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FRMCS Migration Scenarios Telecom On-Board Architecture Workgroup	Document No. TOBA-7515
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1.0	18.06.2019	Version prepared for review in TOBA#5
1.1	30.09.2019	Update after TOBA 6 Update according to review comments from SNCF CIM, UTG, EIM, UNISIG (SysG and ER), CER (SNCF and DB), X2R3, FWG Inclusion of conclusions from EUG WP8 Meeting on September 26th.
1.2	14.11.2019	Implementation Variant 4A and 4b by Cabradio Variant (5.1.4)

Abstract: This document contains a description and the evaluation of possible FRMCS migration variants for existing ETCS and cab radio on-board units.

1 Introduction and Aim

The aim of this document is to structure the discussion on the possible migration of existing ETCS and cab radio on-board units in the context of FRMCS introduction, with a particular focus on the FRMCS trackside migration period for which both the train and trackside are expected to support dual radio (GSM-R and FRMCS). Key questions to be clarified are here:

- Which specific FRMCS migration variants are most meaningful and should hence be supported by the FRMCS on-board system?

- Which technology constellations should be used when novel trains are ordered that appear during the FRMCS trackside migration period.

2 Functional Architecture of the FRMCS on-board system

The UIC FMS Telecom On-Board Architecture WG (TOBA) currently follows certain key design paradigms and working assumption in their work on specifying the requirements for the FRMCS on-board system.

Key Design Paradigms

Decoupling of Applications and Transport

- With the FRMCS on-board system a decoupling of applications and communication services / transport services shall be achieved

Bearer Flexibility

- The FRMCS on-board system shall be capable of providing transport services using a variety of bearers (i.e. Radio Access Technologies)
- The FRMCS on-board system shall be capable of using a variety of bearers simultaneously

Resource Sharing

- The FRMCS on-board system shall be capable of providing transport services for multiple applications of any category using the same FRMCS on-board system considering the individual QoS requirements of the application and possibly priorities among applications.

Working Assumptions

Following the key design paradigms, the functional architecture depicted in Figure 1, is regarded as the working assumption for the TOBA WG. This architecture shall be further refined in the course of TOBA WG's progress. Consequently, the migration variants described in this document are also following these key design paradigms and the working assumptions for the functional architecture of the FRMCS on-board system.

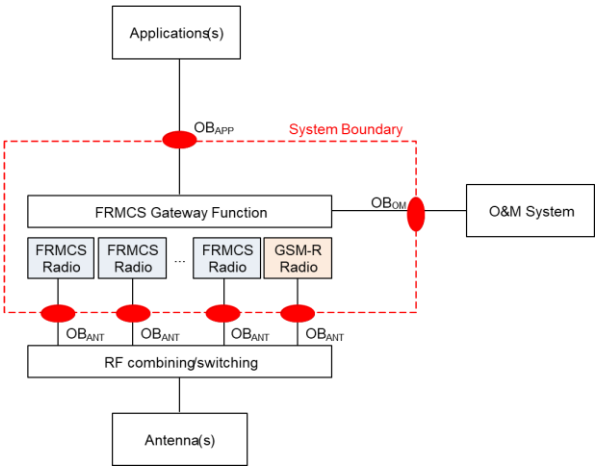

Figure 1: Functional Architecture of FRMCS On-board System

Interfaces:

- Reference point OB_{APP}
  - Layer 3 (IP) interface between the FRMCS On-Board System and the application(s)
  - User plane data from and to the applications(s) are transparently carried over this reference point.
  - Control plane data exchange between application(s) and FRMCS On-Board System is performed over this reference point
- Reference point OB_{ANT}
  - Between the FRMCS On-Board System and the RF combining / switching functionality or the antenna(s)
- Reference point OB_{OM}
  - Between the FRMCS On-Board System and the O&M System responsible for the operation & management of the FRMCS On-Board System
  - Data related to O&M activities are exchanged over this reference point.

FRMCS Gateway Function:
Manages the data flows, has a control plane interface for the applications, distributes the user plane data from data applications over the various radio units depending on the application's QoS requirements and possibly priorities among applications.

FRMCS Radio:
Modem with any 3GPP or non-3GPP radio access technology supported by the FRMCS system. An FRMCS on-board system contains 1..n FRMCS radios.

Note: The FRMCS Radio does not cover GSM-R.

GSM-R Radio:
Existing GSM-R Radio for voice (e.g. Cab Radio modem) or data (e.g. EDOR modem). An FRMCS on board system contains 0..n GSM-R Radio.

Note: Management of GSM-R radio(s) will be managed by the FRMCS Gateway Function depends on the architecture migration variants discussed in this document.

RF Combining & Switching / Antennas:

For further study within TOBA WG. It is assumed that the solution(s) for the antenna sub-system will not impact the principle of the migration scenarios described in this document.

3 ETCS Migration Variants

3.1 Architecture of existing ETCS OBU

In the context of this document, an existing ETCS OBU is represented with the functional blocks depicted in Figure 2. An ETCS OBU in version BL3 MR1 only includes the CS function, a version BL3 R2 unit also includes the PS function, represented by the dotted line. The CS and PS function share the same physical serial interface to the EDOR.

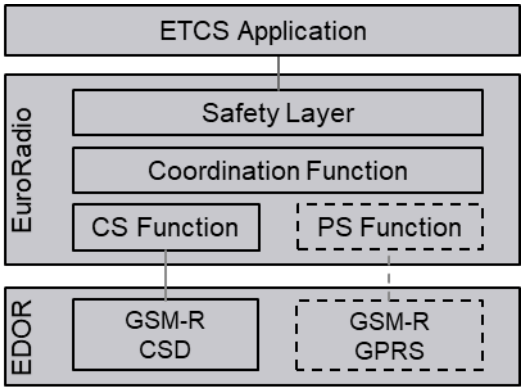

Figure 2: Functional block of existing ETCS OBU[1]

[1] CS and PS links are logically separated, even if they are physically one single interface.

3.2 Description of Variants

Currently, the following variants of ETCS onboard and GSM-R / FRMCS technology constellations are being considered.

3.2.1 ETCS Variant 1a – Existing ETCS OBU with CS and PS Conversion

Description: In this variant, as shown in Figure 3, an existing ETCS OBU, e.g. ETCS OBU BL3 MR1 or BL3 R2 which includes PS (dotted line in the figure below) is connected to the FRMCS gateway function through appropriate protocol conversion. Underneath the FRMCS gateway function, existing GSM-R EDOR unit(s) can be used beside FRMCS radio unit(s).

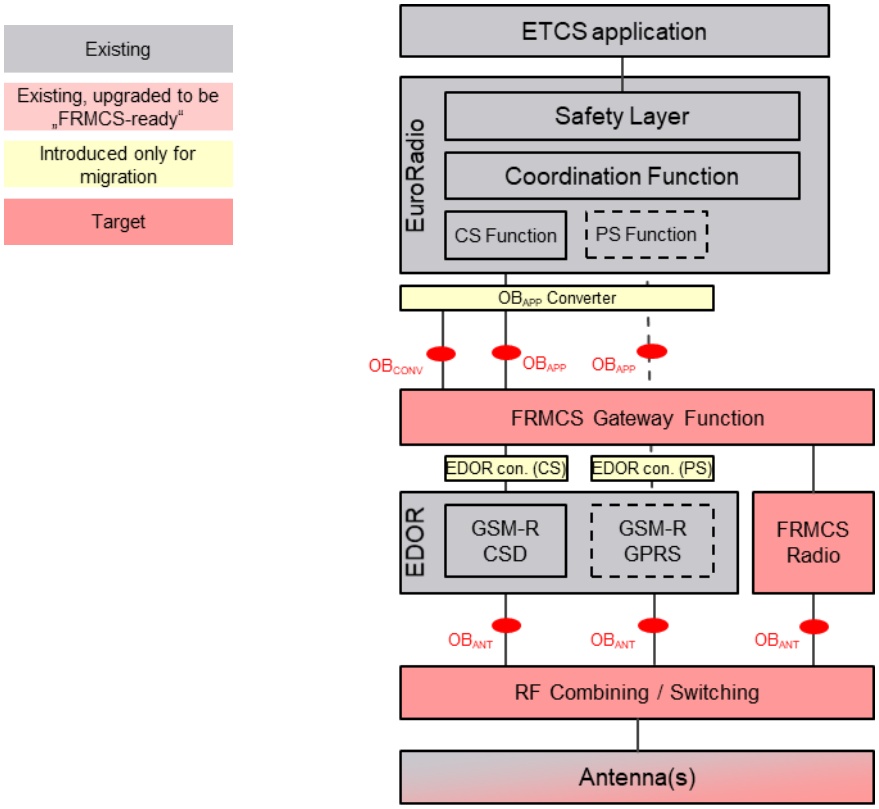

Figure 3: ETCS variant 1a - Existing ETCS OBU with CS and PS conversion.[2]

Needed protocol conversion:

- OB_{APP} Converter: Protocol conversion from serial interface (Euroradio FIS/FFFIS) to the OB_{APP} interface for CS User Plane, PS User Plane and CS/PS Control Plane.
- OB_{CONV} Interface : Complementary interface to OB_{APP} used to allow the OB_{APP} converter to simulate a GSM-R radio for the EVC. It supports Control Plane data not included in OB_{APP}.
- EDOR converter (CS): Protocol Conversion for CS User Plane and CS Control Plane
- EDOR converter (PS): Protocol Conversion for PS User Plane and PS Control Plane

Control Plane

[2] CS and PS links are logically separated, even if they are physically one single interface.

Since in this variant, the existing PS/CS function in Euroradio are not modified, the OB_{APP} Converter is required to emulate the behaviour of a GSM-R modem, although the underlaying FRMCS on-board system is very different from being a GSM-R modem. It is important to note, that the control plane implementation is today tailored to the behaviour of specific modems (incl. SW version) and OBU SW version. Thus, this emulation would have to be implemented in many different variants.

For the implementation of the control plane, there are two different variants:

1) Tunneling: The AT commands sent over the serial interface are tunnelled between the OB_{APP} Converter and the EDOR converters (using a suitable tunnelling protocol like for the CS user plane described further below). This would be rather easy to implement, but the FRMCS on-board system has to give the EDOR exclusive control of the ETCS system. Also, it would not be possible to make use of the FRMCS radio, since the existing control plane implementation can only select between GSM-R CS or GPRS but not a third path. Thus, also rendering the value of this solution limited;
2) Emulation of EDOR: Towards the ETCS, the OB_{APP} converter emulates the AT-Command interface of an EDOR as defined in Euroradio FFFIS. Towards the FRMCS On-Board system, the OB_{APP} Converter implements the OB_{APP} control plane protocol. A translation logic is required in the OB_{APP} Converter for translating between the two control planes. This rather complex and likely also error prone solution, would allow the FRMCS on-board system to perform the bearer management and therefore reach the goal of decoupling application and transport to some degree at least. The AT command interface will however not be able to provide all the functionality the FRMCS On-Board system could offer over OB_{APP} to the ETCS OBU.
   The emulation of the EDOR also needs to retrieve the network and call information from the ETCS application and select the network of the physical EDOR accordingly. With the E.164 phone number retrieved from the balises via the ETCS application, the EDOR emulation can determine if the RBC support GSM-R CS/PS or FRMCS by consulting a lookup table. This look-up table needs to be kept up-to-date on all vehicles, corresponding processes have to be established;

<u>CS User Plane</u>

There are three principle forms of how the CS path from Euroradio could be handled by the FRMCS gateway:

1) The HDLC frames could be tunnelled (e.g. L2TPv3 [IETF RFC 4349], MPLS [IETF RFC 4618]) between the Euroradio System and the GSM-R EDOR passing through FRMCS gateway, so that this would be transparent to the Euroradio protocol. The tunnelling end-points are implemented in the OB_{APP} Converter and the EDOR converter (CS). This would be rather easy to implement, but the CS path could not utilize the FRMCS radio, hence also rendering the value of this solution limited;
2) Using the same method above but terminating the HDLC-tunnel on the RBC side would in principle allow to run a CS data session over the FRMCS radio. This would however require some control mechanism between the FRMCS Gateway and the OB_{APP} Converter to decide if a tunnel shall be established towards the GSM-R EDOR or towards the RBC via the FRMCS radio;

3) HDLC frames would be converted by the OB_{APP} Converter, so that these can make use of GSM-R radio and FRMCS radio. This approach requires the implementation of the CS user plane protocol stack of Euroradio in the OB_{APP} Converter, though resulting in significantly higher protocol conversion complexity both in terms of development and homologation. The figure below depicts exemplarily the various protocol layers that would have to be implemented in the OB_{APP} Converter for the conversion needed for the CS functionality.

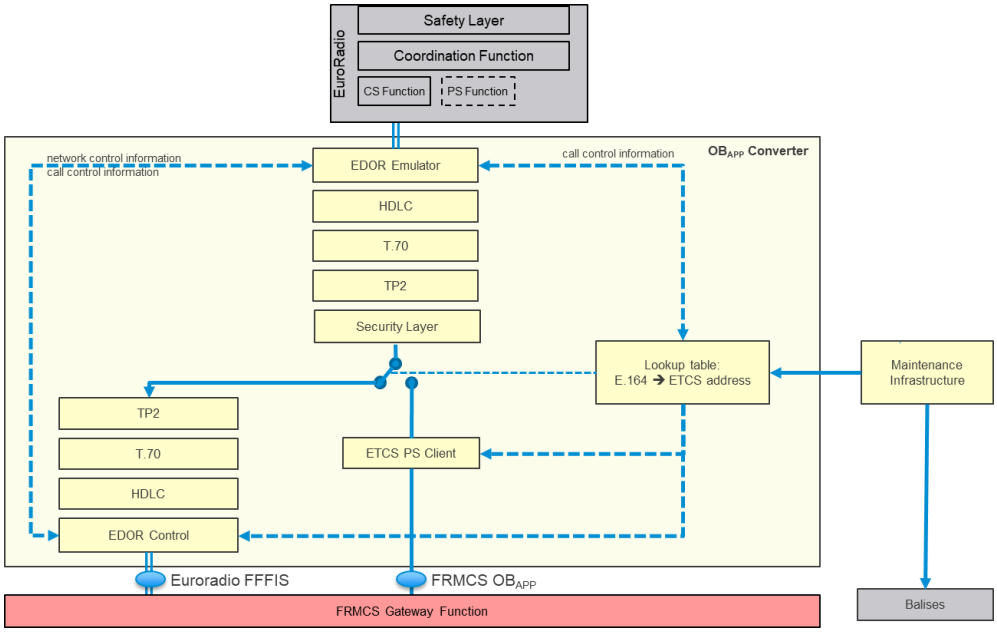

Figure 4: Detailed structure of the OB_{APP} Converter for required for CS conversion

PS User Plane

For PS User data, the OB_{APP} Converter would be the PPP end point to the Euroradio system (emulation of the PPP end-point of the GSM-R EDOR). After that, the IP packets could be routed via OB_{APP} and the FRMCS Gateway function to either the GSM-R EDOR or the FRMCS radio. Aspects of routing / addressing are FFS.

Compatibility Matrix

Not all the combination of control plane / user plane variants described above are feasible / beneficial, the table below indicates valid combinations

	User Plane			
Control Plane	CS-UP 1)	CS-UP 2)	CS-UP 3)	PS-UP
CP-1)	GSM-R only	GSM-R only	GSM-R only	GPRS only
CP-2)	No benefit as CS-UP 1 is limited to GSM-R			

Table 1: Compatibility Matrix - Control Plane and User Plane options

Note: Combinations with CP-1) only support GSM-R and thus, cannot be considered as migration option.

Benefits:

- Allows the usage of existing ETCS OBU (version BL3 MR1 or BL3 R2) as well as existing GSM-R EDOR without any HW/SW change;

Disadvantages:

- Involves heavy protocol conversion, in particular for conversion options CS-UP 2, CS-UP 3 and CP-2 described above;
- Using FRMCS access technology and bearer management by the FRMCS on-board system is only possible with the implementation of the more complex (and likely error prone) emulation of the control plane (CP-2).
- The existing serial interfaces are carried over into an all IP system architecture. It requires another migration step to replace these serial interfaces with an IP interface (OB_{APP}). This second migration step could of course also be achieved in later stage (after migration to FRMCS is completed) by replacing the ETCS OBU with a new system supporting OB_{APP} out of the box.
- For each RBC, also for those that are FRMCS only, an E.164 phone number would have to be assigned and programmed into the balises. Maintenance infrastructure and processes need to be established to ensure the look-up tables required on-board always kept up-to-date (e.g. when adding a new FRMCS RBC).
- The control plane (AT-Commands) is (modem) supplier specific. Thus, many different variants of the control plane emulation have to be implemented.
- CS-UP2 and PS-UP needs to implement additional conversions on the RBC side. Both variants define additional transport channels “Tunnelling CS/PS over FRMCS”. This means in worst case five interfaces for the RBC: CS, PS, FRMCS, Tunneling CS over FRMCS, Tunneling PS over FRMCS.

3.2.2 ETCS Variant 1b – Existing ETCS OBU with PS (or CS) Conversion/Bypass

Description: In this variant, as shown in Figure 5, an existing ETCS OBU BL3 MR1 is connected to the FRMCS gateway function through appropriate CS protocol conversion, for GSM-R the ETCS OBU is directly connected to the EDOR. An ETCS BL3 R2, which includes PS, is connected to the FRMCS gateway through appropriate PS protocol conversion, for GSM-R the ETCS OBU is directly connected to the EDOR for both CS and PS.

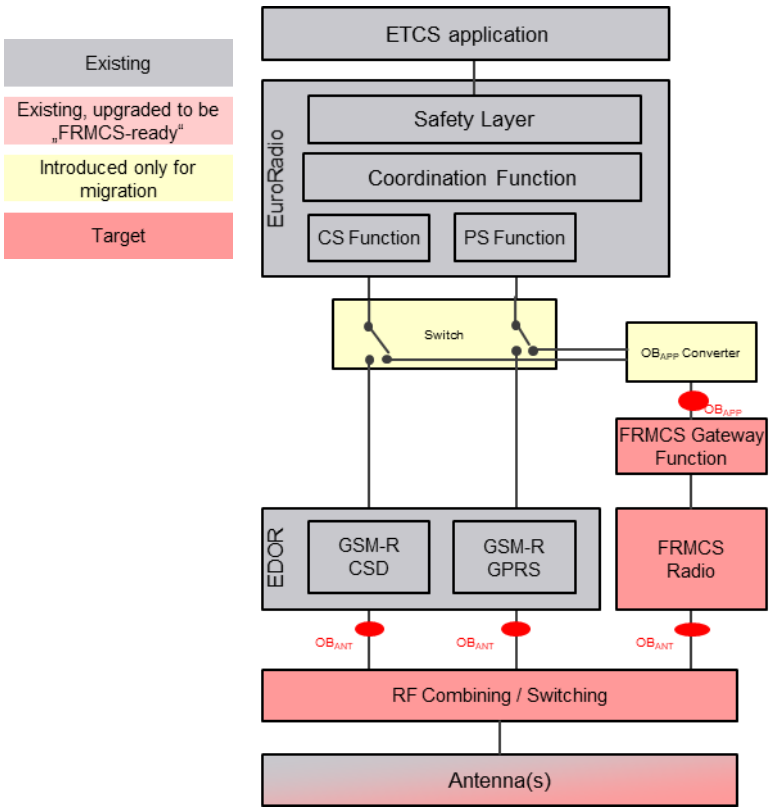

Figure 5: ETCS Variant 1b – Existing ETCS OBU with PS (or CS) Conversion/Bypass[3]

Needed protocol conversion:

- Switch: Switching the paths between the direct connection to the EDOR and the connection through the OB_{APP} converter. Functionality wise it is the same switch as shown in Figure 4 under Variant 1a)
- OB_{APP} Converter: Protocol conversion from serial interface (Euroradio FIS/FFFIS) to the OB_{APP} interface for PS User Plane or CS User Plane and CS/PS Control Plane.

Control Plane:

Same as Variant 1a), but without the need for any conversion in case of usage of GSM-R

CS User Plane:

Same as Variant 1a), but without the need for any conversion in case of usage of GSM-R

[3] CS and PS links are logically separated, even if they are physically one single interface.

PS User Plane:

Same as Variant 1a), but without the need for any conversion in case of usage of GSM-R

Benefits:

- Same as variant 1a), with the additional benefit that no conversion is needed in case of GSM-R usage.

Disadvantages:

- Same as variant 1a) except it only requires the protocol conversion for communication over FRMCS;
- By switching between GSM-R and FRMCS, the CS/PS Function will lose the state of the radio. Depending on the implementation, the driver would be informed about the loss of the radio.

3.2.3 ETCS Variant 2 – Existing ETCS OBU with CS bypass and PS Conversion

Further analyses have proven that the single physical serial interface is indeed making this variant not feasible. The variant is kept in the document for reference only.

Description: Same as in ETCS variant 1a/b, this variant, as depicted in Figure 6, allows the usage of an existing ETCS OBU and existing GSM-R EDOR. The difference is, however, that in this case the CS part of the Euroradio connects directly to the GSM-R EDOR and hence bypasses the FRMCS gateway. The PS path, however, is handled via the FRMCS gateway. **In consequence, this variant is only meaningful for an ETCS OBU and GSM-R EDOR of BL3 R2.**

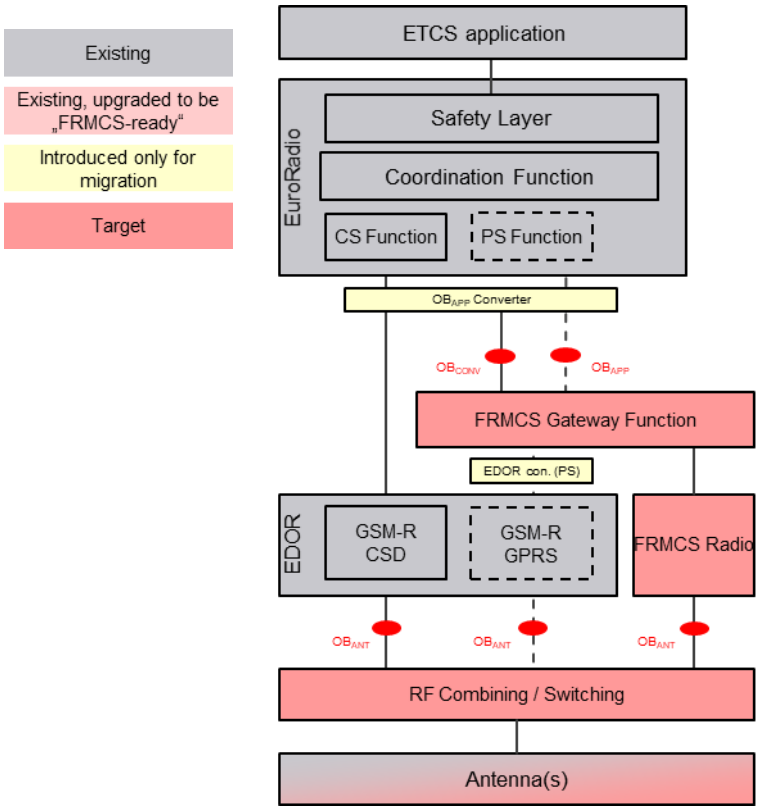

Figure 6: ETCS Variant 2 - Existing ETCS OBU with CS bypass and PS conversion.

Needed protocol conversion:

- OB_{APP} Converter: Protocol conversion from serial interface (Euroradio FIS/FFFIS) to the OB_{APP} interface for PS User Plane and PS Control Plane.
- OB_{CONV} Interface : Complementary interface to OB_{APP} used to allow the OB_{APP} converter to simulate a GSM-R radio for the EVC. It supports Control Plane data not included in OB_{APP}.
- EDOR converter (PS): Protocol Conversion for PS User Plane and PS Control Plane

Control Plane:

Same as Variant 1a)

CS User Plane:

No Conversion required.

PS User Plane:

Same as Variant 1a)

Benefits:

- Allows the usage of existing ETCS OBU (BL3 R2) as well as existing GSM-R EDOR;
- Compared to variant 1a, the protocol conversion complexity for CS user plane and CS control plane is reduced. For PS it is the same as variant 1a;

Disadvantages:

- The disadvantages of Variant 1a apply, except for the CS user/control plane conversion;
- This is variant is only meaningful in the context of ETCS OBU and GSM-R EDOR of BL3 R2, as otherwise the solution would collapse into GSM-R CS only solution without any FRMCS path;
- The solution does not allow for any load balancing between GSM-R CS and FRMCS via the FRMCS gateway;
- A possible showstopper may be that the serial interface of Euroradio is one physical interface for both the CS and PS part.

3.2.4 ETCS Variant 3 – Modified Euroradio involving CS and PS bypass

Description: In this variant, depicted in Figure 7, an existing Euroradio (e.g. ETCS OBU version BL3 MR1 or BL3 R2) is updated such as to support the OB_{APP} interface to the FRMCS gateway. Existing CS and PS paths are connected directly to the GSM-R EDOR, i.e. bypassing the FRMCS on-board system. As implementation variant, the serial connection to the EDOR could be tunnelled over OB_{APP}, in this case the EDOR would be placed under the FRMCS Gateway Function which would terminate the tunnel.

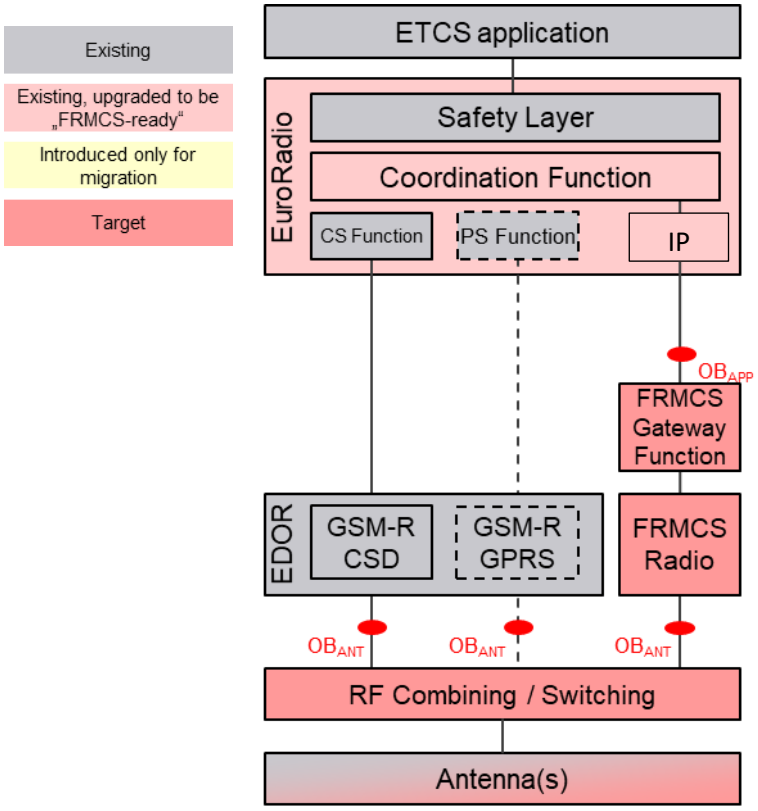

Figure 7: ETCS Variant 3 – Modified Euroradio with CS and PS bypass.[4]

Needed protocol conversion:

- None;

Required changes to Euroradio:

- Implementation of (yet to be standardized) OB_{APP} user plane and control plane protocols.

Editor's Note: An in-depth analysis of the required changes and analysis of the remaining functionality of the current Euroradio stack is for further study.

[4] CS and PS links are logically separated, even if they are physically one single interface.

Benefits:

- FRMCS system itself is kept very lean, no conversion functionality required;
- Euroradio already supports the new IP interface (OB_{APP}) natively and thus can leverage on the full feature set of the FRMCS on-board system (decoupling of application and transport, bearer flexibility, redundancy features, security, etc.)

Disadvantages:

- This variant would imply introducing a new version of Euroradio including an additional physical interface for already installed OBUs. Note: For new ETCS systems a new version of Euroradio will always be required in order to support the new OB_{APP} interface.
- It has to be analysed if this variant has a significant impact oncertification/authorisation– as the Euroradio stack and the ETCS application are often (depending on the vendor) implemented on the same processing platform, a modification of the "coordination" function in the Euroradio stack would require a complete re-certification of the overall setup. There may be implementation variants that could address these issues (FFS).
-
- Future evolution in the ETCS application / security domain would require adaptation to both the FRMCS path and the GSM-R path.

3.2.5 ETCS Variant 4 – Modified Euroradio reduced to FRMCS support

Description: Similar as in variant 3, the Euroradio is here updated to support a direct interface to the FRMCS gateway, but in this case the Euroradio is stripped off the existing CS and PS functionality. Underneath the FRMCS gateway function, an existing GSM-R EDOR (version BL3 MR1 or BL3 R2) can be used, as shown in Figure 8.

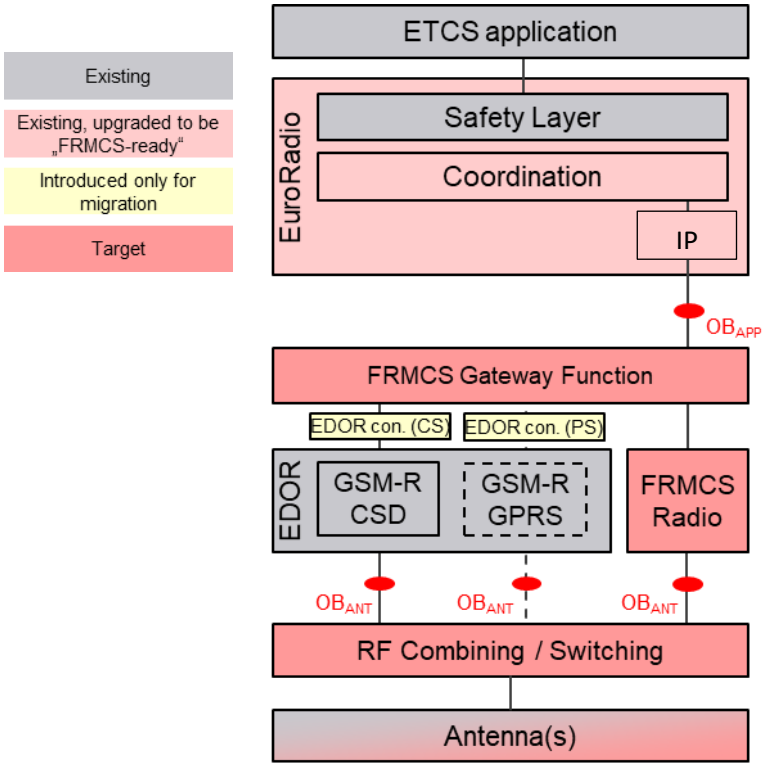

Figure 8: ETCS Variant 4 - Modified Euroradio reduced to FRMCS support.[5]

Needed protocol conversion:

- EDOR converter (CS): Protocol Conversion for CS User Plane and CS Control Plane
- EDOR converter (PS): Protocol Conversion for PS User Plane and PS Control Plane

Control Plane

The new (yet to be standardized) OB_{APP} control plane protocol needs to be implemented in the Euroradio system. CS/PS Modem control of the EDOR according to Euroradio FFFIS needs to be implemented in the EDOR converter. It has to be further analysed if the full scope of Euroradio FFFIS has to be implemented.

[5] CS and PS links are logically separated, even if they are physically one single interface.

CS-User Plane

In this variant CS support is only required in case GSM-R CS is used for connection to an RBC (e.g. operating on non-FRMCS track). Emulation of existing CS Euroradio over FRMCS is not required according chapter 4. There are two variants for implanting GSM-R CS compatibility:

1) The ETCS application IP data packets are converted into a HDLC session in the EDOR Converter (CS). This would require the implementation of the CS Euroradio stack (X.224/T.70/HDLC) in the EDOR Converter.
2) The (re-) implementation of the CS Euroradio stack in the EDOR Converter could be avoided if the existing CS-stack in Euroradio System is maintained and tunneling for transport of the HDLC frames is used. One tunneling end-point resides inside the Euroradio System, the other end-point is implemented in the EDOR converter.

PS-User Plane

The required changes to Euroradio system are relatively simple, since in principle only the PPP part of the current PS implementation has to be omitted and instead directly interface to OB_{APP}. For PS over GPRS, the EDOR converter (PS) needs to implement the PPP session.

The figure below depicts exemplarily the various protocol layers that would have to be implemented in the EDOR Convert for the conversion needed, some of the conversion function would be located in the FRMCS Gateway Function.

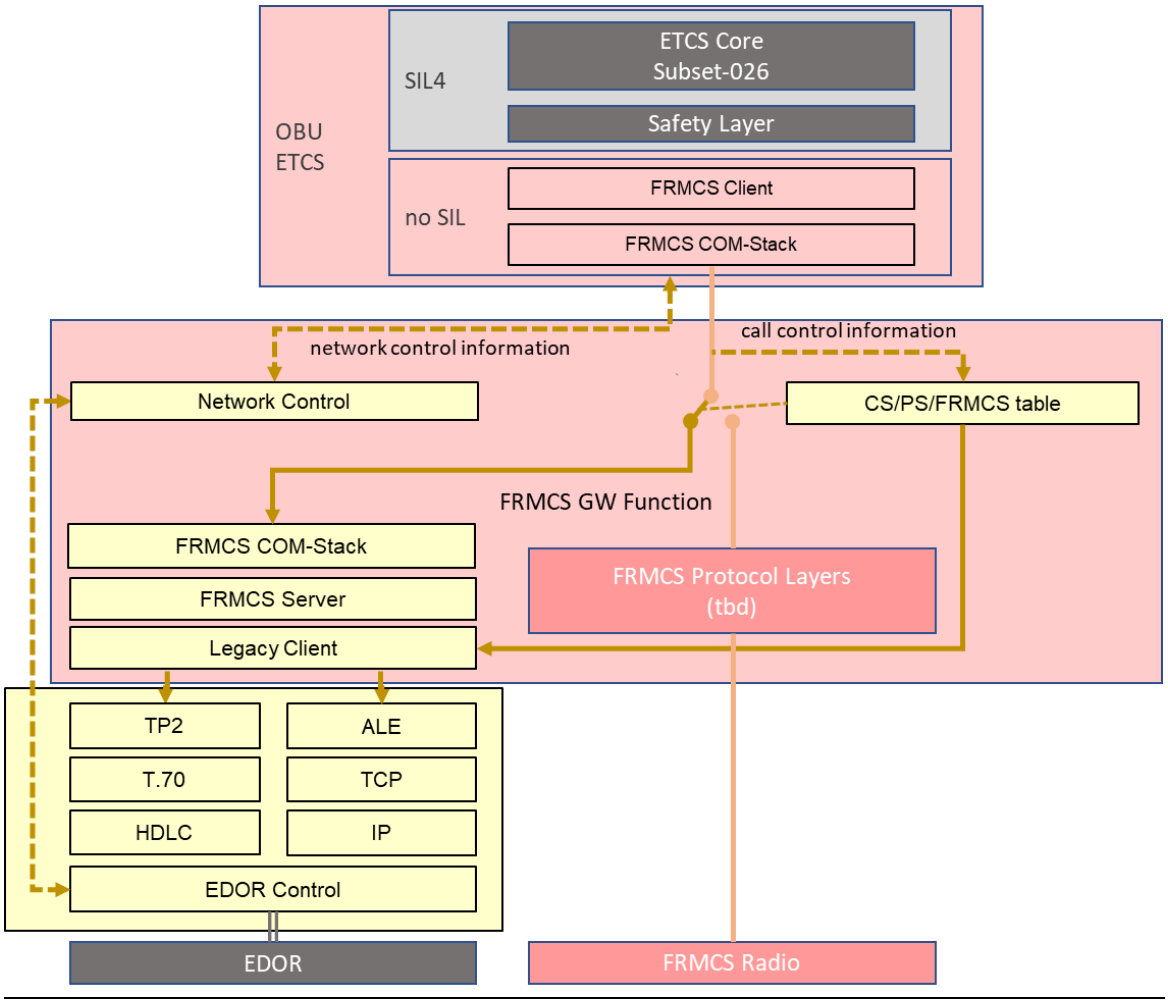

Figure 9: Detailed structure of the conversions needed for variant 4

Required changes to Euroradio:

- Implementation of (yet to be standardized) OB_{APP} user plane and control plane protocols.

Editor's Note: An in-depth analysis of the required changes and analysis of the remaining functionality of the current Euroradio stack is for further study.

Benefits:

- Large parts of the protocol conversion needs from variants 1a/b and 2 are avoided;
- Euroradio already supports the new IP interface (OB_{APP}) natively and thus can leverage on the full feature set of the FRMCS on-board system (decoupling of application and transport, bearer flexibility, redundancy features, security, etc.)
- Compared to variant 3, the FRMCS on-board system will become capable of managing the GSM-R bearers, whereas the ETCS OBU is completely freed from any duty of radio connection management.
- Any future evolution in the ETCS application / security domain could also be deployed using GSM-R connectivity.

Disadvantages:

- Same as for variant 3, a modified Euroradio is introduced for already installed OBUs. ;
- Compared to variant 3, a higher protocol conversion burden applies, since the Euroradio stack has to be implemented in the EDOR converter, including supplier specific adaption to the EDOR in use.
- As a selection key for the “CS/PS/FRMCS table” depicted in Figure 9, the EVC would have to pass the RBC address information to the FRMCS gateway / converter. This results into application specific information elements in the OB_{APP} interface. Based on this RBC address information a look-up table or an algorithm needs to decide which communication path to choose from.

3.3 Comparison

The key characteristics of the different FRMCS migration variants in the context of ETCS are summarized **Error! Reference source not found.**

	Variant 1a - Existing ETCS OBU with CS and PS Conversion	**Variant 1b -** Existing ETCS OBU with PS (or CS) Conversion/Bypass	**Variant 3** - Modified Euroradio involving CS and PS bypass	**Variant 4** - Modified Euroradio reduced to FRMCS support
Decoupling of Application and Transport for FRMCS	No	No	Yes	Yes
Protocol conversion burden / extent of functionality introduced only for migration	Very high, incl. supplier specific implementation of EDOR emulation	High, incl. supplier specific implementation of EDOR emulation (reduced compared to 1a)	None	Very High, incl. supplier specific implementation of EDOR interface
Required HW modification of BL3 MR1/BL3 R2 equipment	None	None	Yes (If no ethernet interface available)[6]	Yes (If no ethernet interface available)[6]
Required SW Update of BL3 MR1/B 3 R2 equipment	None	None	Yes	Yes
Requires additional, temporary interface (along OB_{APP}) to drive the converter(s)	Yes	Yes	No	Yes
Possibility to decommission GSM-R	Yes	Yes	Yes	Yes
Impact on trackside	Depending on chosen implementation option for CS user plane.	Depending on chosen implementation option for CS user plane.	No	No
Evolution of ETCS Cyberscurity Frameork	Independent of the scenarios			

Table 2: Comparison of key characteristics of FRMCS migration variants in context of ETCS.

[6] The impact of this modification will be supplier specific.

3.4 Migration paths

Figure 10 illustrates possible evolution paths for going from an existing GSM-R ETCS on-board (BL3 MR1 or BL3 R2) installation to a FRMCS only ETCS on-board installation. The different paths are described in the following sections of this chapter.

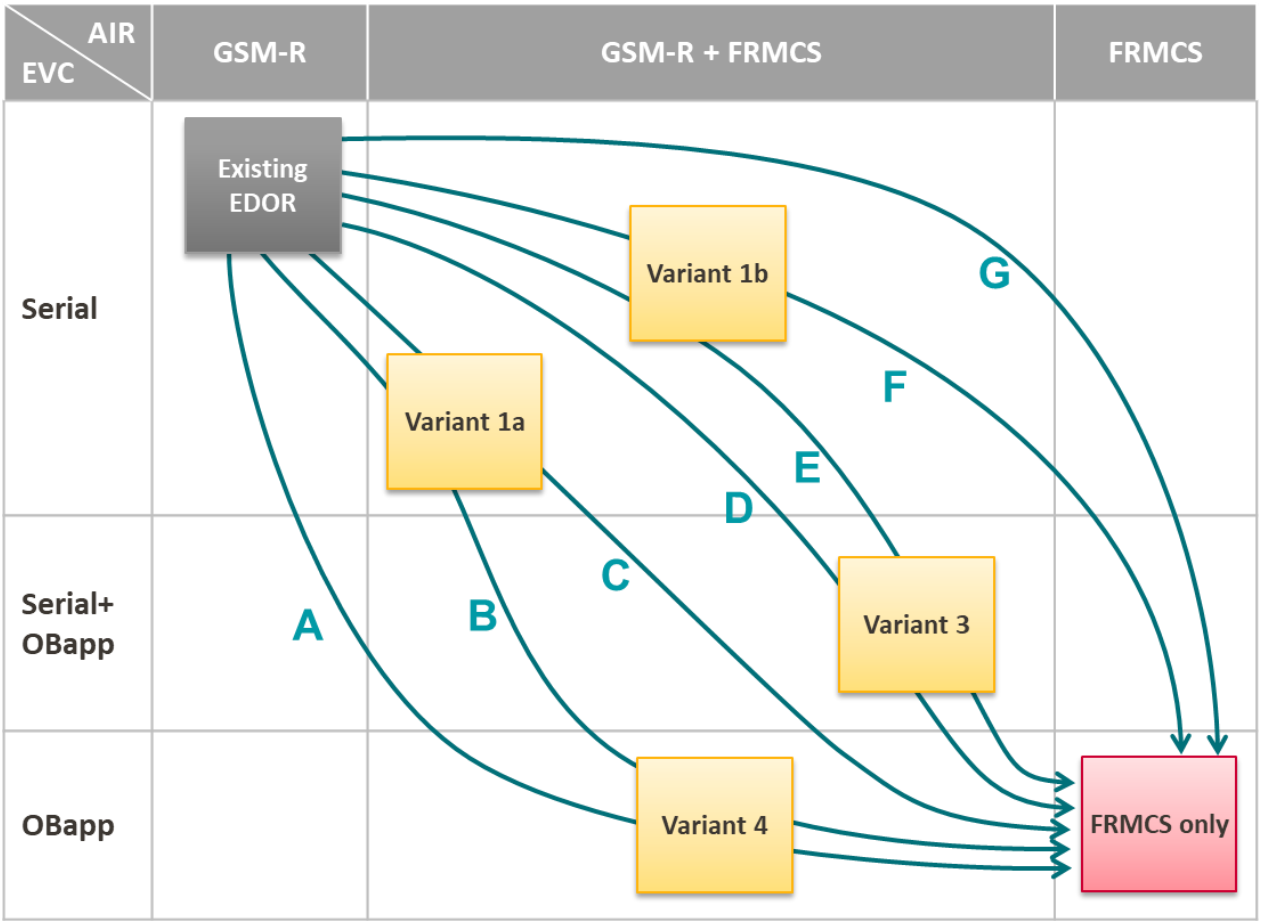

Figure 10: Possible evolution paths for ETCS migration

3.4.1 Scenario A (Existing EDOR → Variant 4 → FRMCS only)

Consequences:

- One intermediate migration step
- Needs to evolve EVC and FRMCS on-board system simultaneously

3.4.2 Scenario B (Existing EDOR → Variant 1a → Variant 4 → FRMCS only)

Consequences:

- Two intermediate migration steps
- Allows to first install the FRMCS on-board system without upgrading the EVC, and then to upgrade the EVC in later phase.
- During the upgrade of the EVC, the FRMCS on-board system is left untouched

3.4.3 Scenario C (Existing EDOR → Variant 1a → FRMCS only)

Consequences:

- One intermediate migration step
- Allows to first install the FRMCS on-board system without upgrading the EVC, and then to upgrade the EVC in later phase.

3.4.4 Scenario D (Existing EDOR → Variant 3 → FRMCS only)

Consequences:

- One intermediate migration step
- Needs to evolve EVC and FRMCS on-board system simultaneously

3.4.5 Scenario E (Existing EDOR → Variant 1b → Variant 3 → FRMCS only)

Consequences:

- Two intermediate migration steps
- Allows to first install the FRMCS on-board system without upgrading the EVC, and then to upgrade the EVC
- During the upgrade of the EVC, the FRMCS on-board system is left untouched

3.4.6 Scenario F (Existing EDOR → Variant 1b → FRMCS only)

Consequences:

- One intermediate migration step
- Allows to first install the FRMCS on-board system without upgrading the EVC, and then to upgrade the EVC
- The upgrade of the EVC has to wait for the complete trackside migration

3.4.7 Scenario G (Existing EDOR → FRMCS only)

Consequences:

- No intermediate migration steps
- Only possible if dual-mode trackside is available or if the whole migration (trackside and all rolling stock) is managed simultaneously (“Big-bang”).

4 ETCS interworking between on-board and trackside

This chapter describes the different combinations of on-board and trackside communication technology that have to be supported during the migration phase from GSM-R to FRMCS, by any of the migration variants under evaluation. Therefore, the figure below does not reference to any particular migration variant described in this document but describes the fact that the ETCS on-board shall have the possibility to connect to the trackside (=RBC) by the means of GSM-R or FRMCS in different ways.

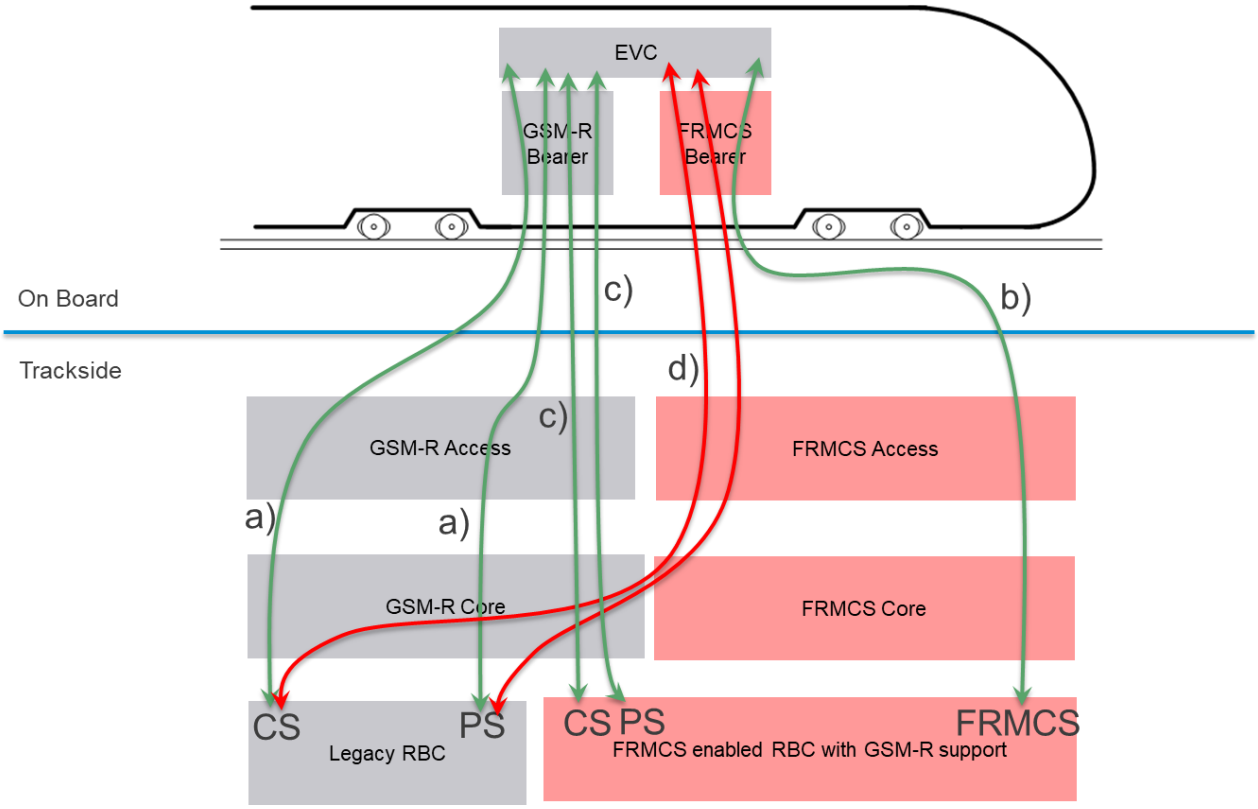

Figure 11: ETCS interworking on-board and trackside

a) GSM-R Radio Access with Existing RBC (CS/PS) via GSM-R Core
   Use Case: ETCS operation on tracks w/o FRMCS access (not yet migrated)
b) FRMCS Radio Access with FRMCS compatible RBC via FRMCS Core
   Use Case: ETCS operation on tracks with FRMCS Access (target)
c) GSM-R Radio Access with FRMCS compatible RBC via GSM-R Core
   Use Case: Maintaining backwards compatibility for tracks that have been upgraded to FRMCS. A existing GSM-R ETCS on-board should therefore be able to run on this track. To avoid CS/PS Conversion the GSM-R CS/PS-Interface is maintained in the FRMCS enabled RBC.
d) FRMCS Radio Access with Existing RBC (CS/PS) via GSM-R Core
   Not Required: If the trackside is being migrated to ETCS over FRMCS Radio Access, it doesn't seem logical to keep the related RBCs untouched. Either the RBC can be modified or complemented to interface with FRMCS or the RBC will be replaced.

Note: One RBC could be under GSM-R and FRMCS as described above. However, it is not foreseen to support changes of access technology (GSM-R to FRMCS or vice versa) for an active ETCS session.

5 Cab Radio Migration

5.1 Description of Variants

In the following subchapters, the term “Train Interface Adapter” (TIA) is used. The TIA can be considered as a physical translation adapter between different train types input and output signals on the one side and OB_{APP} interface on the other side. TIA is specific for each rolling stock type since the train signals are rolling stock specific. It also implements the Proxy Function to interface with OB_{APP}.

5.1.1 Cab Radio Variant 1 – Existing GSM-R Cab Radio + Single Mode FRMCS Cab Radio

Description: A complete existing cab radio setup incl. GSM-R radio is operated in parallel to an FRMCS setup with a new cab radio function and new MI, as shown in Figure 12, only reusing input devices such as UIC, DSD, etc.

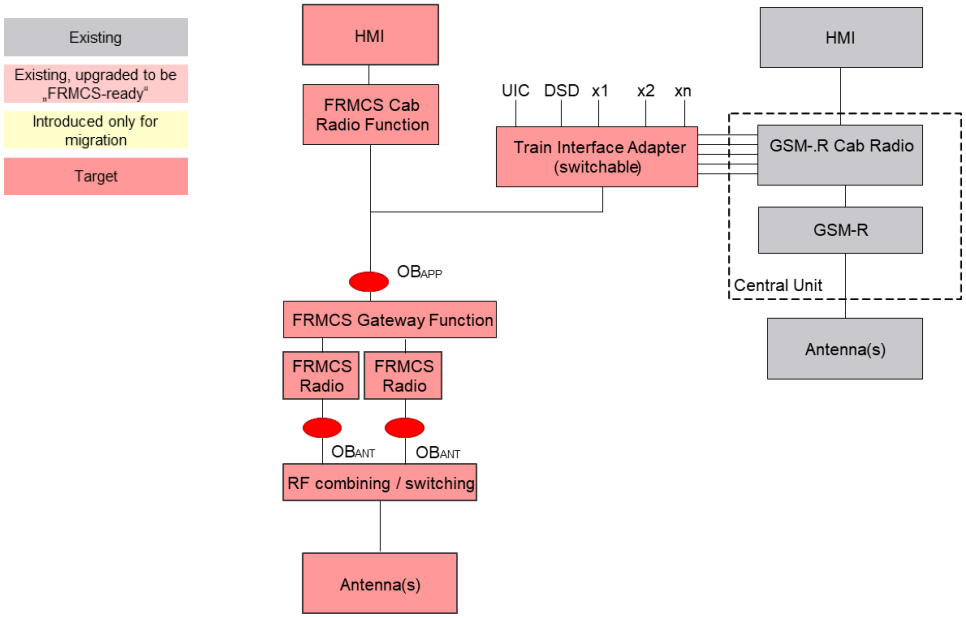

Figure 12: Cab Radio Variant 1 - Existing GSM-R Cab Radio + single Mode FRMCS Cab Radio

Needed protocol conversion:

- None.

Benefits:

- Existing equipment can be reused as-is.

Disadvantages:

- In most trains, there is practically no space for a second MMI.

5.1.2 Cab Radio Variant 2 – New Cab Radio (Dual Mode, Option 1)

Description: A new cab radio setup is introduced. Conversion from VoIP to PCM is introduced to allow using a GSM-R radio underneath the FRMCS gateway.

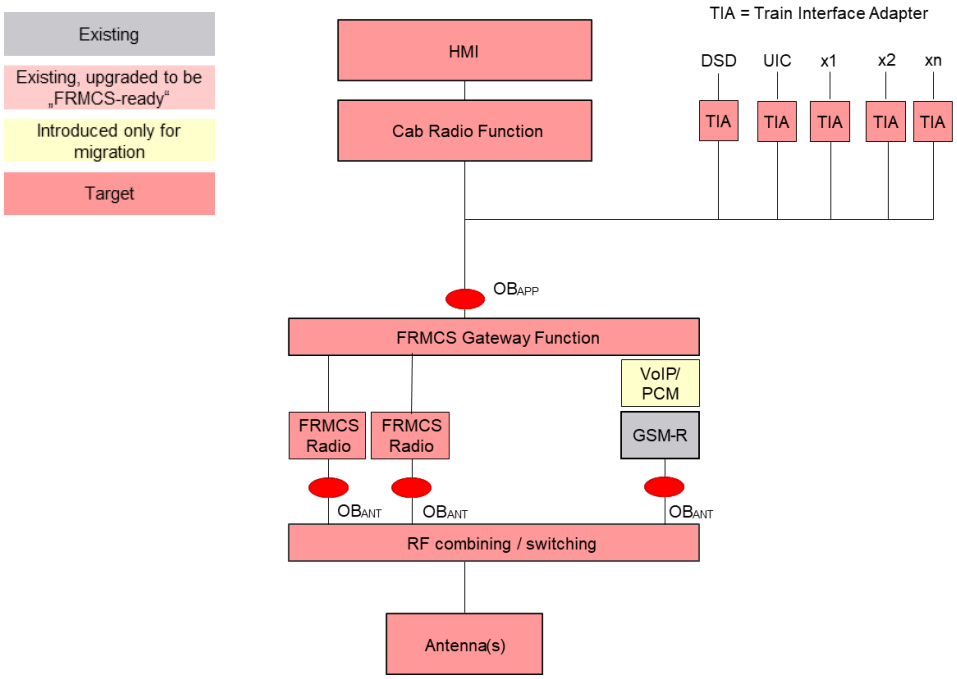

Figure 13: Cab Radio Variant 2 – New Cab Radio (Dual Mode, Option 1)

Needed protocol conversion:

- Conversion from VoIP to PCM.

Benefits:

- Existing equipment (in this case: GSM-R radio) can be reused as-is.
- Load balancing between GSM-R and FRMCS could be exploited.

Disadvantages:

- Tbd

5.1.3 Cab Radio Variant 3 – New Cab Radio (Dual Mode, Option 2)

Description: A new cab radio setup is introduced. Different from variant 2, conversion from VoIP to PCM is performed separate of the FRMCS gateway and is with that outside the FRMCS onboard system boundary.

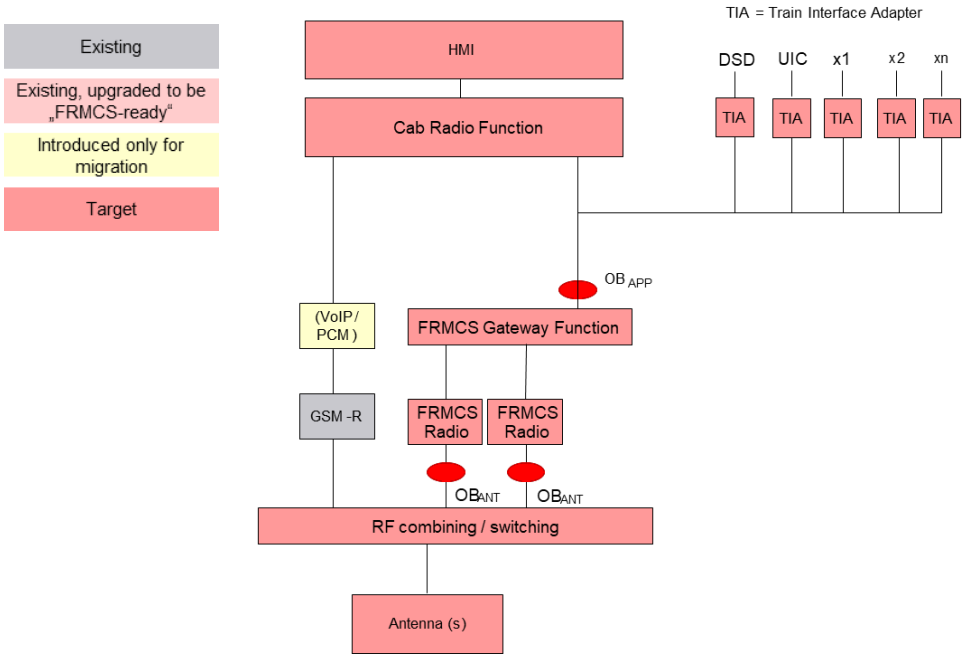

Figure 14: Cab Radio Variant 3 – New Cab Radio (Dual Mode, Option 2)

Needed protocol conversion:

- Conversion from VoIP to PCM.
- Control plane (AT-commands) from Cab Radio Function to GSM-R modem require IP to serial conversion.

Benefits:

- Existing equipment (in this case: GSM-R radio) can be reused as-is.

Disadvantages:

- Setup can likely not exploit load balancing between GSM-R and FRMCS.

5.1.4 Cab Radio Variant 4a – New Cab Radio (Dual Mode, Option 3)

Description: A existing GSM-R cab radio setup is upgraded with a FRMCS Voice Function to interface via OB_{APP} with the FRMCS On-Board System. The GSM-R path is kept unchanged.

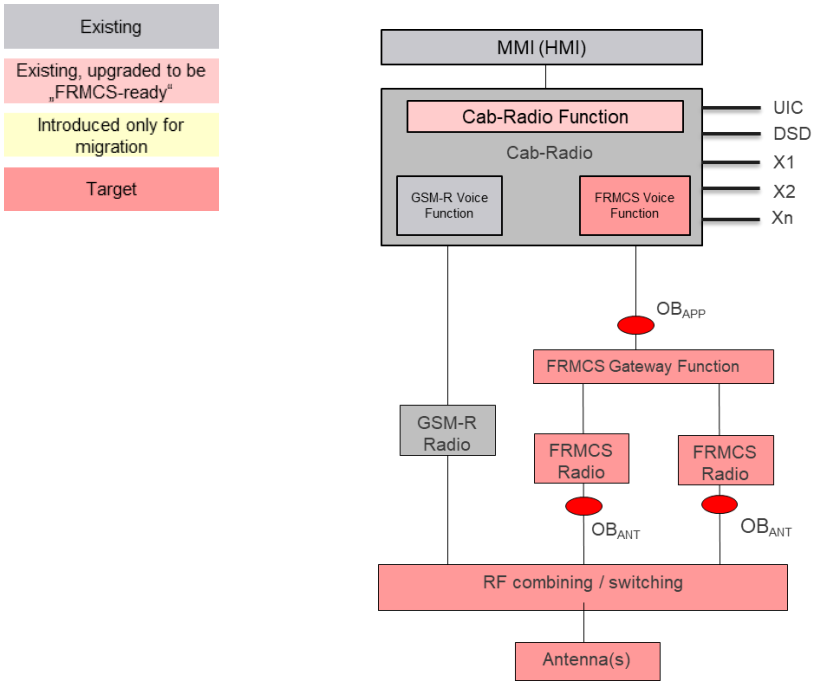

Figure 15: Cab Radio Variant 4a – New Cab Radio (Dual Mode, Option 3)

Needed protocol conversion:

- None.

Benefits:

- Existing equipment can be reused with a upgrade to support FRMCS.
- No protocol conversion required.

Disadvantages:

- The upgrade might only be possible on suitable Cab Radio platforms
- The upgrade might be limited to basic FRMCS Cab Radio features (not yet defined)

5.1.5 Cab Radio Variant 4b – New Cab Radio (Dual Mode, Option 3)

Description: Similar architecture as variant 4a, but reflecting a new Cab Radio supporting FRMCS out of the box.

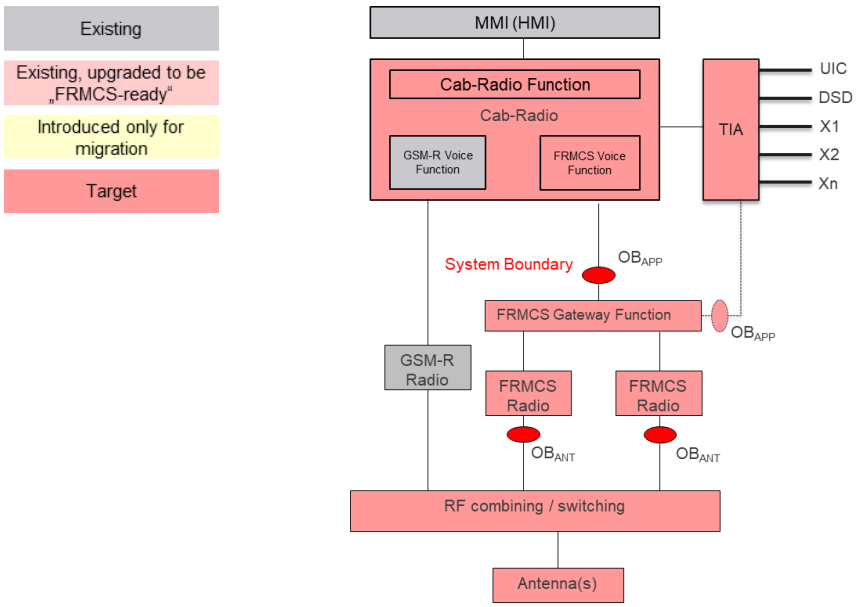

Figure 16: Cab Radio Variant 4b – New Cab Radio (Dual Mode, Option 3)

Needed protocol conversion:

- None.

Benefits:

- Dual Mode variant where a new Cab Radio platform supports GSM-R access.
- Fully supports FRMCS Cab Radio features (not yet defined)

Disadvantages:

- Additional Hardware

5.2 Comparison

The key characteristics of the different FRMCS migration variants in the context of Cab Radio are summarised in Table 3~~. **Error! Reference source not found.**~~

	Variant 1 - Existing GSM-R Cab Radio + Single Mode FRMCS Cab Radio	**Variant 2** - New Cab Radio (Dual Mode, Option 1)	**Variant 3** - New Cab Radio (Dual Mode, Option 2)	**Variant 4a** - Existing GSM-R Cab Radio + Single Mode FRMCS Cab Radio	**Variant 4b** – New Cab Radio (Dual Mode)
Capability to provide load balancing among GSM-R and FRMCS	Only m Only manually anually	Yes	No	Only manually	Yes
Protocol conversion burden / extent of functionality introduced only for migration	None	Moderate	Moderate	None	None
Form factor	Requires two MMIs + additional rack space	Additional rack space needed	Additional rack space needed	Additional rack space needed	Additional rack space needed

Table 3: Comparison of key characteristics of FRMCS migration variants in context of cab radio.

6 ANNEX 1 – Euroradio protocol stack

This Annex provides a brief overview of the Euroradio protocol stack specified in Euroradio FIS, SUBSET-037, version 3.2.0.

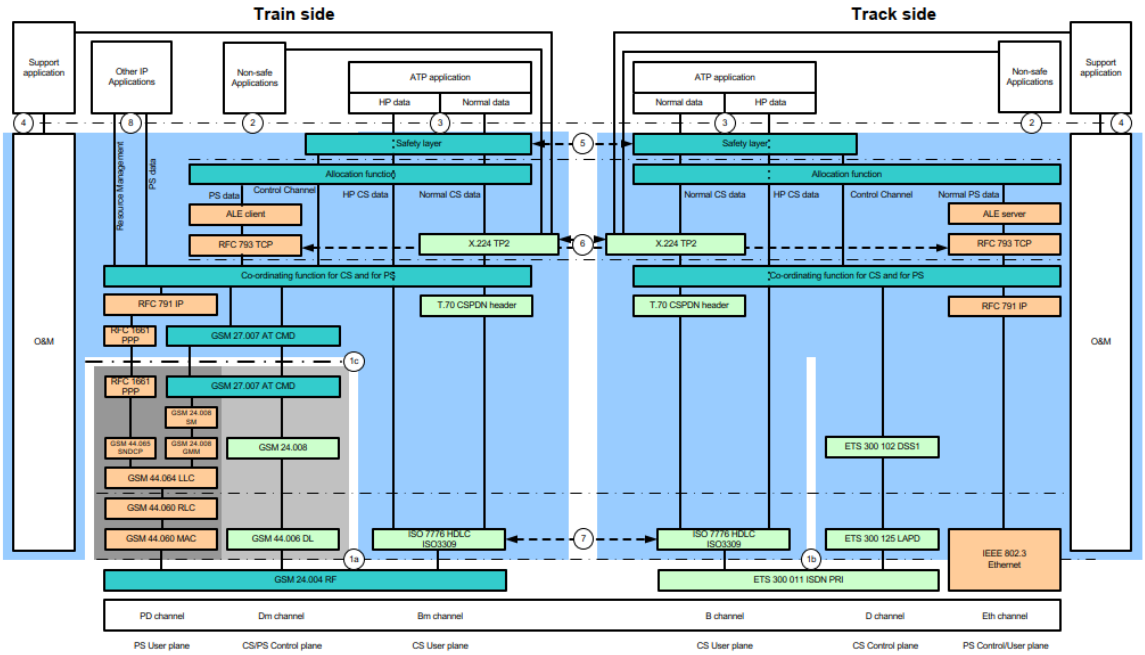

Figure 17: Euroradio Protocol Stack (Source: Euroradio FIS, SUBSET-037, version 3.2.0, Figure 2)

For the analysis of the various ETCS migration variants described in this document, the interfaces 1a and 1c depicted in the figure above are of relevance:

- **Interface 1a** is the GSM/GPRS-Interface (on-board)
- **Interface 1c** is the recommended on-board interface between the RCS (Euroradio System, in blue in the figure above) and the MT (Mobile Termination, the GSM-R/GPRS modem). For details refer to [Euroradio FFFIS]).

Physically the 1a / 1c interfaces are implemented using a single serial interface (ITU-T V.24), referred to as I_{GSM} in the Euroradio FFFIS.

In addition to the interfaces, also the three data planes need to be assessed individually, since each of them uses their own protocols over the above-mentioned interfaces.

- **PS User Plane**: For the transmission of the user data IP packets over interface 1c, the Point-to-Point Protocol (PPP) as specified in IETF RFC 1661 is used.
- **CS User Plane**: The CS user plane data is transported end-to-end using HDLC.
- **CS/PS Control Plane**: Both modes use AT-commands for the signalling between the Euroradio system and the GSM-R/GPRS modem. For the evaluation of the migration variants, it is important to consider that the Co-ordinating function in the Euroradio system requires full control over the modem (i.e. Network Selection, Network Registration, Session Management). Any migration variant avoiding changes to the existing Euroradio will have to ensure that the existing control plane protocol is fully implemented also on the FRMCS on-board system side (or in a converter function).

7 ANNEX 2 – List of Acronym

3GPP	3rd Generation Partnership Project
CS / PS	Circuit Switch / Packet Switch
DSD	Driver Safety Device
EDOR	ETCS Data Only Radio
ETCS	European Train Control System
EUG	ERTMS Users Group
FIS	Functional Interface Specification
FFFIS	Form Fit Function Interface Specification
GSM-R	Global System for Mobile Communications – Railway
HDLC	High-Level Data Link Control
MMI	Man-Machine Interface (this term encompasses all Man-Machine Interfaces including the Driver-Machine Interface and the Controller-Machine Interface)
OB_{ANT}	On-board Antenna system reference point/interface
OB_{APP}	On-board Application reference point/interface
$OB_{O\&M}$	On-board Operation & Maintenance reference point/interface
PCM	Pulse Coded Modulation
QoS	Quality of service
RF	Radio Frequency
TIU	Train Interface Unit
TOBA	Telecom On-Board Architecture
TSI	Technical Specification for Interoperability
TSI CCS	Control Command and Signalling TSI
UIC	Union Internationale des Chemins de Fer
VoIP	Voice over IP