Rail to Digital automated up to autonomous train operation

D25.1 – Consolidate prior research works. Adaptable Communication System and Future Railways Mobile Communication System Comparison

High level approach

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EXECUTIVE SUMMARY

The aim of this deliverable is to carry out a high-level comparison between FRMCS (Future Railway Mobile Communication System) and ACS (Adaptable Communication System), so that similarities between both systems can be established, as well as identify the main differences.

The comparison is established based on the following inputs:

- ACS specifications, work carried out within the S2R initiative for the development of ACS specifications within its research and development process.

- FRMCS (whose regulatory development is led by the UIC), with first prototypes within the 5GRAIL project, based on the FRMCS SRS v1, except for some gaps.

The comparison is made mainly on the architecture of both systems, on-board and trackside.

There are similarities in:

- Both systems differentiate the application layer from the communication layer

- Three layers: User plane, control plane and transport domain.

- They can support different radio technologies (FRMCS will only support 5G SA in v1)

As for the main gaps, without being exhaustive, here are the following:

- Scope of ACS and of the FRMCS

- On-board/Trackside interfaces

- On-board devices

- Security level / Registry

- Quality of Service

- Requirements for service management

It can be concluded that there is some aligment between FRMCS and ACS, but the objective for the development of both systems is different, while ACS wants to seek flexibility in the means of transport, for FRMCS It seeks to replace the GSM-R system, through a standard system, ensuring the coexistence of both and guaranteeing future developments, including a flexibility in the means of transport and separation of the user layer and communication layer.

This document can be considered alive and subject to future developments, since there are still open points for the ACS specification and the FRMCS specification is in its v1 version (for the elaboration of this document).

ABBREVIATIONS AND ACRONYMS

ATO	Automatic Train Operation
R2DATO	Rail to Digital automated up to autonomous train operation
ETCS	European Traffic Control System
ERTMS	European Railway Traffic Management System
ACS	Adaptable Communication System
FRMCS	Future Railway Mobile Comunication System
UIC	Union Internationale des Chemins de Fer
GSM-R	Gobal System for Mobile Railway Communications
X2R	Shift to Rail
3GPP	3rd Generation Partnership Project
CCS TSI	Control Conmmand and Signaling Technical Specifications for Interoperability
X2RAIL/S2R	Shift to Rail (Europe´s Rail Joint Undertaking)
DG Connect	Directorate-General for Communications networks
3GPP	3rd Generation Partnership Project
4G	Fourth Generation mobile networks
5G (5G SA)	Fifth Generation mobile networks (fifth Generation Stand Alone)
ACSapp	ACS application interface
FSmpm	FRMCS multipath management interface
GPRS	General Packet Radio Service
IP	Internet Protocol
MCX	Mission Critical Services
MCPTT	Mission Critical Push To Talk
MCDATA	Mission Critical Data
MCVIDEO	Mission Critical Video
OBapp	On Board application interface
PIS	Passenger Information System
REC	Railway Emergency Call
TCMS	Train Control Monitoring System
TLS	Transport Layer Security
TOBA	Telecom On-Board Architecture
TSapp	Trackside application interface

QoS	Quality of Service
UE	User Equipment
Wi-Fi / Wifi	Wireless Network Protocols based on IEEE 802.11

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1 INTRODUCTION

The work carried out through this deliverable is to obtain a comparison between FRMCS and ACS agreed by the different actors involved in the development of ACS and FRMCS specifications.

The work carried out within X2Rail-5 has been used as a starting point, in which the comparison of ACS with FRMCS (5GRail project) was developed.

A discussion and comparison between ACS and FRMCS need to take the differences of scope between them into account, as well as architectures and available / planned features, and needs to focus on the parts which are comparable.

The comparison made is based on the ACS specifications and FRMCS first prototyping (5GRail Project).

2 FRMCS VS ACS ARCHITECTURE COMPARISON

2.1 MAIN FEATURES

The adaptable communication system was specified within the S2R research and innovation project starting in 2016 based on User Requirements received from the different stakeholders with the objective to demonstrate specific concepts for the future communication system.

FRMCS is foreseen as the successor of GSM-R going to be part of ERTMS referenced in the upcoming CCS TSI, led and standardised by the UIC project since 2016 and to be used for applications relevant for interoperability, train performance, passenger information system, etc.

The scope of the ACS and the scope of the entire FRMCS are different, but they have a certain overlap.

On the one hand, the scope of the ACS, as outlined in in the ACS System specification [1] covers the abstraction layer between the communication services (transport layer) and the applications. The ACS should work as a transparent layer towards the applications to have the ability to use one or more transport layer(s) and to hide the details of the transport layer including changes, interruptions, switchovers, and others from the application.

ACS is best seen as early adopter to test and validate the idea of the abstraction layer between the transport layer(s) and the application, as well as of the “multipath” function, which in essence is allowing bearer flexibility.

On the other hand, the scope of FRMCS is to replace GSM-R and to enable digitalization. This means supporting ERTMS/ETCS and ERTMS/ATO included (CCS TSI), and (set of) applications like TCMS, PIS and other business applications, all via the same TOBA (On-Board FRMCS).

FRMCS is introducing the 3GPP MCX layer to allow strong QoS, the required functionalities for voice (MCPTT), including fit-for-purpose Railway Emergency Call, support for data and video (MCDATA, MCVIDEO) applications.

FRMCS introduces the separation between user plane (application layer) and communication plane (service layer and transport layer), and a separation between the control and transport layer.

FRMCS is bearer flexible, via the multipath and multi access mechanisms, concepts that are introduced, however not yet finalised, at the moment of this report.

2.2 COMPARISON BETWEEN ACS AND FRMCS 5GRAIL

Below a comparison between ACS and FRMCS first prototyping (via the DG Connect co-financed 5GRail Project):

Categories	ACS	5GRAIL (FRMCS first prototypes)[2]
Scope	Demonstrator Field Tests (ACS, Integrated Technical Demonstrator)	First FRMCS prototyping, based on v1 specifications, and where gaps, on assumptions. Factory, lab and field tests
Wireless Technologies	Multiple Radio Technologies covered (3GPP RAT, Wi-Fi, Satcom, GSM-R (GPRS), …)	5G SA; WiFi and 4G used for bearer flexibility tests. (Interworking with) GSM-R.
Application	E2E tests from application point of view (ETCS, CBTC, CCTV, Voice, REC, Internet on Board, Moving Block, Train Integrity …)	E2E tests from application point of view (ETCS, ATO, Voice, REC, TCMS, remote vision, video and PIS)
Control plane	3GPP based / MCx used for some demonstrators. Other demonstrator using different ACS control plane implementations.	3GPP MCX
Test Environment	Lab tests, field tests (Highspeed/Mainline, Regional/Freight, Urban/Suburban)	Factory tests, Lab tests, field tests
Specification	Based on X2Rail-3 ACS System Specification	Aligned with FRMCS V1 Specifications (where gaps, mitigations, ensured via assumptions)
Bearer flexible tests	E2E field tests with transparent switching between multiple bearers listed above	Yes, including e.g. testing of several applications simultaneous over same TOBA, or several bearers for one download
Security	Not really in scope for the demonstrators – nevertheless an ACS protection profile was defined in the Cyber Security work package of S2R	Local Binding, inbound TLS, protocol rupture
Frequencies	Use of Public Networks, Wi-Fi, Satcom and GSM-R (GPRS)	Testing in lab and field based on frequencies in the range of ECC decision (20) 02 1900 MHz, also n8, n78, Wi-Fi, 4G 2,6 GHz, and GSM-R

Table 1: Comparison between ACS and 5Grail

2.3 ARCHITECTURE COMPARISON

The comparison between the architectures from FRMCS and ACS is best started by means of the Architecture drawings.

The FRMCS Architecture in the version including the multi-path functionality is depicted in Figure 1

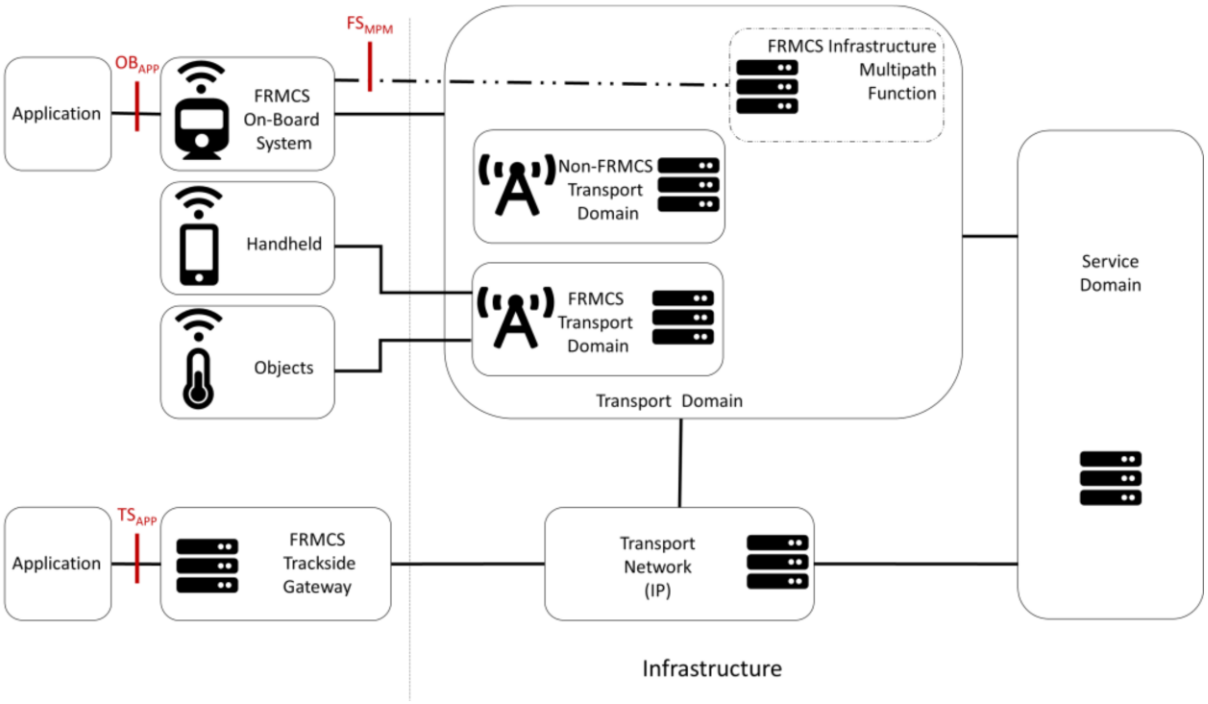

Figure 1: FRMCS SRS System Reference Architecture including Multipath function (source: UIC FRMCS SRS)

Figure 2 is a different representation of the FRMCS Architecture that allows a clearer way to compare the two architectures.

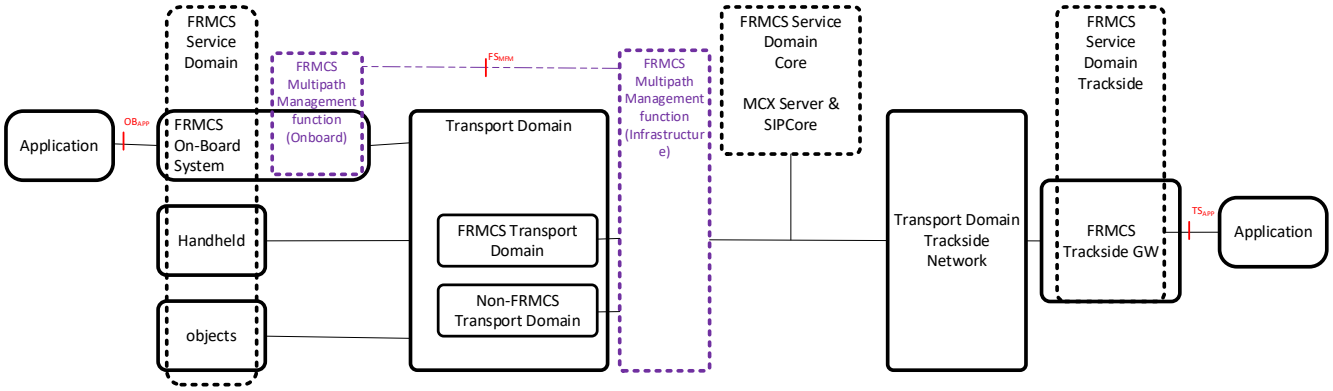

Figure 2: FRMCS System Reference Architecture redrawing to ease comparison

The same building blocks as defined in *Figure 1* are used in *Figure 2*, but in addition the service function building blocks are highlighted in a more transparent way.

The comparison with ACS can be best performed through figure 3 below:

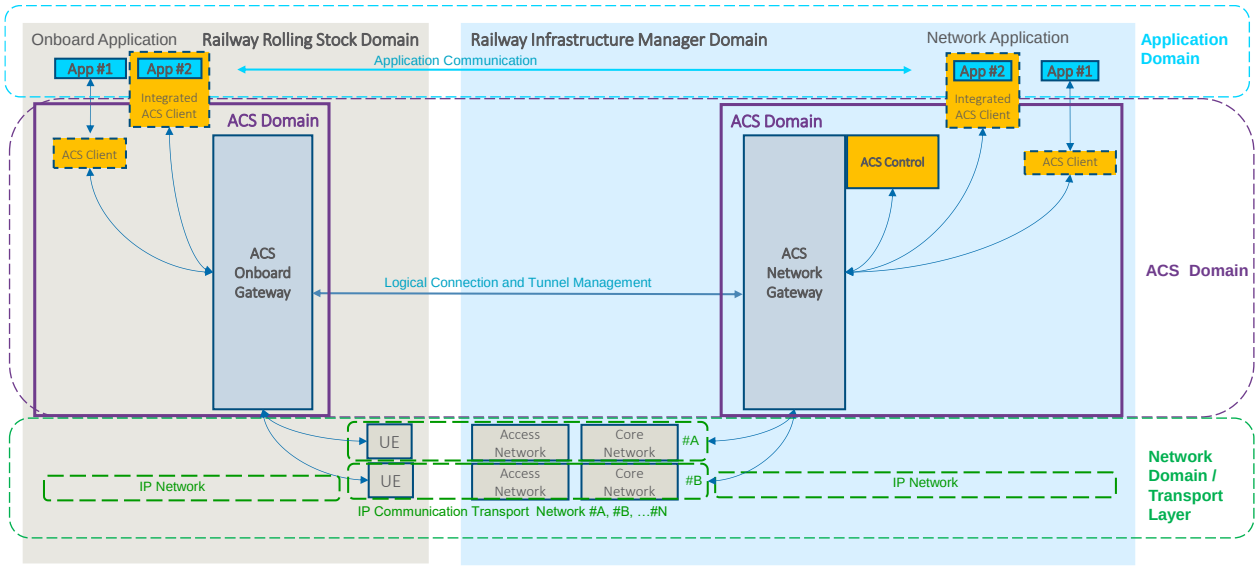

Figure 3: High Level ACS Communication System in view of communication layers

Both systems, FRMCS and ACS, provide communication services to applications to fulfil the communication needs of an application between a mobile entity (named usually in the railway context as “onboard”) and an entity at the fixed network side (“network” or “trackside”).

Comparing FRMCS and ACS architecture from a high-level view we can identify noticeable overlap:

- The applications of both “onboard” and “network” parts are connected via the application interface to On-Board FRMCS and Trackside FRMCS and respectively to the ACS onboard and network gateway. These building blocks are the entities responsible of providing communication service to the applications.
  However, the full scope of the On-Board Application interfaces is not similar, e.g. FRMCS OBapp enforces the Local Binding procedure, and compatibility with the foreseen One Common Bus (under definition), etc.

- The Onboard System/Gateway and Network/Trackside Gateways are then subsequently connected to transport network(s). The Gateways fulfil the communication service via the means of one or multiple transport network. The full scope of FRMCS TS GW is still to be finalised.

- A control logic (“FRMCS Service Domain Core” and “ACSControl”) is responsible to manage the communication service and is used to setup/control/release communication services for the applications. Applications can trigger the communication via this control logic. The applications use “clients” for the communication with the control logic.

MCX-Clients are included in FRMCS On-Board System and FRMCS Trackside Gateway for data communication (MCData), For Voice communication, the MCX clients resides with the application. FRMCS control layer is based exclusively on 3GPP MCX.
MCX Clients are included a similar way in the ACS as “ACSClient”. The Control Logic is connected to the Gateway(s) with some means and need to propagate the communication needs to the Gateway(s).

- The Gateway(s) have the means to use or control (On Board in case of FRMCS) the proper transport network suitable for each communication service.
  Note: in FRMCS the optional Multipath function is required also to use more than one transport network. The ACS has this functionality already inherently defined as major system function).

- The On-Board devices have differences, one of them being that TOBA plan to include e.g. OBrad, which will allow radio modules interchangeability, and remote radio heads.

3 TERMINOLOGY COMPARISON

Although a good functional overlap is identified in the previous chapter 2.3, the terminology used in FRMCS and ACS is sometimes different. The following table provides a comparison of the used terms to help mutual understanding between the two system specifications:

ACS Term	FRMCS Term	Comment/Purpose
Transport network	Transport domain FRMCS defines FRMCS and Non-FRMCS transport domains	
Network	Trackside	Used for entities located on the non-mobile side of the network
Network	Domain	Network may be viewed and perceived as a more precise and definite transport-oriented term and Domain is a more generic construct (can consist of e.g. Network(s) as the “link” to ACS). A domain can also encompass transport as well as service-oriented terms.
Layer	Stratum	
ACSControl	FRMCS Service Domain Core	Logical entity to control the communication setup/control/release of the communication sessions (registration, session management, service management)
Onboard Gateway	On-Board FRMCS	FRMCS Onboard system includes GW + Radio Function, that include mobile radios (UEs)
“Bearer Flexibility”, “Parallel/combined use of networks” and “transparency of networks”	Bearer Flexibility,	Bearer Flexibility, by using multipath or multi access

Table 2: Terminology for ACS and FRMCS

4 MAIN ALIGNMENTS, DIFFERENCES AND GAPS

This chapter highlights the main alignments, differences and gaps between FRMCS and ACS, mainly on high level respectively Group of functions view:

1) Architecture:

We see in general a degree of alignment at functional level between FRMCS and ACS Architecture, especially for data applications.
However, there are differences, e.g. at service layer level, internal interfaces e.g. On-Board OBrad and OBom, and for the OBapp, etc.

2) Functions and features:

Functions and features cover mainly authentication/registration, session management, service management and other network features.
ACS defines a principle registration function whereas FRMCS, already has more implemented mechanisms, e.g. for Local Binding. For session management there is in general a functional alignment.
Service management in ACS and FRMCS have only a smaller overlap - ACS as research project has here less coverage and functionality.
For network features like bearer selection, QoS negotiation, handover between networks and redundancy of networks we see an alignment in the requirements.
However, mechanisms used to enable and action these functions and features do differ.

3) System Layers:

In both solutions (ACS and FRMCS) three system layers are defined: control plane, user plane and transport domain.
Note that both control plane and user plane use the transport domain for actual data transport.
Control plane based on MCX, IP based user plane and finally an independent transport domain are defined in a similar way in both ACS and FRMCS.

4) Addressing:

Addressing is in principle demonstrator specific solved in ACS, also at the time of writing the report. The Addressing principles have been defined in FRMCS v1. What can be already stated is that the following:

a) The concept of Functional Alias is available in both systems.
b) Standard MCX addressing is an option in ACS whilst a basic requirement in FRMCS.
c) FRMCS addressing follows both data and voice, and especially the separation between transport and user layers. Video will also be introduced.

5) Reference points:

A number of reference points are defined in both systems. Reference points are required to enable technical interoperability, and in case of FRMCS also vendor diversity and interchangeability.
The FRMCS set of reference points with respect to interoperability and other intended system characteristics are in different stages to be concluded. As such, reference points should consequently be considered as an ongoing work. However. Their Functional requirements, and for part of them, the majority of features are available.
Reference points defined in ACS are described in ACS System Specification and for FRMCS in (11) FW-AT 7800 FRMCS System Requirements Specification and TOBA FRS 7510.
The currently defined external reference points in FRMCS and ACS show a certain degree of alignment on the functional purpose (ACSapp vs OBapp/TSapp, ACS control plane vs. MCX control plane in FRMCS).
The interfaces to the transport networks are currently based on 3GPP and 5G in FRMCS and left more open in ACS (although with recommendation as well to re-use 3GPP/5G interfaces).
Multipath function currently under finalisation in FRMCS, could close the gap to additional definitions for transport network interfaces and specific ACS internal interfaces to control the ACS user and tunnel management.
Thus some general alignment on functional point of view can also be stated in this section.

6) Bearer flexibility:

Bearer flexibility is one of the main concepts in ACS based on independent transport domains.
This has been addressed in FRMCS with Multi-Access (based on 3GPP functionality) and Multipath functionality aiming also to be 3GPP based. Note that bearer flexibility is still for further study in current version of FRMCS specification.
However, due to intention of having those two functions inside FRMCS we see certain functional alignment between ACS and FRMCS.

7) Quality of Service:

Quality of Service was introduced as generic requirement in ACS to enable the principle possibility to propagate QoS from ACS control towards transport bearers in order to manage the required QoS also for all transport layers. The exact way how to deal with QoS was not in focus of ACS – and also differently implemented in the X2R demonstrators - but the overall concept how ACS can handle QoS was addressed in the scope of X2R. Note that ACS has even the possibility of using transport bearers without specific QoS control and having thus an additional capability compared to FRMCS.
QoS Management within FRMCS is a critical requirement of the system.
FRMCS is using 3GPP, MCX and 5G mechanisms to provide this.

8) Cyber Security:

For ACS a protection profile was provided on component level.
Please refer to Deliverable X2R-3 D8.2 "Security architecture, protection profiles and security for legacy systems - SECURITY ARCHITECTURE, PROTECTION PROFILES AND SECURITY FOR LEGACY SYSTEMS" (14) and Deliverable X2R-3 8.3 "Protection profile for Adaptable Communication System (ACS) components" (15) for the work done in X2R 3.
Cyber Security is a priority for FRMCS. First elements are available through OBapp mechanisms, and inbound cyphering. More measures will be defined in FRMCS v2.
A detailed comparison with FRMCS also including the FRMCS SRS Security requirements was currently not performed as part of X2R WP8.

Following the comparison by Topics level above some functions are not aligned between ACS and FRMCS, due to various reasons. Some examples of them are listed below:

a) Additional security level with local authentication/Registration (“Local Binding") has been introduced in FRMCS.
This is seen mainly as security enhancement and similar function was not foreseen and deemed necessary in ACS also due to the research character of the X2R implementations.
Also a detailed definition of a local API (like OBapp in FRMCS) was not in the scope of the X2R demonstrators as these are mainly implementation specifics.
Note that X2R demonstrators are intended for exploring and showcasing a selection of potential implementations initially not focusing on standardization, however not excluding the potential of standardization.
b) Definition and requirement of service management was only done on high level for ACS. X2R demonstrators have independently solved these functions in different ways, if required, for the demonstrator setup (e.g. communication characteristic management). In order to define an interoperable system, FRMCS needs to be naturally stricter in definition and specification of such features (e.g. location information service).

5 CONCLUSIONS

The scopes of ACS and FRMCS are in general different, with partial but not sufficient overlap to strictly compare the two approaches. The two systems address different use cases, as well as markets, however not in concurrence.

ACS can be seen as a FRMCS precursor, aiming to achieve a “prove of concept” for bearer flexibility and separation between application and telecom. A general ACS architecture was set-up, including service layer control plane proposing 3GPP Mission critical services (as option), distinct IP user plane eventually with clear separation to independent transport plane(s).

On the other side, the FRMCS concrete scope is to replace GSM-R, as a ERTMS subsystem, ensuring at the same time some ten years of coexistence between the two systems, what leads to a much more precise and rich system by nature.

As such, FRMCS is also managing bearer flexibility and separation of applications from communication layer. In addition, due to all its functional and system requirements, it encompasses a comprehensive architecture, with its versatile system interfaces OBapp and TSapp designed on purpose for ERTMS evolutions, and it focuses on a strong Quality of Service, as it is based, among other structuring topics, on 3GPP 5G SA Mission Critical, for economy of scale and future proofness.

This document is an initial version and subject to future development. It should be considered for the development of future demonstrators in ERJU.

Due to the short work time that has been available, it has not been possible to carry out a detailed and low-level analysis of the FRMCS specifications against those of ACS.

Within R2DATO, work should continue on this deliverable so that low level comparison could be established and even prepare a paper that studies how FRMCS and ACS could work together.

REFERENCES

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