OCORA

Open CCS On-board Reference Architecture

Proof of Concept SUBSET-149

Results

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Management Summary

This report describes the findings from the proof of concept for SUBSET-149, which specifies in its current edition an online monitoring system for the ETCS system.

In the proof of concept, for one year two vehicles of a Swiss Railway Undertaking were equipped with OMS (Online Monitoring System) onboard units. For the onboard and server infrastructure as well as the SW implementation of the monitoring system, a system solution from the railway-experienced company Railnova was chosen in order to reduce risks. In regular operation the vehicles run exclusively on ETCS Level 1 LS lines.

Due to problems with data availability that could not be solved, final statements about the feasibility of the SUBSET-149 regarding the monitoring of ETCS on- and offboard are also based on data imported separately.

The main findings for the proof of concept are:

- Without the possibility to implement a standardised interface with a corresponding specification, for third-party providers it is a challenge to acquire the needed data in the given format and in its completeness.
- The data, data format and interfaces defined in SUBSET-149 allow implementing the monitoring function as defined in the NNTR CH-TSI CCS-026 "Online Monitoring of Trackside Equipment on Rolling Stock" at least to the same level as it is done today. The main difference between the currently operational solution and the solution based on SUBSET-149 is that currently the data is evaluated onboard, and the concentrated results are then sent to trackside. With SUBSET-149 the whole data is sent to trackside where the evaluation process has then to be performed.
- The data according to SUBSET-149 allows additionally a monitoring of the performance of the ETCS OBU to the extent that system reactions can be detected. However, it is not possible to diagnose which function or subsystem of the ETCS on-board led to an issue.
- The data volume to be expected when implementing the SUBSET-149 functionality is about 0.7 MB per hour for one ETCS on-board equipment. This corresponds roughly to the figures estimated during the development of SUBSET-149.
- For the operationalisation of SUBSET-149, agreements need to be made between the different organisations involved in the data processing regarding data access and transmission. Furthermore, the OMS wayside application needs to provide functions for data management, evaluation, filtering and forwarding.

Revision history

Version	Change Description	Initial	Date of change
0.x	▪ Initial draft	TF	19.06.2023
0.1	▪ Final version for OCORA Release R4	TF	30.06.2023
1.0	▪ Updated version for OCORA Release R5	TF	17.11.2023
1.2	▪ Review version for OCORA Release R6	TF	29.11.2024
2.0	▪ Final version for OCORA Release R6	TF	31.01.2025

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References

Reader's note: please be aware that the numbers in square brackets, e.g. [1], as per the list of referenced documents below, is used throughout this document to indicate the references to external documents. Wherever a reference to a TSI-CCS SUBSET is used, the SUBSET is referenced directly (e.g. SUBSET-026). OCORA always reference to the latest available official version of the SUBSET, unless indicated differently.

[1] OCORA-BWS01-010 – Release Notes

[2] OCORA-BWS01-020 – Glossary

[3] OCORA-BWS01-030 – Question and Answers

[4] OCORA-BWS01-040 – Feedback Form

[5] OCORA-BWS03-010 – Introduction to OCORA

[6] OCORA-BWS03-020 – Guiding Principles

[7] OCORA-BWS04-010 – Problem Statements

[8] OCORA-TWS15-050 – PoC SS-149 Concept description

[9] MVB ETCS Verkabelung_Rotstift.pdf - Red pencil drawing of the Railster and interposer integration in the MVB ring bus

[10] SUBSET-149: Online Monitoring System, Version 0.0.8

[11] SUBSET-027: FIS Juridical Recording, Version 3.1.0

[12] Generisches Lastenheft Online Monitoring auf ETCS Fahrzeugen, Version 1.3.3

[13] Investigation Railnova MVB Sniffer, Siemens

[14] SBB Infra // Subset 149 feasibility study: Conclusions, Version 1.0.0, Railnova

1 Introduction

1.1 Purpose of the document

The purpose of this document is to describe the results of the proof of concept of SUBSET-149 [10]. The development of [10] is in the responsibility of UNISIG as part of UNIFE in the working group for the implementation of CR 1362. OCORA project participants were also involved in the development as part of the RU resources on SBB side. This proof of concept was initiated to gain knowledge about implementation possibilities.

This document is addressed to experts in the CCS domain and to any other person, interested in the OCORA concepts for on-board CCS. The reader is invited to provide feedback to the OCORA collaboration and can, therefore, engage in shaping OCORA. Feedback to this document and to any other OCORA documentation can be given by using the Feedback Form [4].

If you are a railway undertaking, you may find useful information to compile tenders for OCORA compliant CCS building blocks, for tendering complete on-board CCS system, or also for on-board CCS replacements for functional upgrades or for life-cycle reasons.

If you are an organization interested in developing on-board CCS building blocks according to the OCORA standard, information provided in this document can be used as input for your development.

1.2 Applicability of the document

The document is informative. Subsequent releases of this document will be developed based on a modular and iterative approach, evolving within the progress of the OCORA collaboration.

1.3 Context of the document

This document is published as part of an OCORA Release, together with the documents listed in the Release Notes [1]. Before reading this document, it is recommended to read the Release Notes. If you are interested in the context and the motivation that drives OCORA we recommend reading the Introduction to OCORA [5], the Guiding Principles [6], and the Problem Statements [7]. The reader should also be aware of the Glossary [2] and the Question and Answers [3].

2 Framework of proof of concept

Within the framework of this proof of concept, the specifications from SUBSET-149 [10] are to be implemented in two test vehicles and an OMS wayside environment is to be created.

After various discussions on the feasibility of implementation on vehicles operated internationally by DB AG, as a company involved in the OCORA project, it was decided to carry out the proof of concept with a Swiss operator. As a result, two vehicles with a Siemens Baseline 3 SUBSET-26 version 3.4.0 ETCS system could be equipped with the OMS prototypes. In regular operation, the vehicles run exclusively on ETCS Level 1 LS routes. ETCS Level 2 routes are only operated sporadically in the event of short-term changes to the vehicle circulation.

Version 0.0.6 of SUBSET-149 was used as the basis for the implementation. A list of the implemented functions is provided in chapter 5. Since the test vehicles are not equipped with an ATO system and no custom messages have been defined so far, the information to be transmitted to the server side is limited to the messages according to SUBSET-027 [11].

Because a defined interface for the transfer of OMS data from the EVC has not existed up to now, the solution for the proof of concept had to choose a different data access point. From a safety point of view, however, it was absolutely necessary that the data access is implemented without any retroactive effect and thus while maintaining the currently valid safety verification for the ETCS system.

For Railnova's solution, an extensive verification dossier was available, which also includes an expert opinion on the non-intrusiveness of the reading device, the interposer. This allows the reading of data on the ETCS internal bus.

The proof of concept implementation takes advantage of Railnova services both for the OMS unit on the vehicle and for storing, viewing and evaluating the OMS data. In principle, the structure corresponds to the “Alternative architecture” described in chapter 3.2.4 of SUBSET-149.

3 Installation and implementation

3.1 Installation and data acquisition

As already described in the concept description [8] the Railster UG2 installation on the vehicle is relatively simple. It requires a sniffing device to read the data between the EVC and JRU on the MVB, a connection to the power supply protected with an adequate circuit braker, an antenna to receive the GNSS data, as well as to transmit via mobile network data to the server as well as grounding of the potentially current-carrying surfaces and parts in the event of a fault.

The Railster UG2 is a hardware device containing a Linux computation unit with digital and analogue interfaces. The Railster functionality is to read and process data from various sources and forward the data to the server. In case it is required the Railster may also store data temporarily.

The Railster UG2 has a GNSS input and transmits the data collected and processed through public mobile networks.

For the purpose of this proof of concept, only one data input is required. Data is only read via a sniffing device called “MVB interposer”, collecting the data non-intrusively. This is based on a two-stage principle:

First, the Railster UG2 is passive by design, as its internal MVB-dedicated FPGA is only reading the signals coming from the MVB Interposer cable. The Railster UG2 firmware doesn't include functions for implementing active MVB features. Second, the MVB interposer only sends a copy of the signals transmitted on the MVB network to the Railster UG2. This passivity by design ensures that the Railster UG2 cannot interfere with the MVB network. The Railster reads only the data from one of the two redundant MVB lines. The interposer is inserted as a DB9 connector at an existing connection point of the MVB.
The absence of retroactive effects is supported by technical analysis and an expert opinion.

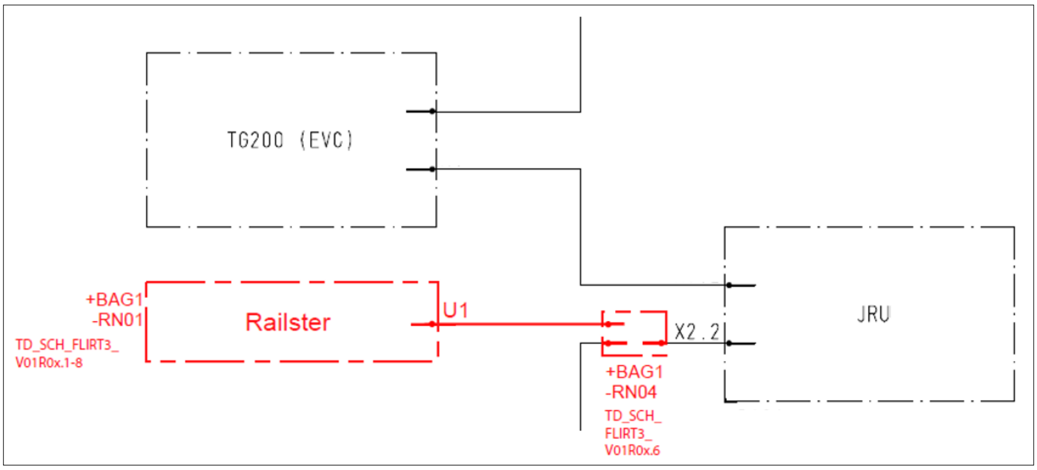

Figure 1 Excerpt from the red pencil drawing of the Railster and interposer integration in the MVB overview diagram [9]

The necessary GNSS/mobile radio combination antenna was placed under the GRP bonnet of the driver's cab. Sufficient distance to antennas of safety-relevant systems was ensured. The specifications of the GSM-R network operator and Swiss GSM-R system manager SBB Telecom are complied with.

The power supply is protected by a separate two-pole CB. The Railster is directly connected to the battery voltage and is thus charged even without the main switch being switched on.

Figure 2 Photo of the Railster installation in the ETCS cabinet
From top to bottom: the Railster UG2 mounted on a slide-in unit, the JRU HaslerRail Teloc 3000 as well as the MVB interposer installed on the JRU-MVB connection X2.2 and the Siemens EVC Trainguard 200.

For the installation, compliance with common railway standards (EN 50155, EN 45545 as well as IEC61375-3-1), as well as further specifications for EMC and antenna positioning of the GSM-R system leader in Switzerland were evaluated. Following each installation, commissioning tests and a SIOP-B were carried out.

The duration of installation of the two test systems on the vehicles is shown in **Table 1**.

Unit #	Integration of test system	Removal of test system
Unit #1	12.01.2023	28.08.2024
Unit #2	15.05.2023	16.07.2024

Table 1 Duration of the installation of the two test systems

3.2 Software implementation

To prove the functional suitability of the SUBSET-149, the existing Railnova SW suite was used. Adaptations were only implemented explicitly where the SUBSET-149 specifies a different solution.

As a general approach the Railnova SW stack is based as much as possible on open-source software subject to long term support releases and permissive licenses such as MIT or BSD. The data transfer between Railster and server is done via MQTT. The Railster devices communicate over the mobile network (GPRS/3G/4G) using TLS1.2 encryption. For the purposes of the SUBSET-149 proof of concept, only mobile data transmission is used. When connected to the mobile network, the Railster is within a private IP network using Network Address Translation (NAT) to connect to Railnova's servers. More specifically, it means that the Railster has a local IP only.

The setup also offers the capability to check for, transmit and execute over the air updates of the firmware, OS patches and Linux Kernel updates to cope with security related updates.

The OMS data is stored on Railnova's servers. The view of the data is possible via a web-accessible dashboard. The platform also allows the creation of rules for the triggering of alerts.

To protect the on-board and off-board equipment from unauthorised access, Railnova has implemented extensive technical measures, specifications and processes, which will not be further elaborated.

As described above, the data of the MVB is read and decoded by the FPGA according to the different layers of the data stream, the relevant data is identified according to SUBSET-027 and the format is transposed according to SUBSET-149.

SUBSET-149 does not actually provide for decoding the message content.

```
"definitions" : {
         "EtcsMsg"          : { "Header"       : {"ref": "EtcsMsgHeader"},
                                     // Header of SUBSET-027 ETCS message
                            "        EtcsDataBase64" : {"type": "string", "nullable": true}
                                     // Content of SUBSET-027 ETCS message encoded to Base64
                            },
                  },
```

Figure 3 Specification for ETCS message content in SUBSET 149, chap. 3.3.3 [10]

In order to be able to generate the alarms in accordance with the specifications of the Swiss Online Monitoring System [12] within the proof of concept the message type NID = 6 and NID = 12 are also decoded, unlike in SUBSET-149. It is not necessary to make the complete content readable, but only those variables which are relevant for the Swiss OMS.

NID_Message 12 BALISE GROUP ERROR

- NID_C
- NID_ERRORBG
- M_ERROR

NID_Message 6 TELEGRAM FROM BALISE

- NID_C
- NID_BG
- M_COUNT
- NID_PACKET

For the NID = 6 messages, it must be taken into account that these can contain several telegrams (NID_PACKET).

Not implemented for resource reasons were the decoding of the content of packets of NID = 6 -messages. As the information of loop announcements (EOLM packet) was not analysed, it was not possible to detect loop faults (fault code K07 of the Swiss OMS).

In addition, no rule has been implemented that takes into account balise errors when starting up a vehicle. This concerns the special situation of vehicles that come to a standstill with their balise antenna directly above a balise group. In various situations of ‘joining, splitting, turning’ and also in other situations, the vehicle must be restarted (rearmed) in this position. The balise group under the vehicle could be incorrectly declared as faulty. In the Swiss OMS, the generated messages are assigned to the fault code K71.

4 Proof of concept experience

4.1 Data validation

To reduce risks and ensure feasibility, Railnova as potential supplier for the proof of concept was invited to carry out tests on the vehicle in June 2022.

During this visit, based on Railnova's know-how and knowledge of the MVB implementation in other projects, an attempt was made to make the data on the MVB readable in relation to SUBSET-027. From this site visit, specific activities for the implementation of the readability of the necessary signals could be defined, the feasibility in principle was assessed as positive.

After the installation of the first unit and for data validation, JRU data was read from the vehicle, the data according to SUBSET-027 was converted into a readable format, and then compared with the records of the OMS. The comparison showed, however, that only roughly half of the data was processed by the OMS.

The situation will be exposed in more detail below in order to highlight the challenges of the non-proprietary solution that is independent of the OBU supplier.

Figure 4 represents the NID_MESSAGE of detected messages over the recording duration for the data of the first installation, whereas each point indicates a detected message. As defined in SUBSET-027, a message every five seconds would be expected. As can be clearly recognised in this specific example, there's a gap of approximately two-minutes in the data, which is repeated cyclically, meaning that this phenomenon occurs periodically.

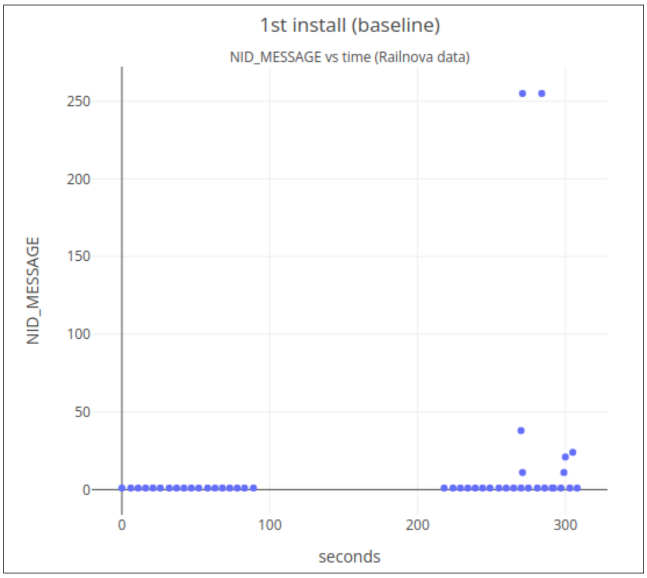

Figure 4 First installation: Representation of NID_MESSAGE of detected messages over the recording duration, each point describes a detected message.

The data acquisition alternates between high acquisition rates (>~95%) and low acquisition rates (~ 0%). In total only about 48% of the data packets are processed by the OMS (compared to the JRU data).

This was observed in both vehicles, but with different characteristics: While virtually no messages at all could be read in the two-minutes gaps in the first installation, this is not the case in the second installation, meaning that here other messages on the MVB, beside the messages according to SUBSET-027, could be detected. However, here too, no messages concerning the SUBSET-027 and the JRU could be read.

To further isolate the cause, a double interposer was used during the second installation so that the two redundant lines of the MVB could be read. Having the double interposer installed shouldn't have changed anything. But it did.

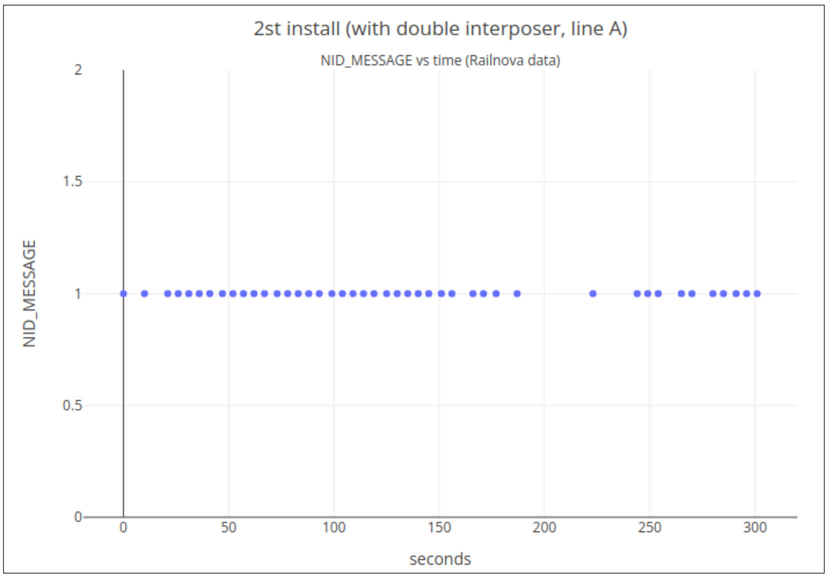

Figure 5 Second installation, double Interposer, MVB line A: Representation of NID_MESSAGE of detected messages over the recording duration

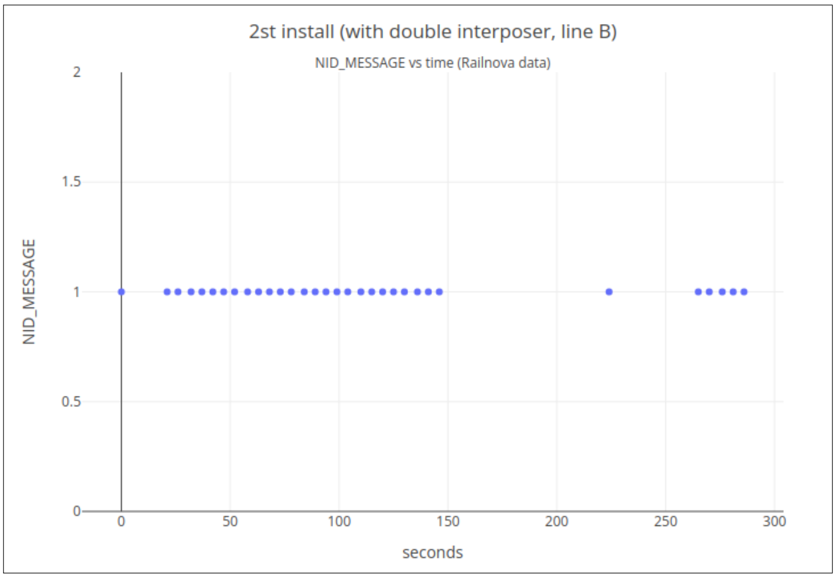

Figure 6 Second installation, double Interposer, MVB line B: Representation of NID_MESSAGE of detected messages over the recording duration

Figure 5 and **Figure 6** show the messages according to SUBSET-027 received over time with the double interposer installed within the same period. The "Line A" figure shows the data on the A line of the MVB; "Line B", on the B line of the MVB. Sensibly it was expected that the data on the two different lines would be the same.

Also, when looking at the detection rate of the overall MVB messages with the double interposer installed, the data acquisition rate is much better on “Line A” than on “Line B”. And both are better than with the simple interposer installed. Again, assuming no significant difference regarding transmitted data and signal quality between both lines, the only varying factor is the cabling / interposer.

To conclude, it can be stated that the MVB signal quality at the specific connection points fluctuates with a two-minute periodicity. These variations are not significant enough to affect the JRU data acquisition, but somehow, they do impact the MVB interposers to different extents. This suggests a signal loss on the analogue level that isn't considered in the implemented setup, yet, but also isn't present in any other fleet Railnova is familiar with.

However, the next steps would be to change the data access point, checking whether the same occurrences can be seen also there. Further, it would be required to collect extensive analogue-level data to pinpoint where exactly the signal is losing integrity.

In a further vehicle test on the vehicle on 07.07.2023, the interposer was placed at other interfaces, directly at the MVB port of the EVC (X4) and at the second port of the JRU (X3.2). The tests were repeated with both, the standard and the double interposer, which records both MVB lines.

During the tests, the same behaviour was observed as before as shown in **Figure 7**. Accordingly, the involvement of the ETCS supplier Siemens was driven forward following the test. Following consultation with the operator of the vehicles, a further vehicle test was set up.

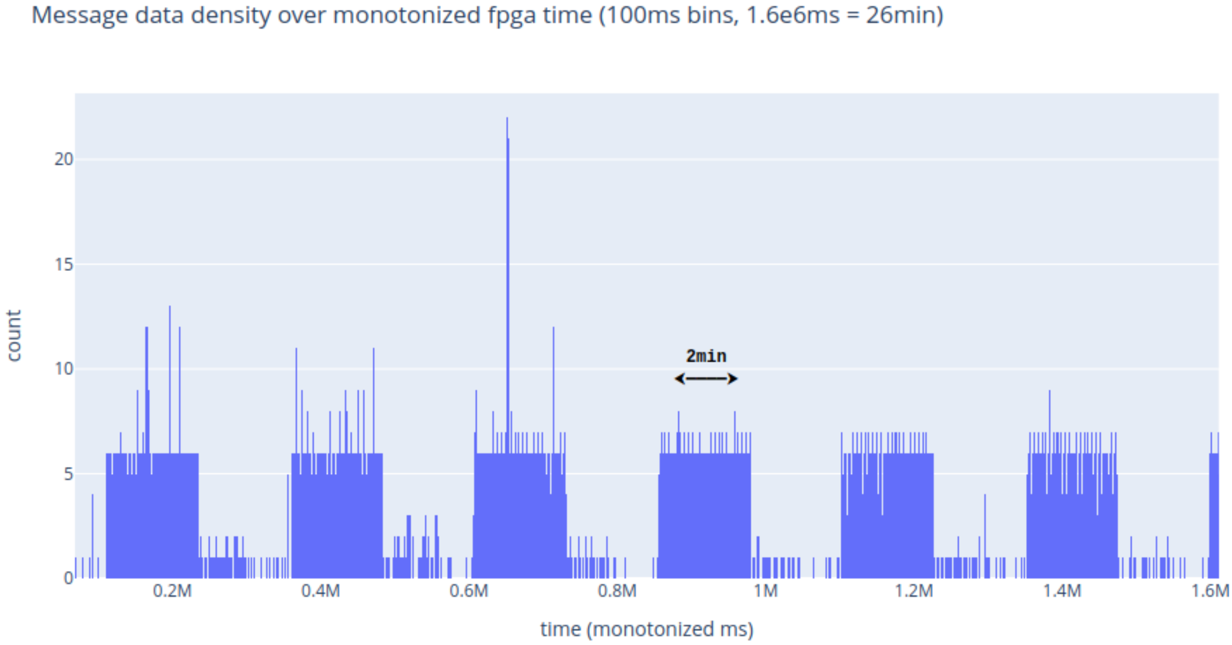

Figure 7 Additional vehicle test: Message density at port X4

The tests were carried out on 12 December 2023 in with representatives from Siemens, Railnova, the keeper and SBB.
It became clear that the special behaviour of the ETCS communication and the structure of the sniffing device and data acquisition are the main cause of the missing data recordings:
The investigation and measurements have confirmed that the quality of the received MVB data by the interposer of line A fluctuates every 120 sec. The main reason is the change of ownership of the four MVB bus master every 60 sec and the possible switching off of the master frames either on line A or line B of the redundant MVB bus. The interposer is only connected to the line A, whereas all the other devices are connected to both lines. The other devices select the master frames from the so-called trusted line and are therefore not affected. During normal operations, the receiver of these devices toggles from line A to line B and vice versa. The Railster can only process a slave frame on line A if previously a master frame has been sent on line A.
Two of the possible bus masters are located at the near end of the MVB bus and two of them are located at the far end. The ownership of the MVB bus master changes therefore every 120 sec from the near end to the far end. The line length from the active bus master to the other slave devices changes therefore over a distance of more than 100 meters. Noise on a long line could have more influence than on a short line due to damping of the signal.
Additionally, the thresholds of the receiver on the interposer are lower than required by the standard (see chapter 4.1) and has therefore less noise immunity than other devices. Measurements with noise on the lines were not done, because of the problems with the master frames [13].

The rationale was that despite the intermittent absence of master frames, the slave frames would consistently be present. Consequently, by focusing on parsing only the slave frames within the specific confines of this MVB data acquisition project, it was anticipated that sufficient consistent patterns could be identified to effectively filter the slave frames, even without their corresponding master frames. With access to those slave frames, Railnova could then extract the SUBSET-27 packets, similarly to how it would've been handled under ideal conditions. After updating the FPGA code, Railnova successfully collected more packets: However, the data from these packets were not valid.

For instance, their size was not consistent, as would be expected based on the MVB Message Data specification.

```
rug2-3481[~]# msgdump -c mvb1 -f | awk -F ',' 'substr($5, 1, 1) == "C" { print $0 }'
268668023,11,C0,38,C00610048007B0FFFF8FD5FE9DFFFFFFE6C180FFFFFFFDFFEAEBFFFFFFD1E5FBEB87FF9030DC
268674957,11,C0,34,C0041006800408000A000A4139D07000000000000000000000000000000000000000
268687957,11,C0,38,C006100480061000A80E8EA9FFFFFF4F3F5B7FFFFFDF7FFEAFFFFFFFFD1E5FBEB87FF909210
268690957,11,C0,34,C0041006800405000A000A6139D07000000000000000000000000000000000000000
268695957,11,C0,34,C004100680040D000A000A003F6100000000700054085811AFFCC4CCCCE080808080
268708957,11,C0,34,C0061004800608000A000AC13F617000000000000000000000000000000000000000
270092939,11,90,39,C00E95ED100480061B000A00380A8039D1000000193970000000000A000A8500000000BA0D013D
270098939,11,C0,34,C0041006800408000A000A4139D17000000000000000000000000000000000000000
270107938,11,C0,34,C0061004800610000A000A9800000A0B06020000000D410A000A00000000BA0D013D
270110938,11,C0,37,C0041006800405000EFFEFD6EC8BC0FFFFFBFFFFFFFFFFFFFF80FFFFFFFFFFFFFFFE909210
270116938,11,C0,34,C004100680040D000A000A003F6200000000700054085811AFFCC4CCCCE080808080
270128938,11,C0,37,C0061004800608000A002AF6F6D8FFFFFFD4FFFFFFFFFFFFFFFEFFFFFFFFFFFFFFFE909210
271467921,11,C0,38,C006100480061B000A000A8039D2000000197000000020F5FFD5D7FFFFFFA2E5FBEE97909210
271473921,11,C0,34,C0041006800408000A000A4139D27000000000000000000000000000000000000000
271487917,11,C0,34,C0061004800610000A000A9800000A0B06020000000D410A000A00000000BB0D013D
271490920,11,C0,34,C0041006800405000A000A6139D27000000000000000000000000000000000000000
271495920,11,C0,34,C004100680040D000A000A003F6300000000700054085811AFFCC4CCCCE080808080
271508920,11,C0,38,C0061004800608000A000AC13F9CC0FFFFF59FFFFFFFFFFFFFE0C0FFFFFFFFFFFFF0EF909210
271834916,11,C0,37,C004100680041BFFEDFDE09FE090FFFFFCD6DCFFFFFFFFDBFFBFFFFFFFFFFEF8CEDCD909210
271847916,11,C0,39,C0061004800608000900009413F647020FFFFC3FFFFFFFFFFFFFEFCFFFFFFFFFFFFFFFEFF909210
271850916,11,90,43,C00437ED100680041B0009009E0990C89A180E30FEFD049D54085811AFFC70C4CCCCE0827FFDFBA7909210
271853916,11,90,37,C00434E4EFF3F6FFEDFFFE9980FDFBF7EFFFC0BFFFF6E8FCE1DCB9F9C5DF9FF3D3A2909210
271887915,11,C0,38,C006100480060D000900090039D300000000700000D410A000A02FFFFFDD897ECBB9F909210
271890915,11,C0,34,C00410068004080009000 9C139D37000000000000000000000000000000000000000
272328713,11,90,39,C0AABEDAFFFFFFFFFFFFFFFEFFFFFFFFFFFFEFF9CFFFFFFFFFFFFFFFFEFFFFEBECD6E68083909210
272731310,11,80,39,C2ECBBED9A520000000000000430000000000000000FF0000000000000000FF0000000000000000
272868504,11,C0,34,C006100480061B000A000A8039D4000000197000000000A000A00000000BC0D013D
272874504,11,C0,34,C0041006800408000A000A4139D47000000000000000000000000000000000000000
272888504,11,C0,38,C0061004800610000A000A9800000A0B06020000000D410A000EFFFFFFFFD0F9FDEDC7909210
272891569,11,C0,34,C0041006800405000A000A6139D47000000000000000000000000000000000000000
272896502,11,C0,34,C004100680040D000A000A003F6500000000700054085811AFFCC4CCCCE080808080
272908504,11,C0,39,C0061004800608000A1241EAFEF6A8FFFFFFB0FFFFFFFFFFFFFFFFEFFFFFFFFFFFFFFFFEFF909210
```

Figure 8 Increased Packet Capture

Railnova then dug deeper into the MVB signal and discovered that the collision rate was higher than expected.

As a potential corrective measure, Railnova also implemented a signal debouncer to address those particular signal issues. However, this did not improve the overall data acquisition yield, suggesting a more fundamental issue with the signal, which couldn't be addressed by software alone [14].

As a technical solution would have required adjustments to the Sniffer and thus also to the safety case, further tracking was stopped.

In order to at least increase the data completeness, the read data was extended with JRU data. To do this, the JRU data was downloaded from the vehicles, the data exported and then imported into the monitoring system. This made it possible for data to be fully available between April and August 2024.

For the SUBSET-149, it can be summarised that without the possibility to implement a specific and standardised interface with a corresponding specification, for third-party providers it is a challenge to acquire the requested data in the given format and in its completeness.

4.2 Observed anomalies

4.2.1 Infrastructure monitoring

As part of the proof of concept, alerts on infrastructure faults have been compared with data from the SBB Infrastructure - Online Monitoring System.

The SBB Infrastructure specifications [12], which define the requirements for fault monitoring, describe in section 5.2 the different types of fault messages that should be generated by the on-board unit in the event of detected anomalies on the infrastructure side.

The following table shows the fault message as provided by SBB Infrastructure with the comparison of the generated alarms from the PoC system. If the same alarms could be triggered with the test system, the result is rated OK.

In some cases, alarms are not available because they should be generated within the two minute gaps or because the vehicle was travelling in a test configuration to check the software approach to achieving data completeness.

Unit #	Timestamp	Fault Code OMS	Failure description	Result
Unit #1	04.01.2024 17:21:40	S34	Balise input fault (ZUB262ct or ETCS)	OK
Unit #2	17.01.2024 17:35:53	K77	Linking error	2 min gap - No Data
Unit #2	17.01.2024 17:36:27	K77	Linking error	2 min gap - No Data
Unit #1	19.02.2024 17:35:00	K77	Linking error	2 min gap - No Data
Unit #1	19.02.2024 17:35:31	K77	Linking error	2 min gap - No Data
Unit #2	12.03.2024 17:55:30	K78	Inconsistent balise group with linked balises	2 min gap - No Data
Unit #2	24.03.2024 14:29:23	S34	Balise input fault (ZUB262ct or ETCS)	OK
Unit #2	11.04.2024 10:31:49	S34	Balise input fault (ZUB262ct or ETCS)	OK [1]
Unit #1	24.04.2024 09:01:34	K78	Inconsistent balise group with linked balises	Test phase - No Data [2]
Unit #1	31.05.2024 01:03:22	S33	Input fault LEU (ZUB262ct or ETCS)	OK [1]
Unit #2	23.06.2024 14:55:18	K78	Balise Consistency Error	OK [1]
Unit #1	14.08.2024 00:38:42	S33	Input fault LEU (ZUB262ct or ETCS)	OK [1]
Unit #1	20.08.2024 17:47:53	K77	Linking error	OK [1]
Unit #1	27.08.2024 20:18:44	S33	Input fault LEU (ZUB262ct or ETCS)	OK [1]
Unit #1	28.08.2024 17:35:02	K77	Linking error	OK [1]

Table 2 Identified faults code of the SBB Infrastructure OMS and comparison with alarms in the test system

Euroloop errors (fault code K07) are not shown as these were not created by PoC configuration. Messages according to fault code K71, which are generated by operational circumstances were not taken into account in the list.

4.2.2 Onboard monitoring

To identify the added value of the SUBSET-149 in terms of detecting issues on the onboard side, it was possible to compare the stored data with the vehicle diagnostics recording.

Regarding the ETCS system, the following issues are relevant over the observation period from January 2024 to May 2024:

Unit #	Timestamp	Failure description	Result
Unit #1	25.01.2024 09:45:31	ETCS: System failure	OK

[1] These error messages could be subsequently reproduced by importing JRU data. The error messages actually fell within the 2-minute gap for which no data could be read, or the onboard units were already deactivated.

[2] In order to test the implementation for decoding the data using the slave frames, the active configuration on the Railster was replaced by a test configuration within this week. During this period, the read data was not assigned to the productive data tables.

Unit #2	05.02.2024 14:44:22	ETCS: Time disturbed	No info
Unit #2	12.02.2024 08:31:12	ETCS: System failure	2 min gap - No Data
Unit #2	12.02.2024 08:31:14	ETCS: Brake test failed	No info
Unit #2	18.02.2024 00:02:08	ETCS: System failure	OK
Unit #2	16.04.2024 09:35:40	ETCS: Mode not plausible	No info
Unit #2	24.04.2024 09:51:33	ETCS: System failure	OK
Unit #2	28.04.2024 16:02:12	Several Messages ETCS Vact-Deviation too high	Hints in confidence interval
Unit #2	16.05.2024 14:26:47	ETCS: Mode not plausible	No info
Unit #1	31.05.2024 13:19:13	ETCS: System failure	OK

Table 3 Identified error messages of onboard vehicle diagnosis and comparison with alarms in the test system

Furthermore, there were several brake applications triggered by ETCS during operation, which are also represented in the OMS alarms.

Decoding of additional EVC messages that would make it possible to understand the system behaviour and the actions from the perspective of the train driver on the server side, e.g. NID message 21 - DMI SYMBOL STATUS, 23 - DMI SYSTEM STATUS MESSAGE or 11 - DRIVER'S ACTIONS, was not carried out.

Overall, it can be stated that although the data according to SUBSET-149 and SUBSET-027 allow a monitoring of the performance of the ETCS OBU to the extent that system reactions can be detected. Based on the defined SUBSET-027 data, it is not possible to diagnose which function or subsystem of the ETCS on-board led to the fault. From the point of view of the entity in charge of maintenance, it is desirable that faults or defects can be localised more precisely for the planning of corrective measures.

4.3 Volume of data stream and storage

Within the setup of the proof of concept, the data volumes indicated in **Table 4** were handled with regard to data acquisition and storage in a specific test period.

It should be noted that for the first unit, the date of activation does not coincide with the date of installation. This is because, although data was read from the time of installation, it could only be viewed in a structured manner after the server-side implementation.

	Date of OMS activation	**OMS operating time**	**# of OMS messages**		**Volume of OMS data**	
			measured	corrected	measured	corrected
Unit #1	29.03.2023 15:25	82 d, 21 h	737'600	1'536'700	647 MB	1'348 MB
Unit #2	15.05.2023 11:32	36 d, 01 h	358'600	747'083	315 MB	656 MB

Table 4 Representation of the volume of data stream and storage, the corrected values respect a data acquisition rate of 48 %

The operating time of the OMS can be simplified as the operating time of the vehicle. The vehicles are not switched off even when stationary, so that at least GENERAL MESSAGES are generated every 5 seconds.

If we also consider the availability of the OMS data for only about 48% of the whole generated data, the following averaged values for one hour of operation result, based on OMS data exclusively containing messages according to SUBSET-027:

- Number of messages ca. 850 messages per hour
- Volume of OMS data 0.7 MB per hour

4.4 SUBSET-149 analysis from monitoring and operationalisation perspective

4.4.1 Feasibility for infrastructure monitoring: Comparison with the requirements of Swiss ETCS System Manager's Online Monitoring System

In the generic ETCS System Manager's Guide for Online Monitoring on ETCS Rolling Stock in Switzerland, which is used as part of the Notified National Technical Rules in Switzerland (NNTR CH-TSI CCS-026 "Online Monitoring of Trackside Equipment on Rolling Stock", version 2.1), the functional requirements for fault and positive messages from OMS systems, implemented on rolling stock with ETCS BL3-OBU, are defined in chapters 3.1 and 3.2.

The notifications to be generated are based on Track-To-Train telegrams (or messages) content, as well as on status parameters of the ETCS system (train number, time and date, train position reports).

For the SUBSET-149 it can be summarised, as the information is part of the data transmitted to the JRU according to SUBSET-027, that this data is available in the messages according to SUBSET-149. From a Swiss point of view, this allows implementing the monitoring function of the ETCS offboard elements at least to the same level as it is done today.

The main difference between the currently operational solution and the SUBSET-149 is that currently the data is evaluated onboard, and the concentrated results are then sent to trackside. With SUBSET-149 the whole data is sent to trackside where the evaluation process has then to be performed.

4.4.2 Feasibility for Onboard monitoring

In addition to the monitoring of fix defined messages according to the SUBSET-027, additional messages can be recorded with the NID_MESSAGE 255 - ETCS ON-BOARD PROPRIETARY JURIDICAL DATA. These messages can also be defined on behalf of a vehicle owner by the OBU supplier. The practicability of this implementation, respective the consideration of a possibility to configure these messages in the context of the gradual further development, conditional recertification, and the associated costs, depends on the implementation of the OBU supplier.

For the SUBSET-149, it can be stated, that the subset also allows the generation of additional messages with the creation of custom messages. However, it must be taken into account that this is done by the onboard device of the OMS, thus only data transmitted by the EVC or other onboard sources are available for the message generation.

On any account, a flexible technical solution should be implemented for the management of the OMS onboard application regarding custom messages.

4.4.3 SUBSET-149 operationalisation

So far, the operationalisation of SUBSET-149, and thus also legal issues, is not part of the working group. Also, in the context of the proof of concept, the situation of the vehicles could not be emulated according to the complexity of international traffic. The following considerations are therefore based on indications of the previous version of the SUBSET-149 (available at the setup time). The latest version 0.0.7, which was issued on 16.06.2023, does not include these points yet, but the need for agreements to enable the exchange of data between the involved parties is included as remarks.

Due to the internationalisation and liberalisation of rail transport, especially rail freight transport, in recent years there has been a market segregation in fleet responsibility. As a result, the business model of the classical integrated operator, which is owner, keeper (and ECM) and exclusive operator of the vehicles, is becoming increasingly rare. Instead, transports are handled in partnerships of several RUs across national borders with the common use of the same traction unit. Further, traction units are rented from leasing companies on a short or medium-term basis, whereby the keeper responsibility mostly remains with the keeper.

According to chapter 5.3.1.1 of SUBSET-149, the data of an OMS should always be transmitted to the same server without handover between different servers. The server address is subsequently part of the (static) configuration data, see chapter 5.3.1.2. Implicitly, the responsibility for the OMS wayside server is thus attributed to the vehicle owner.

Since the train operations are in the responsibility of the different RUs which have registered the train journey at the respective infrastructure managers, to the users only access to the specific data is granted that is relevant for the train journey they are considered as responsible for. To implement this in an automated way, the train routing information must be provided by the IM. The assignment of the OMS SUBSET-149 data of a specific vehicle to the respective RU can then be realised depending on the implementation of the signalling infrastructure by evaluating either the train number, or the timestamp and the GNSS position data from the header of the SUBSET-149 messages, alternatively the train position data (NID_LRBG) from the header of the SUBSET-027 message can be used.

To pass the information from journey data to the infrastructure managers, agreements between the RUs and IMs and possibly between keepers and RUs are also necessary. This can be done via obligations in the form of NNTRs, or the inclusion of corresponding requirements in the network access agreement, and/or possibly via separate bilateral agreements. At the same time and although the driver ID is removed, from a data privacy point of view, it is not realistic that IMs have access to the complete data according to SUBSET-149, but only have access to information that is relevant for the provision of their infrastructure services. A complete data access, it would enable an IM to continuously monitor journeys, making it easier to identify misbehaviour of driving personnel, e.g. exceeding the permitted line speeds below the intervention threshold, incorrect switching of ETCS modes, braking due to causes other than the train protection system, etc.

The same applies to additional custom messages, which can be defined by the OBU manufacturers (or others). The forwarding of these messages to the designated party also requires corresponding agreements between the parties with access rights related to the data and the onboard equipment.

It can therefore be summarised, that in addition to agreements between the parties regarding data access and transmission, the OMS wayside application needs to provide functions for OMS data management, filtering and forwarding. Besides general issues such as security, these specific functions can be summarised based on the above considerations as follows:

- acquisition and processing of routing data from the infrastructure managers. This is used for allocation of the SUBSET-149 data to the relevant RU.
- allocation and forwarding of SUBSET-149 data to the responsible RUs.
- filtering of SUBSET-149 data and provision of information according to the agreements to the relevant infrastructure managers.
- forwarding of custom messages from the SUBSET-149 to the OBU manufacturers (or others).
- flexible configuration of the interfaces for data and information forwarding in terms of recipient, active period, data provided and information depending on country of operation, RU and network operator.

5 Appendix

Functionalities of SUBSET-149 considered in the proof of concept, according to SUBSET-149 version 0.0.5, but already including the proposal of JSON formatting are shown in **Table 5**. In terms of content, the differences between the SUBSET versions 0.0.6. and this version 0.0.5 are exclusively of editorial nature.

Furthermore, it should be noted that the changes in version 0.0.7 mainly concern editorial adjustments and restructuring of the chapters. In terms of content, the requirements from version 0.0.5 considering also the JSON format are congruent with version 0.0.7 in the relevant points.

Chapter	Reference	Description	Comment in implementation
3		OMS Architecture	
3.1		Logical architecture	
	3.1.1.1		OK
3.2		Physical architecture	
3.2.1		OMS On Board	
	3.2.1.1	OMS On Board	OK
	3.2.1.2	OMS On Board	OK
	3.2.1.3	OMS On Board	OK
	3.2.1.4	OMS On Board	OK
3.2.2		Radio Infrastructure	
	3.2.2.1	Radio Infrastructure	OK
	3.2.2.2	Radio Infrastructure	OK
	3.2.2.3	Radio Infrastructure	Not part of this phase
	3.2.2.4	Radio Infrastructure	Not part of this phase
	3.2.2.5	Radio Infrastructure	OK
3.2.3		OMS Wayside	Railnova's backend is used the Wayside of the "OMS alternative architecture".
	3.2.3.1	OMS Wayside	Not part of this phase, same server will be used for all countries
	3.2.3.2	OMS Wayside	OK
	3.2.3.3	OMS Wayside	Connection between Railster and Wayside is based on MQTTS, TLS encrypted
	3.2.3.4	OMS Wayside	Not part of this phase
3.2.4		Alternative architecture	
	3.2.4.1	Alternative architecture	OK. This is the architecture used for this phase
4		OMS On Board Interfaces	
4.1		OMS - ETCS Interface	
	4.1.1.1	OMS - ETCS Interface	Not part of this phase
	4.1.1.2	OMS - ETCS Interface	Not part of this phase
	4.1.1.3	OMS - ETCS Interface	Not part of this phase
	4.1.1.4	OMS - ETCS Interface	OK
	4.1.1.5	OMS - ETCS Interface	Not part of this phase
4.2		OMS – GPS Interface	
	4.2.1.1	OMS – GPS Interface	OK

Chapter	Reference	Description	Comment in implementation
	4.2.1.2	OMS – GPS Interface	OK
	4.2.1.3	OMS – GPS Interface	Not part of this phase
	4.2.1.4	OMS – GPS Interface	Not part of this phase
	4.2.1.5	OMS – GPS Interface	Not part of this phase
	4.2.1.6	OMS – GPS Interface	OK
	4.2.1.7	OMS – GPS Interface	OK
4.3		OMS Wayside Interface	Railnova's backend is used the Wayside of the "OMS alternative architecture".
	4.3.1.1	OMS Wayside Interface	OK
	4.3.1.2	OMS Wayside Interface	Not part of this phase
	4.3.1.3	OMS Wayside Interface	OK
	4.3.1.4	OMS Wayside Interface	OK
5 **5.1** **5.1.1**		Functional Requirements OMS On Board OMS On Board	
	5.1.1.1	OMS On Board	Full real-time is a question mark, buffering strategy depending on feasibility
	5.1.1.2	OMS On Board	Not part of this phase
	5.1.1.3	OMS On Board	Not part of this phase
	5.1.1.4	OMS On Board	OK
	5.1.1.5	OMS On Board	Not part of this phase
	5.1.1.6	OMS On Board	OK
	5.1.1.4	OMS On Board	OK
	5.1.1.7	OMS On Board	Full real-time is a question mark, buffering strategy depending on feasibility
	5.1.1.8	OMS On Board	OK
	5.1.1.9	OMS On Board	Not part of this phase
	5.1.1.10	OMS On Board	OK
	5.1.1.11	OMS On Board	Not part of this phase
	5.1.1.12	OMS On Board	OK
	5.1.1.13	OMS On Board	Not part of this phase
	5.1.1.14	OMS On Board	Not part of this phase
	5.1.1.15	OMS On Board	Not part of this phase
	5.1.1.16	OMS On Board	Not part of this phase
	5.1.1.17	OMS On Board	Not part of this phase
	5.1.1.18	OMS On Board	Not part of this phase
	5.1.1.19	OMS On Board	OK
5.1.2 **JSON format Draft07a**	1 1.1	Data packets header Fields Description	The data is formatted according to specifications on the server. The POC is according to the "Alternative Architecture" described in 3.2.4
	1.1.1.1		SS-140 not applicable

Chapter	Reference	Description	Comment in implementation
	1.1.1.2		OK
	1.1.1.3		OK, see 1.1.2 onwards
	1.1.2		
	1.1.2.1		OK. GNSS latency not applicable
	1.1.2.2		OK
	1.2		
	1.2.1.1		OK
	1.2.2		
	1.2.2.1		OK
	1.2.2.2		OK
	1.3		
	1.3.1.1		Not part of this phase
	1.3.2		
	1.3.2.1		Not part of this phase
	1.3.2.2		Not part of this phase
	1.4		
	1.4.1.1		OK
	2		
	2.1		OK
	2.2		OK
5.2		OMS Wayside	
	5.2.1.1	OMS Wayside	OK
	5.2.1.2	OMS Wayside	OK
	5.2.1.3	OMS Wayside	OK (through different data tables, see offer "Data access segregated per country with user rights management")
	5.2.1.4	OMS Wayside	Not part of this phase
	5.2.1.5	OMS Wayside	OK
	5.2.1.6	OMS Wayside	OK
	5.2.1.7	OMS Wayside	OK
	5.2.1.8	OMS Wayside	OK
	5.2.1.9	OMS Wayside	Not part of this phase
	5.2.1.10	OMS Wayside	Not part of this phase
	5.2.1.11	OMS Wayside	Not part of this phase
6.0		Safety and Cybersecurity requirements	
	6.1.1.1	Safety and Cybersecurity requirements	OK
	6.1.1.2	Safety and Cybersecurity requirements	Not part of this phase

Table 5 Functionalities of the SUBSET-149 (based on version 0.0.5, including additionally the proposal for JSON formatting) considered in the proof of concept