = "Gateway";
  long gNAD;      // node address of target node in LIN network
  long gCanTpHandle;     // handle of the CanTp connection
  dword gLinBusContext;
  dword gCanBusContext;
}

on start
{
  // !!!Adapt the parameters in this function!!!

  gCanTpHandle = CanTpCreateConnection(0);    // 0 = Normal mode
  CanTpSetTxIdentifier(gCanTpHandle, 0x400);
  CanTpSetRxIdentifier(gCanTpHandle, 0x200);

  gNAD = 1;

  gCanBusContext = GetBusNameContext("CAN");
  gLinBusContext = GetBusNameContext("LIN");

  setWriteDbgLevel(0);
```

```
}

CanTp_ReceptionInd (long handle, byte data[])
{
  // This function returns the data received
  writeDbgLevel(1,"%s: CanTp_RecepionInd", gECU);

  setBusContext(gLinBusContext);
  LINtp_DataReq(data, elcount( data), gNAD);
}

LINtp_DataInd(long count)
{
  /* This function returns the number of data received */
  byte rxBuffer[4096];
  writeDbgLevel(1,"%s: LINtp_DataInd", gECU);

  LINtp_GetRxData(rxBuffer, count);

  setBusContext(gCanBusContext);
  CanTPSendData( gCanTpHandle, rxBuffer, count);
}

LINtp_ErrorInd(int error)
{
}

CanTp_ErrorInd( long connHandle, long error)
{
}
```

6.0 Common mistakes

Problem	Why are the Diagnostics request or Diagnostics response event categories not available in the symbol explorer of the CAPL browser?
Solution	You must add a Diagnostic Description to your CANoe/CANalyzer configuration, see paragraph 3.1.1 on how to do that.

Problem	Why is the diagnostic request that I send (from CAPL) not visible in trace?
Solution	You must assign the Diagnostic Description to the actual ECU (or bus) that the request is directed to. Additionally, the transport layer communication parameters (e.g. on CAN the CAN IDs for request, response and – if used – functional requests) need to be set correctly in the "Diagnostics/ISO TP" configuration dialog. If you can use the console, the Diagnostic Description is already correctly assigned and make sure the trace window's predefined filters are configured to show diagnostic events.

Problem	Why is the following system message displayed in the Write window: „System OSEK_TP ECU: Could not find mandatory callback function OSEKTL_ErrorInd!"
Solution	Not the complete set of OSEKTL_ callback functions is found. You have forgotten to include the indicated mandatory callback function into your simulated ECU.

Problem	Why is the following system message displayed in the Write window: „System DiagCreate Request: Accessing CANdelaLib lead to an error, e.g. exception, not found."
Solution	A request could not be created because it is missing in the Diagnostic Description or you selected a different variant in the "Diagnostics/ISO TP…" configuration dialog. The request could be incorrectly defined in CAPL – check the request qualifier with the qualifier you can copy via drag & drop from the symbol explorer.

Problem	Why is the following system message displayed in the Write window: "System Request services with complex/uncertain parameters are not supported!"
Solution	When initialising the Diagnostic Console, all defined requests are inspected. But since the Diagnostic Console is currently not able to create requests if they contain complex parameters, those requests are filtered out of the display, i.e. they cannot be sent directly from the console (but you can send them directly by entering the raw bytes in the edit line of the console). This does not have anything to do with the access in CAPL; except that using the Diagnostic Console to find the qualifier path of the service does not work here, since the service will not be listed in the Diagnostic Console tree. (Note that the symbol explorer (see chapter 2.5.8) will display these requests and their parameters too.)

Problem	Why is my simulated ECU marked with "OSEK_TP" in the simulation set-up?
Solution	Nodes that use the transport layer functionality in CANoe (i.e. segmentation and other transport layer functions typically needed for diagnostics) must have this node layer module assigned to them. CANoe needs this information in order to use the DLL file that implements the transport protocol. You can either inform CANoe via the .dbc-file (please see help file how to do this) or via the configuration dialogue of the node itself in simulation set-up. Consult paragraph 4.2.4 for details.

Problem	Why does the Trace window display: "Unknown action::Unknown instance"?
Solution	Data bytes sent or received cannot be found in the Diagnostic Description. Correct either your CAPL or your Diagnostic Description. This behaviour could also occur if the ECU implementation (software) does not comply with the specification, i.e. the ECU diagnostic response contains data bytes that are not described in the Diagnostic Description.

Problem	Why is the value of a diagnostics parameter always written as 0, even though no warning message (like "parameter not found") is printed in the write window?

Solution	In the following typical statement
	
	```Write("%d", DiagGetParameter(object, "Parameter"));```
	
	the double type return value of the access function (cf. CAPL reference) is treated as a long argument, which will lead to printing 0 in most cases. It is necessary to cast the value or use a float format:
	
	```Write("%d", (long) DiagGetParameter(object, "Parameter"));```
	```Write("%g", DiagGetParameter(object, "Parameter"));```

Problem	The following code leads to an error like "[DiagGetParameter(double)] Accessing CANdelaLib leads to an error. Parameter 'SerialNumber' not found!", although a parameter with this identifier is available for that service:
	
	``
	testcase TC_SerNumberRead()
	{
	  DiagRequest SerialNumber_Read req;
	  double Serial;
	
	  DiagSendRequest(req);
	  TestWaitForDiagRequestSent(req, 1000);
	  TestWaitForDiagResponse(req, 1000);
	  Serial=DiagGetParameter(req, "SerialNumber");
	  //...
	}
	``

Solution	If you want to access the Parameters of the Response to a Request, the function `DiagGet`**`Resp`**`Parameter()` needs to be used:
	
	``
	testcase TC_SerNumberRead()
	{
	  DiagRequest SerialNumber_Read req;
	  double Serial;
	
	  DiagSendRequest(req);
	  TestWaitForDiagRequestSent(req, 1000);
	  TestWaitForDiagResponse(req, 1000);
	  Serial=DiagGetRespParameter(req, "SerialNumber");
	  //...
	}
	``

7.0 Abbreviations

API Application Programming Interface

CAPL CAN Access Programming Language

CCI CAPL Callback Interface

CDD CANdela Diagnostic Description

DBC DataBase for CAN

DFS Diagnostic Feature Set - diagnostic support in CANoe/CANalyzer

DIS Draft International Standard

ECU Electronic Control Unit

DLL Dynamic Link Library

DTC Diagnostic Trouble Code

ISO International Organization for Standardization

ODX Open Diagnostic Data Exchange

OEM Original Equipment Manufacturer

SP Service Pack

TFS Test Feature Set - test support in CANoe

TP Transport Protocol

8.0 References

The documents mentioned here are part of the documentation that is included with every CANoe installation. They can be found from Start menu/Programs/CANoe/Help, or as files directly.

[1] ISO/DIS 15765-2 Transport Protocol documentation: Doc/CanTP_Manual.PDF

[2] Generic CDDs implementing standards: Exec32\StandardCDDs\GenericKWP.cdd

Exec32\StandardCDDs\GenericUDS.cdd

9.0 Additional Resources

VECTOR APPLICATION NOTE

AN-IND-1-002   Testing with CANoe

AN-IND-1-004   Diagnostics via CANoe Gateways

AN-IND-1-012   CAPL Callback Interface in CANoe

10.0 Contacts

For a full list with all Vector locations and addresses worldwide, please visit http://vector.com/contact/.