ComboCS - The CCS EVSE Simulator

Trialog

Accelerate and make CCS developments more reliable

Date : 2022-08-24
Version : 11

Trialog is working on EV charge since more than 10 years and had several opportunities to develop a strong expertise on Electro-Mobility charge protocols like IEC 61851-1, DIN 70121, ISO 15118 and OCPP 1.6/2.0.
In this context, Trialog has developed several testing and validation tools.

ComboCS, the EVSE CCS Simulator is one of these tools. It aims to enables and simplifies CCS developments by providing simulation and test means of DIN 70121 and ISO 15118 protocols without any power transfer. This tool allows to:

- Simulate the EVSE part of a CCS implementation in order to perform or simulation charging session following IEC 61851-1, DIN 70121 and/or ISO 15118;
- Follow in real-time the communication though the embedded UI;
- Change in real-time the EVSE behaviour;
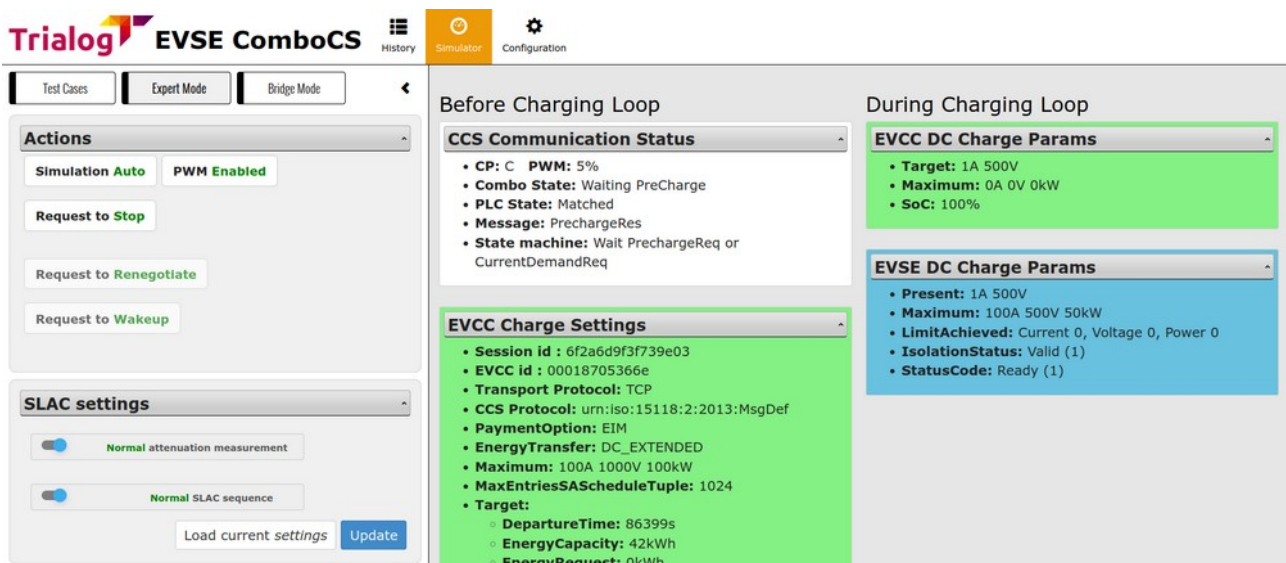- Launch different test case scenario to trigger nominal and non-nominal test cases.

Figure 1: ComboCS User Interface

Technical Details

ComboCS is a box allowing to perform AC or DC, ISO 15118 or DIN 70121 communications, including the HPGP PLC and IEC 61851-1 communications.

Figure 2: ComboCS connectors - Face 1

Figure 3: ComboCS connectors - Face 2

- Size: 23x15x6 cm
- Connectors:
  - Control Pilot and Protective Earth: BNC
  - CAN: DB9 *(reserved for future usage or specific development)*
  - 6 GPIO: AWHW 10G-0202-T *(reserved for power transfer add-on or specific development)*
- Interface
  - WiFi hotspot
  - Ethernet RJ45
- Wires provided with the tool
  - AC/DC 230V/12V barrel jack
  - Type 2 plug with BNC connector
  - Ethernet wire

Supported Features

ISO 15118 and DIN 70121 standards define several use cases and functions. ComboCS supports almost all functions and more specifically:

- ISO 15118-3 / DIN 70121
  - SLAC
  - Validation
- ISO 15118-2 / DIN 70121
  - SDP
  - Supported state machines: AC and DC
  - Supported payment options: EIM and PnC
  - Supported optional functions:
    - Service Details
    - PnC Certificate installation
    - Smart Charging
    - Renegociation
    - Metering Receipt
    - Welding Detection (DC charge only)
    - Pause / Resume

For test purpose, the Simulator could also be used to perform ISO 15118-2 communication over Ethernet without the PLC ISO 15118-3 link.

ISO 15118-20 can be enabled as an option, not provided by default in ComboCS. It is available as a software update. Please see details in section SW UPGRADE TO ISO 15118-20 EXTENSION.

Implementation in progress
"Amplitude Map exchange" of ISO 15118-3 is still under validation and provided as developer preview into the ComboCS.

ComboCS Modes

SIMULATOR MODE

By default, the EVSE ComboCS can be plugged to a vehicle and perform a standalone and nominal CCS charging session without any other inputs.
The default configuration is:

- ISO 15118 or DIN 70121
- DC or AC Charge
- EIM or PnC payement option
- Charge Maximum Limits: 32A, 400V, 22kW
- Charge Minimum Limits: 6A, 0V
- CurrentRegTolerance: 1A, PeakCurrentRipple: 15A

This default behavior can be modified using the Configuration view, and adapted in live using the expert and test case modes defined below.

SUPERVISION **MODE**

ComboCS is provided with a Web interface, compatible with Windows, Linux and Mac, accessible over Ethernet or Wifi. It provides access to real-time evolution of the ongoing CCS communication.

Figure 4: ComboCS interface - Example of ISO 15118 communication

All data exchanged between the EVSE of the EV is available through the user interface. The history of the whole decoded communication can be downloaded as a log file.

SESSION HISTORY **MODE**

An historic of all charging session is kept available on the ComboCS and can be downloaded in CSV format for Excel. It allows to quickly identify a session by a number, to know its status and the failure reason.

Current Charging Session [85%]

#	EVCCID	SessionId	Type	Result	Last message	Current stage	Error code	Actions
39	00018705366e		Not Selected	Pending	None	Waiting PLC	No error	Stop Plugged

Charging Sessions History

[1]

#	Start	Duration	EV MAC	EVCCID	RunId	SessionId	Type	Result	Last message	Last stage	Error code
31	1645201929	17 s	00018705366d	00018705366e	72089631	9db48b9eaad9bf50	DIN DC EIM	Success	SessionStopRes	Finished PCAP	No error
30	1645201223	292 s	00018705366d	00018705366e	1664540707	4f006905f72cb49f	DIN DC EIM	Success	SessionStopRes	Finished PCAP	No error
29	1645201011	170 s	00018705366d	00018705366e	72089631			Failure	None	Ready to charge PCAP	Remote host closed the communication - TCP error: The remote host closed the connection
28	1645200992	9 s	00018705366d	00018705366e	1664540707			Failure	None	Waiting Handshake PCAP	Comm Incompatibility
27	1645199573	1274 s	00018705366d	00018705366e	72089631	f3dc4f1f3702661b	ISO-2 DC EIM	Success	SessionStopRes	Finished PCAP	No error

Figure 5: Session history view

TEST CASE MODE

The Test Case Mode of ComboCS triggers CCS communication session for a list of nominal and non-nominal predefined cases.
The Test Case Mode proposes two types of test cases:

- **Conformance testing:** DIN 70122, ISO 1518-4 and ISO 15118-5 documents define test cases to validate conformance of the implementation to the normative documents. ComboCS is providing a subset of these test cases. The coverage is not yet complete, but increasing regularily.
- **Interoperability testing**: Because of existing ambiguities in the norms and the multiplicity of the implementations, ComboCS is providing several test cases with limit and non-nominal behaviour of the EVSE, and even invalid behaviour of the EVSE observed « in the street ». Thanks to the experience of Trialog in the field, this list is increasing regularily.
  Interoperability tests also allows to reproduce the behaviour of several existing EVSE in the market.

Additionaly to the available test cases, an HTTP/REST and WebSocket API is provided with ComboCS, allowing to define its own test cases and integrate ComboCS to its own validation process (end of line test, non regression tests, …).

These test cases provides a great overview of the implementation state of the Vehicle in several use cases.

Figure 6: ComboCS Test Case Mode

Each test case is provided with a description of the test, explaination of the successive steps, and the expected results with links to the normative requirements.
An indicative result is provided at the end of the scenario.

> **Posibility of custom developments**
> On demand, it is possible to update ComboCS in order to create test cases specific to your needs and projects.

EXPERT MODE

Using the expert mode, it is possible to modify at any time the nominal behavior of the EVSE ComboCS before or during the Charging Loop.

Expert mode allows to define precisely each values sent by the EVSE in a CCS communication. Some cases require synchronisation and timing that cannot be done manually. Therefore, such cases can be passed using the Test Case mode.

Figure 7: Expert mode interface

INSPECTION MODE

When ComboCS Inspection mode is enabled, all PLC trafic is redirected to a Wireshark opened on the operator machine, providing access to the raw Ethernet trafic from SLAC to ISO 15118-2 or DIN 70121 for further analysis.
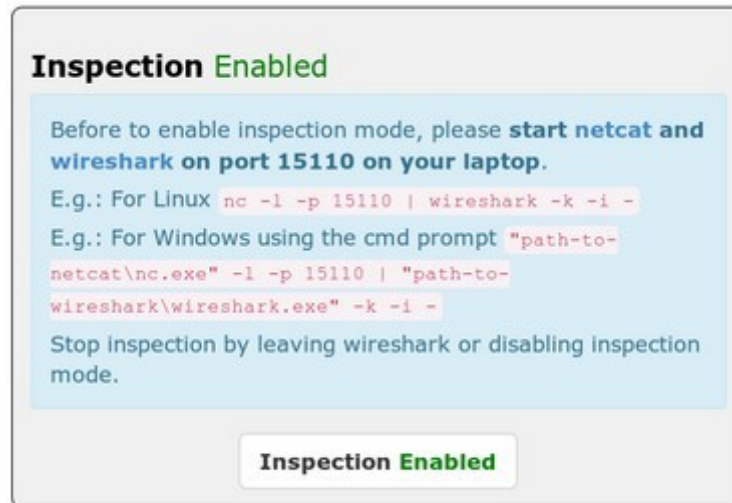
Figure 8: Bridge mode interface

Thanks to a Wireshark plugin developped by Trialog, provided with the tool, the Ethernet traffic is directly decoded in Wireshark and ready for analysis.
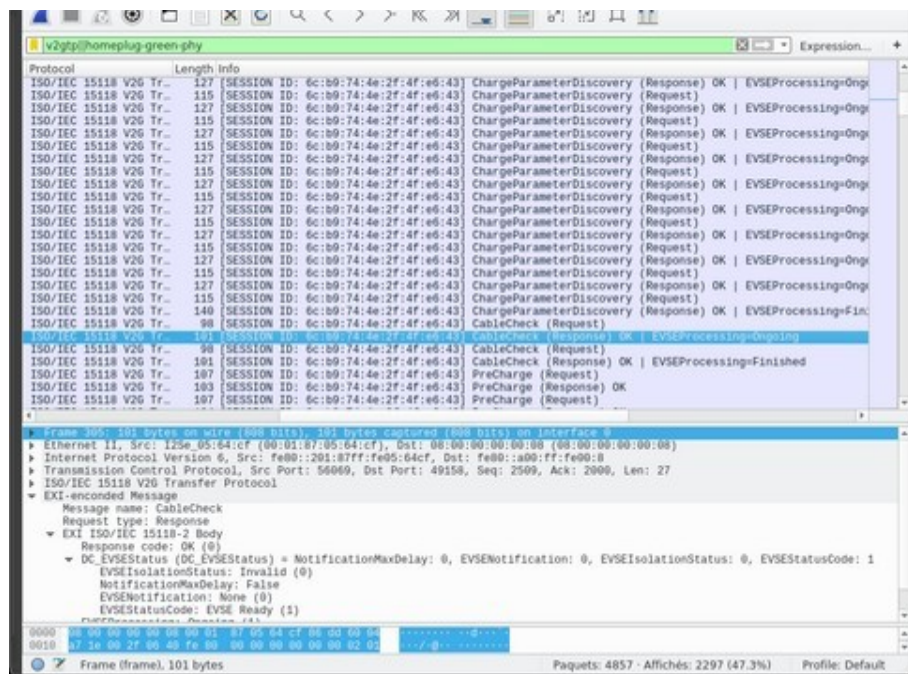
Figure 9: PLC traffic is available through Wireshark

This mode also allows to inject PLC trafic in an existing AVNL.

Please notice:

The CCS communication between the EV and the EVSE can sometime be encrypted with TLS, for example when using the PnC feature.

In order to uncrypt a secured communication, Wireshark shall be configured with a premaster secret generated using the TLS credentials of the charging station or the vehicle. A premaster secret is unique for each charging session.

Implementation in progress

The TLS premaster key will soon be accessible from the ComboCS UI for each session: download the PCAP file, dowload the premaster key and configure them into Wireshark to access the data.

ComboCS LEDs and GPIOs

Figure 10: Face 2 of the ComboCS

The ComboCS is provided with 6 LEDs indicating the progress of the charging session. At plugin LEDs are blinking and lighting one by one. If an error happen, LEDs are kept in their existing state to visualize quickly where it failed.

Meaning and behaviour of each LED is described below:

- **LED 1 : Control Pilot**
  - LED is off when unplugged (state A/E/F).
  - LED is blinking when plugged but not ready to charge (state B).
  - LED is on when plugged and ready to charge (state C/D). Therefore, for DC charge, it should become one at the beginning of the CableCheck process.

- **LED 2 : PLC Matched**
  - LED is blinking when the first SLAC message is received, until the end of the Matching process described in ISO 1511863 and DIN 70121.
  - LED is on when the SLAC process ifs finished with the succesful Matched state.

- **LED 3 : Cable Checked**
  - LED is blinking when the first SDP request is sent, just after the SLAC Matching process, until the end of the CableCheck process described in ISO 15118-2 and DIN 70121. A lot of steps are done in this stage (SDP, TCP/TLS connexion, Hadnshake, SessionSetup, Authorization, ChargeParameterDiscovery and also CableCheck for DC charge).
  - When CableCheck process is started, the LED 1 "Control Pilot" shall be on, since the EV is required to go to state C before CableCheck.
  - LED is on when the end of the CableCheck mechanism is reached.

- **LED 4 : Charging**
  - LED is on when the Charging Loop is reached (CurrentDemandReq in DC or ChargingStatusReq in AC)

- ○ This LED is always either on or off, it does not blink, in order to let the user use this GPIO as a a logical state to switch a charge relay.
- **LED 5 : End of charge**
  - ○ LED is blinking when the end of the charge is requested by the EV or the EVSE
  - ○ LED is on when the charging session is ended
- **LED 6 (red) : Test result**
  - ○ LED is blinking when the session result is "Failure"
  - ○ LED is on when the session result is "Success"

As a sumary:

- A LED is off when the related state is not yet reached.
- A LED is blinking when the related state is in progress. With an exception for PreCharge: LED 4 is kept off until Charging Loop is reached in order to let the user use this GPIO as a a logical state to switch a relay.
- A LED is on when the related state is finished.

Therefore, all LEDs are going off when unplugged.

The GPIO connector of the ComboCS is a mirror of the LEDs. It alows the GPIO to be used to read the digital status of the LEDs, and therefore to know the status of the charging session.
The LED 4 "Charging" is always either on or off, it does not blink, in order to let the user use this GPIO as a a logical state to switch a charge relay.

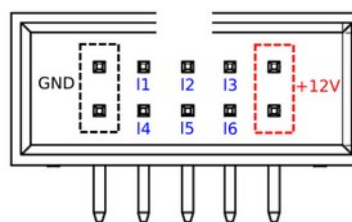The illustration below describes the pinouts of the GPIO connector:

Figure 11: GPIO pinout

GPIO Voltage: 3,3V, Max current: 10mA.
Female connector is not provided with the tool. Search for HCSD-05-D-11.40-01-N-G-R reference (10 pins, 2 entries, 2.54mm space between pins).

ComboCS Options

SW UPGRADE TO ISO 15118-20 EXTENSION

> This feature is an option, not provided by default in ComboCS. It is available as a software update.

> ***Development in progress***
> Implementation in progress. First release available since June 2022.

By default, the ComboCS only supports the original versions of the standard: DIN 70121 and ISO 15118-2. This SW upgrade enables the brand new ISO 15118-20 support on ComboCS.

This option provides the same feature basis as the default one but for ISO 15118-20. However, it does not provide any test case mode for ISO 15118-20 since conformance tests are not defined yet byt the normative comitee.

In order to simplify validation of ISO 15118-20, the tool allows to disable TLS or to use the TLS 1.2 mechanism defined in Iso 15118-2.

The following table is listing the current status of the implementation:

Use Case	Status
SDP	Available
V2GTP	Available
Protocol selection with SupportedAppProtocol	Available
AC unidirectional and bidirectional state machines Dynamic mode	Available
DC unidirectional and bidirectional state machines Dynamic mode	Available
AC unidirectional and bidirectional state machines Schedule mode	To be scheduled
DC unidirectional and bidirectional state machines Schedule mode	To be scheduled
TLS 1.3 with Mutual Authentication	Implementation in progress
Service Renegotiation	Implementation in progress

User Mobility Needs exchange	First version already available Implementation in progress
Plug&Charge Authorization	To be scheduled
Plug&Charge Contract Installation	To be scheduled
Pause & Resume	To be scheduled

SW UPGRADE TO OCPP EXTENSION

This feature is an option, not provided by default in ComboCS. It is available as a software update.

Development in progress
Implementation in progress. First release is already available with an almost complete OCPP implementation but a limited User Interface. A more complete release is excepted for December 2022. For more information, please contact us.

With the OCPP extension, the EVSE ComboCS4M could be used in any setup in needs of a Mode 3 or CCS EVSE implementation for OCPP validation. For example, to validate the correct behaviour of an OCPP 1.6 or 2.0.1 CSMS implementation.

The ComboCS4M OCPP configuration and CSMS endpoint can be configured from the Web interface.

Figure 12: OCPP configuration interface

The OCPP ComboCS4M is supporting both OCPP 1.6 and 2.0.1 versions. All OCPP messages are supported, but the OCPP ComboCS4M does not react necessarily to all of them. The following use cases are currently supported:

Use Case	Status
A01 - Update Charging Station Password for HTTP Basic Authentication	Available
A02 - Update Charging Station Certificate by request of CSMS	Validation in progress
A03 - Update Charging Station Certificate initiated by the Charging Station	Validation in progress
B01 - Cold Boot Charging Station	Available
B02 - Cold Boot Charging Station - Pending	Available
B03 - Cold Boot Charging Station - Rejected	Available
B04 - Offline Behavior Idle Charging Station	Validation in progress
B05 - Set Variables	Validation in progress
B06 - Get Variables	Available
B11 - Reset - Without Ongoing Transaction	Available
B12 - Reset - With Ongoing Transaction	Available

C01 - EV Driver Authorization using RFID	Available
C08 - Authorization at EVSE using ISO 15118 External Identification Means (EIM)	Available
C15 - Offline Authorization of unknown Id	Validation in progress
Additional UC: T-C01: Authentication through EVCCID	Not implemented yet
E01 - Start Transaction Options	Available
E02 - Start Transaction - Cable Plugin First	Available
E03 - Start Transaction - IdToken First	Available
E04 - Transaction started while Charging Station is offline	Available
E06 - Stop Transaction options	Available
E07 - Transaction locally stopped by IdToken	Validation in progress
E11 - Connection Loss During Transaction	Validation in progress
E12 - Inform CSMS of an Offline Occurred Transaction	Validation in progress
E13 - Transaction related message not accepted by CSMS	Validation in progress
E15 - End of charging process	Validation in progress
F03 - Remote Stop Transaction	Available
F04 - Remote Stop ISO / IEC 15118 charging from CSMS	Available
F05 - Remotely Unlock Connector	Validation in progress
F06 - Trigger Message	Available
G01 - Status Notification	Available
G02 - Heartbeat	Available
G03 - Change Availability EVSE	Implementation in progress
G04 - Change Availability Charging Station	Implementation in progress
J02 - Sending transaction related Meter Values	Available
K01 - SetChargingProfile	Implementation in progress
K02 - Central Smart Charging	Implementation in progress
K05 - Remote Start Transaction with Charging Profile	Implementation in

	progress
K06 - Offline Behavior Smart Charging During Transaction	Implementation in progress
K07 - Offline Behavior Smart Charging at Start of Transaction	Implementation in progress
K16 - Optimized charging with scheduling to the CSMS	Implementation in progress
K17 - Renegotiating a Charging Schedule	Implementation in progress
N01 - Retrieve Log Information	Validation in progress

Notes:
- About G03: a first version is already available, the EVSE replies correctly to a ChangeAvailability request but remains enable for next charging sessions.
- About K01, K02, J05, K06, K16 and K17: a first version is already available and working with limitations. Charging profile can be sent to the EVSE and will be correctly applied. However, sending multiple charging profiles with different ChargingProfilePurpose will not work properly and not generate a valid CompositeSchedule.

OCPP communication logs can be downloaded to analyse the OCPP connexion status and the last exchanged OCPP messages and OCPP errors.

NON-INTRUSIVE SNIFFER OPTION

This feature is an option, not provided by default in ComboCS. It requires to add some measurement hardware.

In Sniffer mode, the ComboCS does not simulate anymore an EV or a Charging Station, but is plugged directly between an EV and a Charging Station communicating using CCS. ComboCS can then snif passively the communication without interacting in any way with the PLC trafic. In such a mode, all PLC trafic is available on a dedicated RJ45 port, providing access to the raw Ethernet trafic from SLAC to ISO 15118-2 or DIN 70121. This trafic can be displayed on a Wireshark opened on the operator machine, for further analysis.
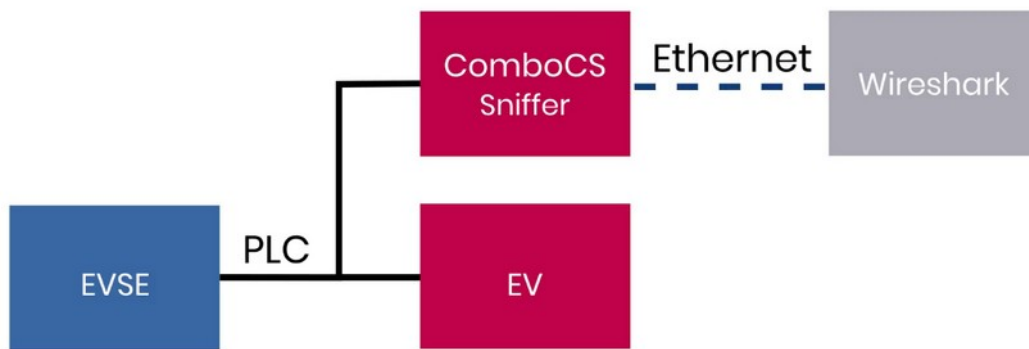
Figure 13: ComboCS + sniffer option

Thanks to a Wireshark plugin developped by Trialog, the same used in the Bridge mode described above, the Ethernet traffic is directly decoded in Wireshark and ready for analysis.
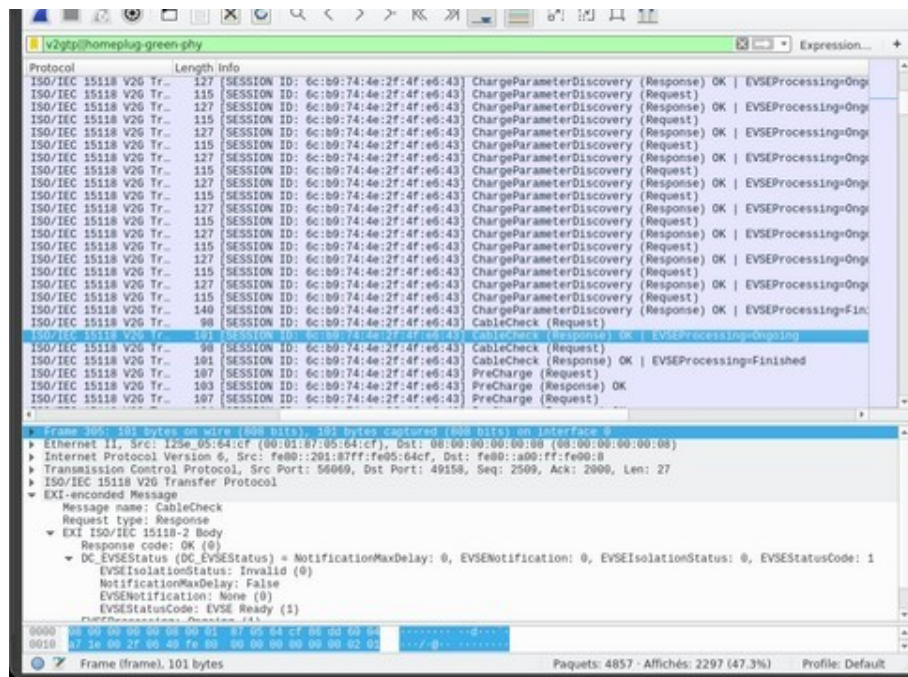

Figure 14: PLC traffic is available through Wireshark

Such a mode could have an impact on PLC power emission and shall not be used during PSD measurement.

PSD MEASUREMENT OPTION

This feature is an option, not provided by default in ComboCS. It is available as a software update and delivery of new hardware parts.

> **Specific development required**
> To fully automate the process, the CCS implementation shall be adapted to use the ComboCS interface, or a custom development is required on the ComboCS to put the CCS implementation in a dedicated measurement mode and change the PLC calibration.

In order to comply with ISO 15118 and DIN 70121, a CSS implementation shall emit a PLC level of -35dBm (i.e. -75dBm/Hz) for each PLC carrier beween 1.8MHz and 30MHz. The measurement shall be done at the Vehicle inlet , a calibration shall be done according the internal wiring of the Vehicle from the point of measurement to the PLC Modem.

The generic PSD Measurement option of the ComboCS facilitates the calibration of a CSS implementation. In this mode, the ComboCS shall be connected to a Vehicle that communicates permanently over PLC[1]. A specific development shall be done on the Vehicle to trigger such a communication. The ComboCS will then measure the PLC power emission on each carrier thanks to the setup defined in ISO 15118-3 and DIN 70121 summarized below.
The result is analysed and computed by the ComboCS in order to provide the delta to be applied on the Vehicle PLC Modem calibration.
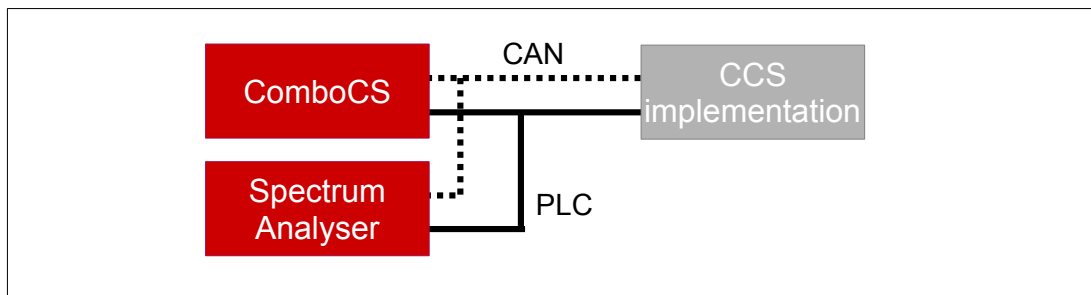
PSD measurement add-on basic setup

The ComboCS also provides a generic communication interface over HTTP to:
- trigger the permanent PLC communication on the Vehicle
- retrieve the current PLC Modem calibration of the Vehicle
- apply the new PLC Modem calibration of the Vehicle

If the Vehicle is adapted to integrate this communication interface, the PSD measurement setup could be completely automated. Otherwize, it requires several manuel steps.

A custom development can also be discussed with the *TRIALOG* team and added into the ComboCS in order to adapt the setup to your specific needs.

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1 Some other solution are available on the market, that do not required the implementation of this permanent communication over PLC on the Vehicle, but they are not compliant with ISO 15118-3 and DIN 70121.

POWER TRANSFER SUPPORT

In order to perform power transfer using DIN 70121 or ISO 15118 communication, you can plug your power modules for AC and DC to the ComboCS4M and use the LED4 GPIO and HTTP API to synchronize the tool with your power bench.

Trialog can provide hours of support to help your team during this integration process.

VDC261 and OPPCharge OPTION

This feature is an option, not provided by default in ComboCS4M. It is available as a software update.

Development in progress
Implementation of these specific modules for buses and trucks are still under investigation. For more information, please contact us.

ADDITIONAL ACCESORIES

Additional accessories are available.

	Additional Type 2 / BNC plug One is already provided with the tool.
	External 12V battery An external battery allows to use the ComboCS tool even when no AC high power source is available.

Annual Subscription

The ComboCS tool described in this document is ready to use. It has been tested and validated by the Trialog team, tested with several Vehicles in the field and during 3 Testing Symposiums and 3 CharIN Testivals and is currently used by more than 50 companies around the world.

The ComboCS is also still actively maintained by Trialog to fix eventual remaining bugs, test with new Vehicles, facilitate the usage of the tool, and ensure the correct behaviour of the Simulation mode regarding the current consensus of the normative groups and ISO 15118 User Group.

Access to releases

In order to provide such corrective and evolutive updates of the ComboCS, Trialog is proposing an annual subscription including:

- Access to corrective releases of the ComboCS
- Access to evolutive releases of the ComboCS

Trialog will deliver **at least one major release per year** to deploy new test cases, enhancement of existing features (same feature basis) and to fix remaining bugs that might have been detected.

Trialog can share its internal previsional roadmap but does not garanty any delivery planning in the scope of this annual subscription. A dedicated contract can be defined to adapt this roadmap to your company requirements.

Access to Trialog's hotline

In addition to the access of these releases, the subscription also offers access to Trialog's hotline through an online ticketing system. It can be used to ask questions about ComboCS usage and report issues encounter with the ComboCS.

Activation of the subscription on a yearly basis

The subscription is done on a yearly basis. The first year of the ComboCS subscription is already included when buying the tool. Subscription for upcoming years is done on the conditions defined when buying the tool if done continuously. In case of interruption, paying for the not covered period is necessary to get the update.

This subscription is strongly recommended by Trialog but does not modify the licence rights that can be acquired from Trialog. Your company will be able to continue to fully use the ComboCS without this subscription. However, without subscription, your company will not get access to any release nor Trialog's ticketing system.

Contact us

*For more information about **ComboCS**, please contact us:* emobilitysales@trialog.com.

Do you know CumboCS4M for End of Line testing?

Trialog has developped a simple version of ComboCS, the ComboCS4M, dedicated to Vehicle On-Board Charger End of Line testing: plug the ComboCS4M to your On-Board Charger and get a quick result about the status of PLC and ISO 15118 status to know if the system is ready or not to be used. The perfect tool for end of line testing or to managing curative maintenance.

Check below the differences between the 2 versions:

	ComboCS4M	ComboCS
Session History view	✓	✓
Supervision view	✓	✓
Simulation mode	✓	✓
Analogic output at charge startup	✓	✓
HTTP API	✓	✓
PCAP per session	✓	✓
Expert mode	Limited	✓
Test case mode		✓
Inspection mode		✓
SW upgrade to ComboCS option	Compatible	N/A
SW upgrade to ISO 15118-20 option *soon available*	Compatible	Compatible
SW upgrade to OCPP option *soon available*	Compatible	Compatible
Sniffer option	Compatible	Compatible
PSD measurement option	Compatible	Compatible
Custom development	Compatible	Compatible

ComboCS4M is the perfect tool for end of line testing and quick simulation.

Interested? Please contact us!