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Foreword

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Executive summary

Since the first studies on the successor to GSM-R have been launched by UIC in 2012, the railway community has been considering how to meet railway requirements with a future proof and flexible radio communication system.

The rail needs are defined in the User Requirements Specification (URS) [i.1] and the Telecom Onboard Architecture (TOBA) Requirements [i.2] delivered by the UIC Project Future Railway Mobile Communications System (FRMCS). From the UIC requirements, requirements relevant to 3GPP have been captured in 3GPP TR 22.889 [i.3]. Altogether, the stated requirements are the basis for the development of the GSM-R successor.

The present document is a study on FRMCS system architecture, which initially describes a potential logical FRMCS architecture that is suitable to meet the rail requirements according to the requirement documents cited before, and the key reference points that are to be specified. As one input to the design, it provides an analysis of specific challenges such as security, migration, positioning, etc., and derives their implications on the FRMCS architecture. The present document also describes several deployment scenarios (for instance related to setups with multiple transport networks operated by different entities), which are also relevant to the design of the FRMCS system architecture, as this should support all deployment scenarios that are currently envisioned. Beyond the description of the logical FRMCS architecture, the present document then elaborates on possible technical realizations of the FRMCS architecture through building blocks from 3GPP and from other standards bodies. Special emphasis is here put on consideration for the support of multiple onboard/handheld radios and/or multiple trackside transport domains, and the support of border-crossing scenarios. Finally, the present document provides a functional gap analysis and identifies risks, before listing topics for further study.

Introduction

The Technical Committee Rail Telecommunications (TC RT) is the "home" for those telecommunication aspects of rail transportation which are not part of the specification of the current mobile communication technologies themselves. TC RT is in particular responsible for the development and maintenance of GSM-R standards.

GSM-R has been a great success not only in Europe, where more than 100 000 km of railway tracks are daily operated through GSM-R, but also worldwide, and this number will double within the next years due to the on-going installations of this technology all over the world.

As the needs of the railways are constantly evolving, in particular in the context of the digitalisation of rail operation that is pursued in many countries, and considering the upcoming obsolescence of GSM-R technology, UIC launched in 2012 the first studies for a successor to GSM-R, pertinently named Future Railway Mobile Communication System (FRMCS). The UIC project then concretely delivered the new User Requirements Specifications (URS) [i.1] focusing mainly on rail communication needs - as a basis for the development of the GSM-R successor.

The present document is a study on the FRMCS system architecture, which defines a logical FRMCS architecture and likely deployment scenarios, and which elaborates in detail on possible technical realizations of the FRMCS system. The result of this study is expected to provide the basis for the subsequently following normative work on FRMCS in ETSI.

1 Scope

The present document is a technical report, in line with the scope and field of application of its related Work Item. In particular, it covers:

- Definition of key terms and a high-level description of the FRMCS architecture, as agreed among UIC and ETSI (see clauses 3 and 4, respectively).
- An analysis of the architectural implications of various requirements on the FRMCS system captured in UIC TOBA and 3GPP TR 22.889 [i.3], and of aspects such as identification and addressing, security, positioning and migration (see clause 5).
- A description of the logical architecture of the FRMCS system, including a description of the main logical entities and key reference points among these (see clause 6).
- A derivation of key deployment and border-crossing scenarios that the FRMCS architecture should support (see clause 7).
- An investigation of possible technical realizations of the FRMCS system, based on the usage of building blocks from 3GPP and other standards bodies (see clause 8).
- A gap analysis and identification of risks related to the FRMCS standardization, for instance due to its dependency on timelines of different standards bodies (see clause 9).

Finally, the present document identifies the next steps to ensure the complete definition of the FRMCS system.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document, but they assist the user with regard to a particular subject area.

[i.1] UIC FRMCS URS v5.0: "User Requirements Specification".

[i.2] UIC FRMCS TOBA-7510 (V1.0.0) (April 2020): "FRMCS Telecom On-Board System - Functional Requirements Specification".

[i.3] 3GPP TR 22.889 (V17.2.0) (January 2020): "Study on Future Railway Mobile Communication System (FRMCS)".

[i.4] 3GPP TS 21.905 (V16.0.0) (June 2019): "Vocabulary for 3GPP Specifications".

[i.5] 3GPP TS 23.501 (V16.4.0) (March 2020): "System architecture for the 5G System (5GS) (Release 16)".

[i.6] 3GPP TS 24.501 (V16.4.1) (April 2020): "Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3 (Release 16)".

[i.7] 3GPP TS 22.280 (V17.2.0) (December 2019): "Mission Critical Services Common Requirements (MCCoRe); Stage 1".

[i.8] 3GPP TR 28.801 (V15.1.0) (January 2018): "Telecommunication management; Study on management and orchestration of network slicing for next generation network".

[i.9] 3GPP TS 23.228 (V16.4.0) (March 2020): "IP Multimedia Subsystem (IMS); Stage 2".

[i.10] 3GPP TS 23.003 (V16.2.0) (March 2020): "Numbering, addressing and identification".

[i.11] 3GPP TS 23.280 (V17.2.0) (March 2020): "Common functional architecture to support mission critical services; Stage 2".

[i.12] UIC FRMCS TOBA-7540 (V1.0.0) (April 2020): "FRMCS Telecom On-Board System - Architecture Migration Scenarios".

[i.13] 3GPP TR 23.796 (V16.0.0) (March 2019): "Study on application architecture for the Future Railway Mobile Communication System (FRMCS) Phase 2".

[i.14] 3GPP TS 27.007 (V16.4.0) (March 2020): "AT command set for User Equipment (UE)".

[i.15] ETSI TS 123 002 (V15.0.0): "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Network architecture (3GPP TS 23.002 version 15.0.0 Release 15)".

[i.16] 3GPP TS 24.193 (V1.2.0) (May 2020): "5G System; Access Traffic Steering, Switching and Splitting (ATSSS); Stage 3".

[i.17] IETF RFC 8743 (March 2020): "Multi-Access Management Services (MAMS)".

[i.18] 3GPP TR 23.783 (V0.10.0) (June 2020): "Study on Mission Critical (MC) services support over the 5G System (5GS)".

[i.19] IETF RFC 7542 (May 2015): "The Network Access Identifier".

[i.20] IETF RFC 1035 (November 1987): "Doman names - implementation and specification".

[i.21] IETF RFC 1123 (October 1989): "Requirements for Internet Hosts -- Application and Support".

[i.22] IETF RFC 3966 (December 2004): "The tel URI for Telephone Numbers".

[i.23] IETF RFC 3261 (June 2002): "SIP: Session Initiation Protocol".

[i.24] IEEE 802.11™: "IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.25] ETSI TS 123 271: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Functional stage 2 description of Location Services (LCS) (3GPP TS 23.271)".

[i.26] ETSI TS 123 282: "LTE; Functional architecture and information flows to support Mission Critical Data (MCData); Stage 2 (3GPP TS 23.282)".

[i.27] TIA-603-D: "Land Mobile FM or PM Communications Equipment Measurement and Performance Standards".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

communication services: services enabling the exchange of information between two or more service users

complementary services: ancillary services, e.g. providing and/or utilizing the location of the service user, supporting communication services and the railway application stratum

FRMCS Mobile Application Client: client that enables authorization of an application to the FRMCS Mobile Gateway

FRMCS Mobile Gateway: gateway that provides access to the FRMCS Transport Stratum for FRMCS Users through FRMCS Service Client(s)

FRMCS Service Client: client that enables the use of the Communication Services and/or Complementary Services for the railway applications

FRMCS System: telecommunication system conforming to FRMCS specifications, consisting of Transport Stratum and Service Stratum

FRMCS User: human or machine making use of Communication Services and/or Complementary Services

FRMCS User Identity: unique identity associated with a single or multiple FRMCS User and can be complemented by alternative addressing schemes

legacy conversion: function that provides conversion towards legacy interfaces (e.g. V.24 serial interface)

NOTE: The Legacy Conversion provides encapsulation/de-capsulation for control and user plane data as well as the necessary conversion of the physical interfaces between legacy GSM-R UE and FRMCS.

mobile radio: 3GPP User Equipment or non-3GPP equivalent, which supports selected 3GPP and/or non-3GPP access (e.g. 4G, 5G, Wi-Fi, satellite)

on-board transport system: system that provides on-train only transport services and enables the interaction with the FRMCS Gateway and the FRMCS Service Stratum where applicable

proxy: person or entity that is acting or being used in the place of someone or something else

railway application stratum: railway-specific functionalities using services offered by the service stratum

reference point: conceptual point applicable for interaction between functional services that enables authorized functions, e.g. in the network, to access their services

service domain: implementation of (parts of) the Service Stratum which belongs to and/or is operated by a unique organization

service stratum: communication services and complementary services

train communication network: sub-system of the on-board transport system that aggregates various train backbones

transport domain: implementation of (parts of) the transport stratum which belongs to and/or is operated by a unique organization

transport stratum: set of access and corresponding core functions applicable for the FRMCS system

User Equipment (UE): equipment according to 3GPP terminology (see 3GPP TS 21.905 [i.4]) that allows access to 3GPP transport services

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
4G	Fourth Generation Mobile Networks
5G	Fifth Generation Mobile Networks
5GS	5G System
AF	Application Function
AKA	Authentication and Key Agreement
AMF	Access and Mobility Management Function
APN	Access Point Name
ARP	Allocation and Retention Priority
AS	Access Stratum
ATO	Automatic Train Operation
ATSSS	Access Traffic Steering, Switching & Splitting
ATSSS-LL	Access Traffic Steering, Switching & Splitting - Low Layer
CAPIF	Common API Framework
CCM	Client Connection Manager
C-MADP	Client Multi-Path Data Proxy
CP	Control Plane
CS	Circuit-switched
CT	Call Type
CTCS	Chinese Train Control System
EAP	Extensible Authentication Procedure
eDECOR	enhancements of DEdicated CORe networks
eNB	evolved NodeB
EPC	Enhanced Packet Core
EPS	Enhanced Packet System
ETCS	European Train Control System
EUG	ERTMS Users' Group
E-UTRA(N)	Evolved Universal Terrestrial Radio Access (Network)
E-UTRAN	Enhanced UMTS Terrestrial Radio Access Network
FC	Functional Code
FFS	For Future Study
FRMCS	Future Rail Mobile Communications System
FSSI	FRMCS Service Session Interface
FTS	Fixed Terminal Subsystem
GNSS	Global Navigation Satellite System
GRUU	Globally Routable User-agent URI
GSM-R	Global System for Mobile communication for Railways applications
GW	Gateway
HW	Hardware
IC	International Code
IEEE	Institute of Electrical and Electronics Engineers
IMEI	International Mobile Equipment Identity
IMPI	IP Multimedia Private Identity
IMPU	IP Multimedia Public identity
IMS	Internet Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IN	Intelligent Network
IoT	Internet of Things
IP	Internet Protocol
ISDN	Integrated Services Digital Network
IWF	InterWorking Function
KASME	Key Access Security Management Entries
LAA	Licensed-Assisted Access

LAN	Local Area Network
LBS	Location Based Service
LDS	Location Dependent Service
LTE	Long Term Evolution
LTE-U	Long Term Evolution-Unlicensed
LWA	LTE-WLAN Aggregation
MAC	Media Access Control
MAMS	Multi Access Management Services
MC	Mission Critical
MCData	Mission Critical Data
MCPTT	Mission Critical Push To Talk
MCVideo	Mission Critical Video
MCX	Mission Critical Services
MOCN	Multi Operator Core Network
MPTCP	Multi-Path Transmission Control Protocol
MSISDN	Mobile Subscriber ISDN Number
NAI	Network Access Identifier
NAS	Non-Access Stratum
NCM	Network Connection Manager
N-MADP	Network Multi Access Data Proxy
NR	New Radio
OB_{APP}	Onboard Application Interface
OB_{RAD}	Onboard Radio Interface
OSI	Open Systems Interconnection
PCF	Policy Control Function
PDU	Packet Data Unit
PLMN	Public Land Mobile Network
PLMN-ID	Public Land Mobile Network Identification
PS	Packet-Switched
PSTN	Public Switch Telephone Network
QCI	QoS Class Identifier
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RBC	Radio Block Centre
RFC	Request For Comments
RG	Residential Gateway
RRC	Radio Resource Control
RTT	Round-Trip Time
SBA	Service Based Architecture
SDAP	Service Data Adaptation Protocol
SDF	Service Data Flow
SDS	Short Data Service
SEPP	Security Edge Protection Proxy
SIEM	Security Information and Event Management
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SMF	Session Management Function
SRS	System Requirement Specification
SS7	Signalling System No 7
SST	Slice/Service Type
SW	Software
TCP	Transmission Control Protocol
TCRT	Technical Committee Rail Telecommunications
TETRA	Terrestrial Trunked Radio
TS_{FS}	Trackside FRMCS Service Interface
UE	User Equipment
UIC	Union Internationale des Chemins de fer (English: International Rail Union)
UIN	User Identification Number
UN	User Number
UP	User Plane
UPF	User Plane Function

URI	Uniform Resource Identifier
URLLC	Ultra-Reliable Low-Latency Communications
URS	User Requirements Specification
URSP	User Equipment Route Selection Policy
W-AGF	Wireline Access Gateway Function
WiFi™	Wireless Fidelity
WLAN	Wireless Local Area Network

3.4 Notion of logical architecture, technical realization and physical implementation

In the remainder of the present document, the FRMCS architecture is described in different forms, with a general differentiation between:

- **Logical architecture:** Describes the FRMCS system in the form of logical function blocks and reference points in between. The logical architecture is purposely kept solution-agnostic. Clauses 6 and 7 in the present document describe the FRMCS system from a logical architecture perspective.
- **Technical realization:** Describes one or multiple possibilities to realize the FRMCS system by using building blocks from 3GPP or other bodies. In the present document, clause 8 delves into technical realization options for the FRMCS system, with the aim to identify any possible technology gaps and ensure that the reference points in the logical architecture are defined in a meaningful way.
- **Physical implementation:** Describes how (parts of) the FRMCS system could be mapped to physical entities or products from a vendor. Since physical implementations are not relevant for standardization, they are only used for illustration purposes in the present document, for instance in clause 8.4 in the context of onboard architecture.

These forms of architecture description are also illustrated in figure 3-1.

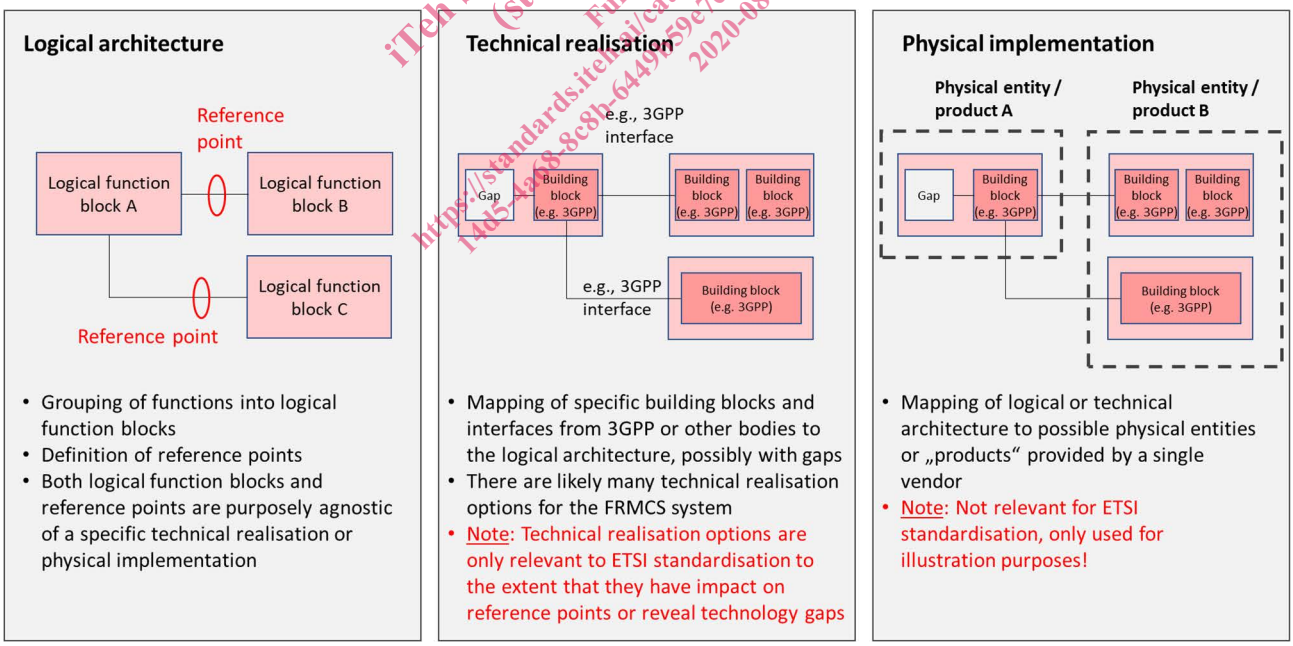

Figure 3-1: Notion of logical architecture, technical realization and physical implementation