
# Final Report

# Design and Evaluation of an FRMCS E2E System using Mission Critical Services for Future Rail Operation

Research Collaboration between Kontron Transportation and Deutsche Bahn within the sector initiative „Digitale Schiene Deutschland“

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kontron S&T Group Digitale Schiene Deutschland DB NETZE

**Authors**: Manfred Taferner, Kontron Transportation
Peter Beicht, Kontron Transportation
Karl Kernstock, Kontron Transportation
Ulrich Geier, Kontron Transportation
Fang-Chun Kuo, Digitale Schiene Deutschland, Deutsche Bahn
Richard Fritzsche, Digitale Schiene Deutschland, Deutsche Bahn

## About Kontron Transportation

Kontron Transportation is leading and trusted partner for railways and paving their way to a modern world of end to end communication in real time with high reliability and up to date features. Based on the future FRMCS standardization (3GPP, ETSI), Kontron Transportation offers tailor made solutions for Railways across Europe, developed with regard to transmission security and enhanced with features such as a voice recorder, a heartbeat function, a messenger service and the dispatcher.

## About DB Netz

With more than 33,000 km of track, DB Netze Track operates the largest rail network in Europe. More than one billion train-path kilometers are traveled each year on the tracks in Germany. DB Netze Track is also responsible for managing infrastructure operations as well as for securing long-term infrastructure quality and availability, and non-discriminatory access to train-paths and service facilities. This includes preparing schedules in close cooperation with customers, operations management, construction management and maintenance.

# Contents

# 1 Introduction

Less traffic, less congestion, less particulate matter – and more people and more goods on the rails: The rail sector in Europe is on the verge of a technological leap into the digital future. The sector initiative "Digitale Schiene Deutschland" is taking advantage of this opportunity and bringing future technologies into the rail system. This benefits not only passengers, but also the climate and Germany as a business location. And all this without having to construct a single new track.

The foundation for this is being laid with the fundamental modernization and digitalization of the infrastructure through the consistent introduction of digital control and safety technology. In addition, Digitale Schiene Deutschland is working on a far-reaching digitalization of the railway system. For this, a system architecture will detail the tasks of individual components of the railway system, and how they should work together.

On this basis, numerous digital technologies will then be tested and further developed for use in the system: for example, an AI-based traffic and incident management system will provide intelligent and automated control of trains in the future. These will then run fully automatically and at an optimal distance from each other. The latest sensor technology for environment perception coupled with high-precision train location and an automated interruption detection are further technologies that will play an important role in the digitalization of the railway system. Overall, a significant improvement in capacity, punctuality and efficiency of the railway system will be achieved, all of which are requirements for more traffic on the railway and a strengthening of the railway as the climate friendly mode of transport of the future.
The rail system of the future will be characterized by data-intensive applications that must communicate with each other in real time. New connectivity and IT platforms are therefore necessary in order to achieve this goal.

This study "Design and Evaluation of an FRMCS E2E System using Mission Critical Services for Future Rail Operation" conducted by Kontron Transportation and Deutsche Bahn (DB) within the sector initiative Digitale Schiene Deutschland (DSD) aims to investigate design aspects of an end-to-end (E2E) FRMCS (Future Railway Mobile Communication System), which is successor of GSM-R (Global System for Mobile Communications – Railway). The UIC launched FRMCS as a project in 2014. The UIC is working in close cooperation with the EU Agency for Railways and stakeholders on FRMCS specifications, namely FRS (Functional Requirement Specification) and SRS (System Requirement Specification). FRS and SRS are the foundation for the operation of FRMCS networks and will be the base in the CCS TSI for train radio and ETCS critical applications.

European Commission has recently mandated ETSI TC RT (Technical Committee for Railway Telecommunications) to provide the normative specifications for FRMCS by end of 2022. Therefore, FRMCS specifications (FRS and SRS)) will be based on 3GPP and ETSI specifications, defining technique building blocks as well as interfaces and ensuring the interoperability across the countries. Accordingly, this study on the FRMCS system architecture assumes the utilization of 3GPP 5G and Mission Critical Services (MCX)[1]. A special focus in this study is to explore the support of 3GPP MCX technology in the FRMCS. The goal of this study is to maximally leverage standardized technologies to fulfil requirements of various applications envisioned for future railway operation. Particular attention is expected on

- determining a set of key FRMCS services required for representative DB railway applications
- defining E2E architecture with MCX building blocks and reference points

[1] During the time of the project, 3GPP Rel 15 was available for the study and Rel 16 was still in the progress of being specified.

- examining challenges on the integration of MCX and 5G
- understanding the QoS procedure to enable FRMCS services

The report is structured as follows: A set of railway applications are presented in Chapter 2. These applications, including Voice, ETCS, ATO, Remote Driving and Video Surveillance are utilized as railway reference applications for the study. FRMCS will require a set of functions in MCX Specifications. Chapter 3 identifies the key MCX functions required for the representative Railway applications, including common MCX functions as well as service-specific functions in MCPTT, MCData and MCVideo. Chapter 4 details the required MCX building blocks and reference points for the specific Railway reference applications described in Chapter 2 embedded in the overall FRMCS logical system architecture defined in ETSI TR 103 459 [1]. Chapter 5 discusses the integration of 5G and MCX in terms of standardization status and technique challenges, including reviewing 3GPP study items regarding integration of MCX/IMS and 5G as well as investigating the separation of control plane and user plane for MCX when integrating with distributed 5G deployment. Chapter 6 describes the end-to-end Quality of service procedure in FRMCS with the detailed interaction between MCX and the 5G. Chapter 7 summarizes the current FRMCS standardization timeline and identifies standardization gaps for FRMCS. Finally, Chapter 8 concludes the study by summarizing the overall finding and proposing possible field trial setups.

# 2 Railway Reference Applications

For this study a set of railway reference applications is utilized for the considerations in the later sections of this report. For that purpose, the use cases Voice, ETCS, ATO, Remote Driving and Video Surveillance are described together with its requirements on the FRMCS communication system. In general, this study targets a fully automatic train operatio n, referring to GoA4 (Grade of Automation), even though train operation with lower degree of automation needs to be supported by the system as well.

## 2.1 Voice

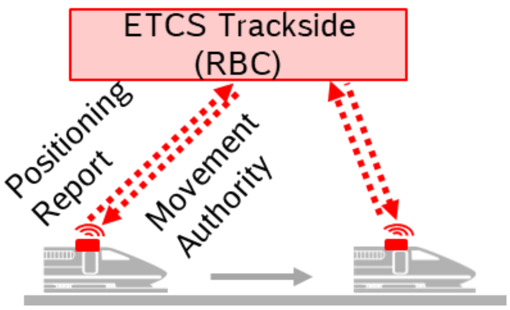
The main scenarios for the use of voice services are subject to operation in below GoA2. In that cases, voice communication can happen between any groups consisting of dispatchers or controllers at the train operation centers, train drivers and maintenance staff at the tracks. The railway voice services comprise several features already implemented in th e current used GSM-R system, e.g., functional and location dependent addressing of communication endpoints, group call services, etc.

For the operation in GoA4, where no railway staff is assumed to be located at the train and the dispatching system is automated as well, there are still situations where voice communication is required. One example is an emergency case, where the trackside emergency staff needs to speak with passengers at the train or vice versa. This might be realized by a dedicated emergency device inside the train. The communication requirements for voice services are listed in Table 2-1 Communication requirements for voice communication (regular and emergency) The reliability numbers are referring to the number of IP packets, successfully transmitted within the given latency.

| Message Type | Transmission Type | UL/DL | Distribution | Data Rate per Train | Latency[2] | Packet Reliability |
|---|---|---|---|---|---|---|
| Audio | Occasional Stream | 50/50 | Point-to-point & point-to-multi-point transmission | 24 kbps | <100 ms | 99.9 % |

**Table 2-1 Communication requirements for voice communication (regular and emergency)**

## 2.2 European Train Control System (ETCS)




[2] The latency requirement in this document refers to the length of time it takes for a signal to travel in one direction on IP level.

The purpose of the European Train Control System (ETCS) is to ensure the safe operation of train traffic. Therefore, movement authorities are transmitted from trackside Radio Block Centres (RBCs) to trains, in order to indicate the permission to enter a certain rail segment. The rail system is sub-divided into rail segments, and only a single train is permitted to be located within a segment. The basis for the system is periodic position reporting of each train, including information such as front/rear end position of the train, speed, integrity details, etc. The ETCS system can then dynamically authorize trains to access new rail segments by sending movement authorities (MAs). The periodicity of both message types is related to the speed of the train. Fast moving trains must send position reports more frequently than slowly moving trains. Note, that the periodicity of movement authorities is not triggered by a time counter rather than due to the frequent entering of rail segments.

In the future, a so-called ETCS Level 3 Moving Block approach is envisioned, which operates in a train-centric manner and allows trains to travel in minimum distance through the usage of train-based train integrity information and advanced train-based localization.

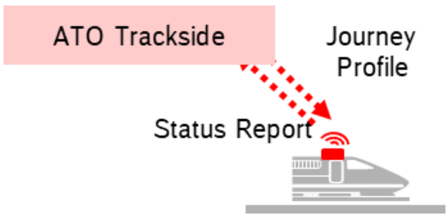
The overall controlling system is typically deployed in a distributed fashion, where the RBCs are responsible for a certain area of the overall rail system of the Infrastructure Manager (IM). In case a train crosses the border of two RBC areas, a so-called RBC handover needs to be performed. In GSM-R a dedicated modem is used to establish a connection to the new RBC. For FRMCS such procedure would conflict with fundamental FRMCS design paradigms, where the utilized underlying transport resource shall be transparent to the application.

The overall communication requirements for the two message types are presented in Table 2-2. Note that the data rate estimates indicate requirements on average.

| Message Type | Transmission Type | UL/DL | Distribution | Data Rate per Train | Latency | Packet Reliability |
|---|---|---|---|---|---|---|
| Position Report | Periodic messages | UL | Point-to-point transmission | 10 kbps | 100 ms | 99.9999 % |
| Movement Authority | Periodic messages | DL | Point-to-point transmission | 10 kbps | 100 ms | 99.9999 % |

**Table 2-2 Communication requirements for ETCS**

## 2.3 Automated Train Operation (ATO)



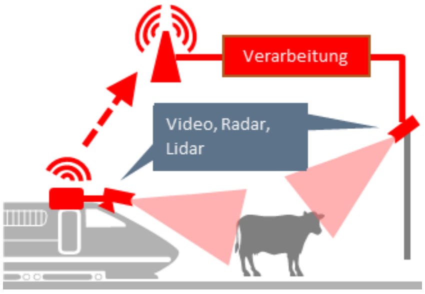

Future rail operation targets the fully automated operation in GoA4. The implementations of GoA2, 3 and 4 are based on the rail operation application ATO, which utilized so called “Journey Profiles” including information about the driving behaviour of the train. Journey Profiles are transmitted from the centralized ATO trackside system to the train. While the MAs for ETCS indicate the permitted driving behaviour, the Journey Profiles inform about the optimal acceleration and breaking. Journey Profiles are frequently updated, but the update frequency is assumed to be below the one for MAs. The trackside ATO system get vitality information from the train via the status report.

The automation functions rely on up-to-date maps and segment profiles including, e.g., geographical description of the relevant rail segments and environmental elements. At the beginning of the journey, the train obtains the latest version of all relevant maps and segment profiles, which will be traversed during the journey. In addition, it can happen, that relevant updates become available while the journey already started or there is a change in the journey, which requires the download of further data.

| Message Type | Transmission Type | UL/DL | Distribution | Data Rate per Train | Latency | Packet Reliability |
|---|---|---|---|---|---|---|
| Journey Profile | Periodic message | DL | Point-to-point transmission | 10-50 kbps | 100 ms | 99.9 % |
| Segment Profiles, Digital Maps | Occasional message | DL | Point-to-point transmission | 100 kbps | 1 s | 99.9 % |
| Status Report | Periodic message | UL | Point-to-point transmission | 1 kbps | 100 ms | 99.9 % |

**Table 2-3 Requirements for ATO**

## 2.4 Perception of environment: video surveillance




Due to the reduced amount of staff in above GoA2 operation, video surveillance becomes more relevant, to empower remote staff to identify and act on critical situations inside as well as outside the train. In such cases the remote staff is assumed to be located at a distributed location (e.g., an operation centre) similar to the remote driver.

| Message Type | Transmission Type | UL/DL | Distribution | Data Rate per Train | Latency | Train Speed | Packet Reliability |
|---|---|---|---|---|---|---|---|
| Video/ Audio Stream | In non-regular operation | UL | Point-to-point transmission | 3-4 Mbps | < 10 ms | ≤ 40 km/h | 99.9 % |
| | | | | | < 100 ms | otherwise | |

**Table 2-4 Communication requirements for Video Surveillance**

## 2.5 Incidence management: remote driving

In GoA4 there is no staff on the train that would be able to drive the rolling stock in case of incidents. In order to provide an option to still operate the train if automated operation is not possible, remote driving shall be implemented. In this case a remote driver is located, e.g., at a distributed operation centre receiving video data from the train front camera (and potentially other cameras). Based on the video and audio data the driver can operate the train remotely on sight. The driver's train control information is transmitted back to the train. The control information shall be transmitted frequently for safety reasons and better detection of transmission interruptions. The remote train driving operation is assumed to be utilized only for train speeds below 40 km/h. As indicated in Table 2-5, the application applies for non-regular operations only. Due to latency requirements its assumed that the remote control system is deployed in distributed locations with dedicated serving areas. Crossing an area border shall result in a handover situation from one train driver to another. As the remote driver might also be supported with additional automation functions which are based on low latency data, edge cloud handover mechanisms with below 10 ms interruption times are targeted.

| Message Type | Transmission Type | UL/ DL | Distribution | Data Rate per Train | Latency | Train speed | Packet Reliability |
|---|---|---|---|---|---|---|---|
| Video/Audio Stream | In non-regular operation | UL | Point-to-point transmission | 1-7 Mbps | <10ms | <40km/h | 99.9 % |
| | | | | | <100ms | otherwise | |
| Control Information | In non-regular operation | DL | Point-to-point transmission | 10-100 kbps | <10ms | <40km/h | 99.9999 % |
| | | | | | <100ms | otherwise | |

**Table 2-5 Communication requirements for remote driving**

# 3 Key MCX Functions in FRMCS Required for Representative Railway Applications

FRMCS will require a set of functions in MCX Specifications. This chapter describes the key MCX functions required for the representative Railway applications defined in Chapter 2. Firstly, Sec 3.1 presents common MCX functions which are required for all the MC Services, namely MCPTT, MCVideo and MCData. Moreover, the required service-specific functions in MCPTT, MCData and MCVideo are defined in Sec 3.2, Sec 3.3 and Sec 3.4, respectively. Finally Sec 3.5 summarizes the chapter by mapping the relevant MCX specifications and functions (common and service-specific) to the railway reference applications [3,4,5,6].

For more detailed MCX functional description and reference points, please refer to corresponding 3GPP specifications. Note that depending on the use case, some functions listed in this chapter may be mandatory or optional.

## 3.1 Common functions

Common Functions are defined in MCX Specifications as Functions which are used by different MCX services like MCPTT, MCData and MCVideo. Not every common function might be used or required by each of the MCX Services.

### 3.1.1 Registration and service authorization

Registration and Service Authorization are the common basic functionality used by multiple services
Prior using any MCX services a MC service client has to perform the registration step. During registration the MC service server creates a binding between IMS public identity and the MC service identity. This is applicable for MCPTT, MCData, and MCVideo.
Two options are possible:

- Via 3rd party registration (together with SIP registration, requires access tokens available in advance)
- Via SIP publish. SIP registration is executed as first step. In the 2nd independent step, MCPTT registration is executed via SIP publish.

### 3.1.2 Configuration management procedures

The configuration and management procedures allow

- subscription to and retrieval of UE configuration documents.
- subscription to and retrieval of profile configuration documents.
- subscription to and retrieval of service configuration documents.
- subscription to and retrieval of group configuration documents.

The profile and group configuration documents are the main elements which are basically mandatory required in the FRMCS use case.
This common function is applicable for MCPTT, MCData, and MCVideo.

### 3.1.3 Affiliation

Affiliation is the procedure used by an MC service client to indicate interest in one or more MC service groups and therefore affiliation is only relevant for the group communication[3]. Similarly, de-affiliation is the procedure used by an MC service client to indicate that he is no longer interested in one or more MC service groups. (De-)affiliation can be done in two ways:

- Explicit affiliation/de-affiliating: The operation is triggered manually or automatically be the MC service client.

[3] Note that affiliation is only relevant to group communication which including MCPTT, MCData and MCVideo.

- Implicit affiliation/de-affiliation: The operation is determined through configurations and policies within the MC service and performed by the associated MC service server.

Besides the basic affiliation functionality defined in the existing MCX specifications, the rail specific group functionality is specified in Rel 16. It will rely on automatic way that is depending on functional alias and location. A solution based on explicit affiliation is currently in progress in the 3GPP CT1 standard.

### 3.1.4 Policing

Policing is used to setup and modify unicast MC dedicated bearers utilizing the Rx reference point to the PCRF. With this functionality the Quality of Service on the transport network (4G/LTE or 5G) can be ensured by the MCX layer (FRMCS layer). Please refer also to Chapter 6 where the QoS Models are described.

### 3.1.5 Location management:

Location Management for MC service user is provided by the location management client to the location management server. The location information reporting triggers are based on the location reporting configuration. Different type of location information can be provided.

- Location reporting configuration
- Location information report (on demand/periodically, on trigger)

Location Management is planned to be used for example for the following FRMCS use cases:

- Location dependent addressing on MCPTT
- Location dependent addressing for ETCS (e.g. Regional RBC)
- Local Edge breakout (e.g. Video perception use case)

### 3.1.6 Functional alias

The Functional alias is used to define function specific addressing identifiers which can be used in FRMCS environment in a similar way like functional numbering in GSM-R.
The Basic operations in the life cycle of Functional alias are:

- Activation
- Deactivation
- Interrogation
- takeover [4]

Origination side: Determines the Origination side of the communication when a functional Alias is included. The Origination side including Functional alias is covered in current standardization.
Specification of termination side still is in progress in the standardization. The main open points are:

- Security: Procedures have to be defined to support E2E encryption.
- Calls to functional alias which are simultaneously activated by multiple users (could be avoided by configuration, which is recommended)

### 3.1.7 Security (optional)[5]

Security Functions are needed for E2E encrypted communications. The functionality includes Voice and floor encryption for private and group communication. For encryption required key material should be downloaded from KMS to MC client and MC server. The Security Functions include also the key management from MC client to MC server (CSK upload). Another included security functionality is to encrypt XML contents.

[4] Please refer to 3GPP TS 22.280, Requirement [R-5.9a-009] for more details.

[5] None of the Security Functions are mandatory, i.e. all are optional.

## 3.2 MCPTT functions

The MCPTT Functions define all functions used specifically for the Voice Push-to-Talk service. The MCPTT application specific functional architecture is shown in the figure below. It consists of the server parts mainly Media distribution function and Floor control server as part of the MCPTT server and the client parts Media mixer and Floor participant [6].

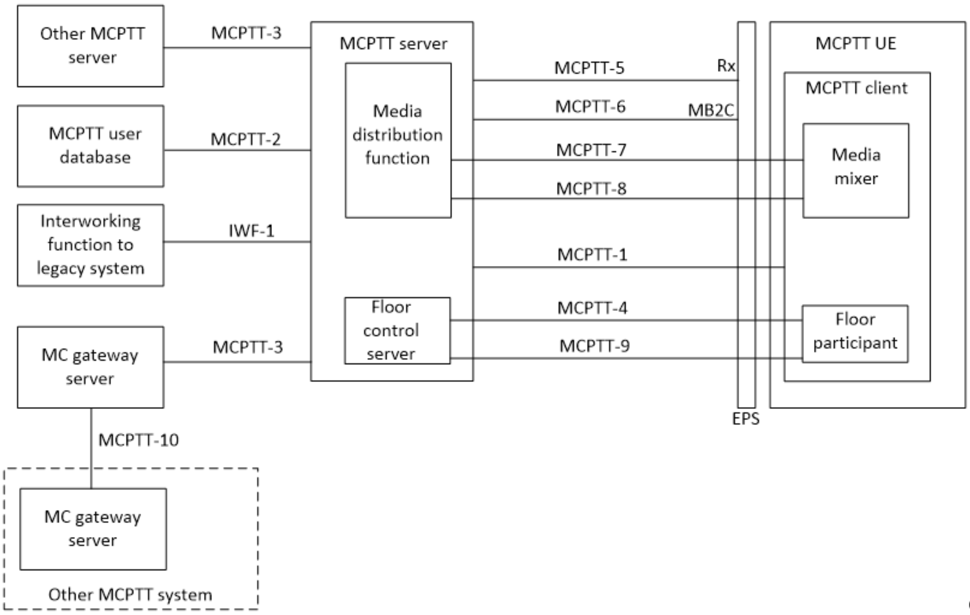



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**Figure 3-1 Functional model for the application plane of the MCPTT service.**

The MCPTT application fits mainly to the Voice Railway reference application defined in Chapter 2. MCPTT application comes in several flavors which have different functional behavior and attributes. The different MCPTT call types are outlined in the following:

### 3.2.1 Private call

A MCPTT private call (point-to-point call) can involve functional alias and is in FRMCS mainly a “driver to controller” call. In general call can be made as “on demand” or as “pre-established” session type. The functionality of the resulting call is the same. For simplicity it would make sense to use “on demand” calls. Private calls can be with manual or auto-commencement. Floor control for private calls is optional.
Calls can involve functional alias, see common required functions for more details on Functional alias. Driver to controller calls are the main application in FRMCS. Some building blocks are already defined in 3GPP for this use case, but likely the specification requires FRMCS specific extensions.

### 3.2.2 Group call

MCPTT defines two types of group calls: pre-arranged and chat group call
The rail specific group call will be based on the pre-arranged group call. Chat group call should not be required.
The following functional attributes can be available for MCPTT calls

- manual or auto-commencement
- Floor control has to be included (if single talker is sufficient)
- Multi talker control is required if multiple talkers are required.
- Emergency alert functionality can be indicated in the group call request
- Emergency group call (In stage 2 FRMCS is currently specifying a REC communication based on application priority using a “regular2 MCPTT group call” and not the MCPTT emergency group call)

- o Late Entry
- o Dynamic group management (potentially used in FRMCS)
- o Temporary groups (potentially used in FRMCS
- o Client based automatic group affiliation and de-affiliation based on location or functional alias)

### 3.2.3 Voice handling

Voice respectively Media handling includes the following aspects:

- o Support for G.711 and G.722.2 (AMR-WB)
- o Media distribution only (no transcoding)

### 3.2.4 Pre-emption:

MCPTT specification currently do not specify pre-emption behavior at the application layer (only the EPS bearer level). Pre-emption in rail is foreseen to be controlled by the newly introduced application priority. Detailed behavior will be most likely specified outside 3GPP[6].

## 3.3 MCData functions

The MCData Functions define all functions used specifically for the Data transmission service. The MCData application specific functional architecture is shown in the figure below. It consists of the server parts mainly capability function and (if applicable) an MCData message store as part of the MCData server and the client parts capability functions and Message Store client participant. The specific function of IP connectivity (described below) is currently under specification and not fully reflected in the architecture figure below [5].

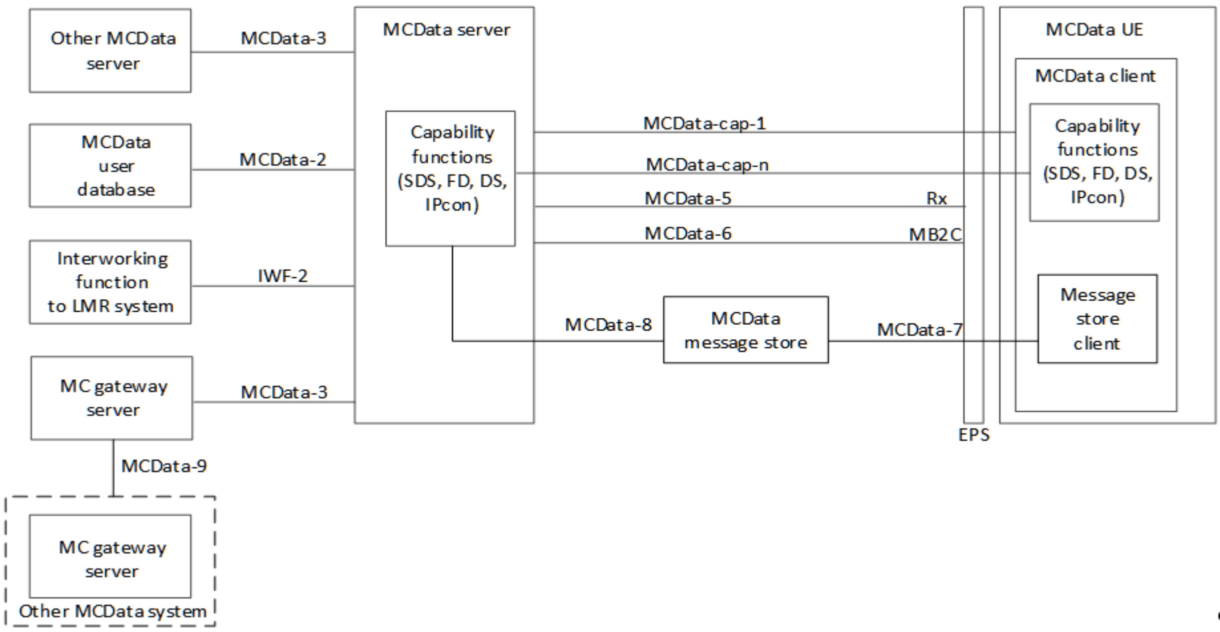



**Figure 3-2 Functional model for the application plane of the MCData service.**

The MCData application fits to several Railway reference application defined in Chapter 2, including

- ETCS/APS,
- perception of environment and
- ATO

6 This could be either in ETSI TC-RT or in UIC ATWG.

MCData application comes in several flavors which have different functional behavior and attributes.
The main FRMCS MCData flavor will be IP connectivity. Other MCData include Short Data Service with a central of distributed message store[7], File Distribution (FD), and Data Streaming.

### 3.3.1 IP connectivity

**IP connectivity** is currently in specification in 3GPP and provides a means to exchange of IP Data between MCData clients. For addressing the corresponding MCData users the MCData ID is used [5].

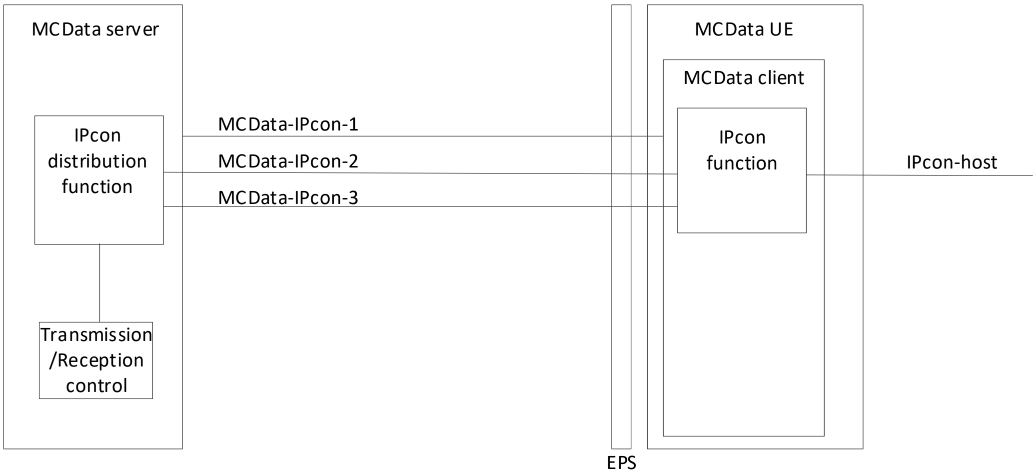



**Figure 3-3 Functional model for the application plane of the MCData-IPcon service.**

Note: Functional alias to be used for addressing is defined in stage 2 in release 17. Stage 3 is still not yet specified.
IP connectivity defines a point-to-point MCData transport service

- MCData IPcon point-to-point request/response

IPcon is already specified in 3GPP stage 2 (TS 23.282 in Rel-16, [5] ) and Stage 3 (TS 24.282 and TS 24.582 in Rel-16).

## 3.4 MCVideo functions

The MCVideo Functions define all functions used specifically for the Video service. The MCVideo application specific functional architecture is shown in the figure below. It consists of the server parts mainly Media distribution function and Transmission control server as part of the MCVideo server and the client parts Media mixer and Transmission Control participant [4].

[7] Message store function is not used in the DB reference applications and also is a rare use case in the railway scenarios.

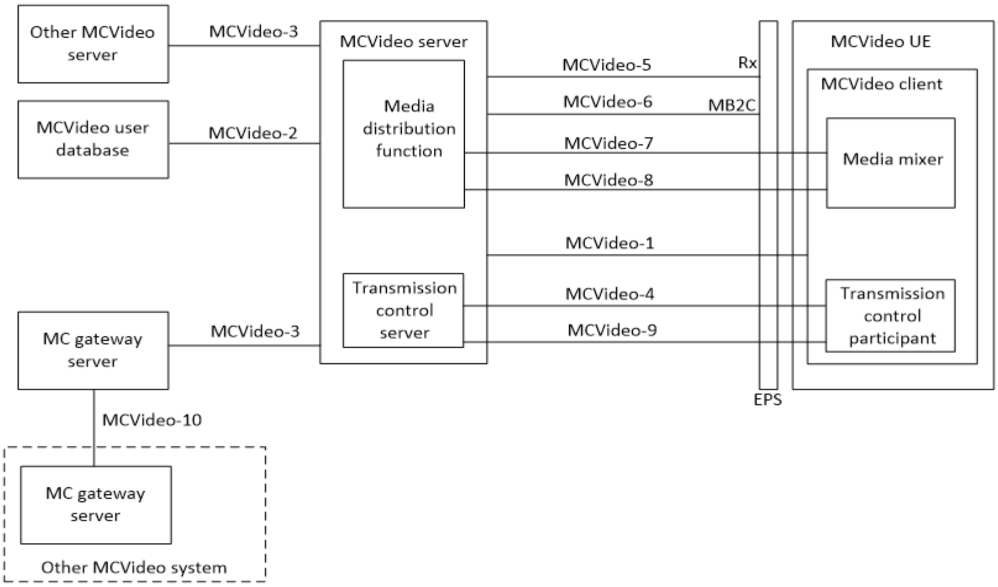



**Figure 3-4 Functional model for the application plane of the MCVideo service.**

The MCVideo application fits the Incidence Management Railway reference application defined in Chapter 2.
A specific function for the MCVideo service is **Video pull**:
The procedure for Video pull describes the case where an MCVideo user is initiating an MCVideo private call to pull video from called MCVideo user in an automatic or manual commencement mode. Only the called party is allowed to transmit video. This is specifically a one-to-one video pull – call setup.

## 3.5 Summary

The following table provides a brief summary of the relevant specifications and functions (common and specific) which are defining the MCX services. On the left-hand side, the corresponding Railway reference application is added where the MCX Functions are used.

<table>
<tr><th>Railway reference Application</th><th>Specific MCX Functions</th><th>Common MCX Functions</th></tr>
<tr><td>Voice</td><td>MCPTT<br>TS 24.379 - MCPTT call control; protocol<br>• Registration and service authorization<br>• Pre-established session<br>• Affiliation and Functional Alias<br>• Prearranged Group Call<br>• Private Call<br>• Emergency Alert<br>• Location Procedures<br>TS 24.380 - MCPTT media plane control<br>• On-network floor control<br>• SDP procedures</td><td rowspan="4">TS 24.484 - MCS configuration mgmt<br>• Online Configuration/Document Retrieval<br>• UE initial config<br>• MCPTT/MCVideo/MCData user profile<br>• MCPTT/MCVideo/MCData service configuration<br>TS 24.481 - MCS group mgmt<br>• Online Configuration / Document Retrieval<br>• NC/MCPTT Group Document<br>TS 24.482 MCS identity mgmt<br>• User Authentication and Token exchanges<br>• HTTP Proxy<br>TS 33.180 - Security of MCS</td></tr>
<tr><td>ATO</td><td rowspan="3">MCData<br>TS 24.282 - MCData signalling</td></tr>
<tr><td>ETCS/APS</td></tr>
<tr><td>Perception</td></tr>
</table>

| | | |
|---|---|---|
| | • Registration and service authorization<br>• IP Connectivity<br>• SDS<br>• Dispositions and Notifications<br>• Enhanced Status<br>**TS 24.582 - MCData media plane**<br>• SDS Media plane (MSRP) | • User Authentication<br>• MCX service authorization<br>• Key distribution for Signalling and Media<br>• Logging and Audit<br>**TS 24.483 - MCS mgmt object** |
| Incidence Mgmt | **MCVideo (and MC Data)**<br>**TS 24.282 - MCVideo signalling**<br>• Registration and service authorization<br>• Private Call<br>• Video Pull<br>• Ambient viewing call<br>**TS 24.581 - MCVideo media plane**<br>• On-network transmission control<br>• SDP procedures | |

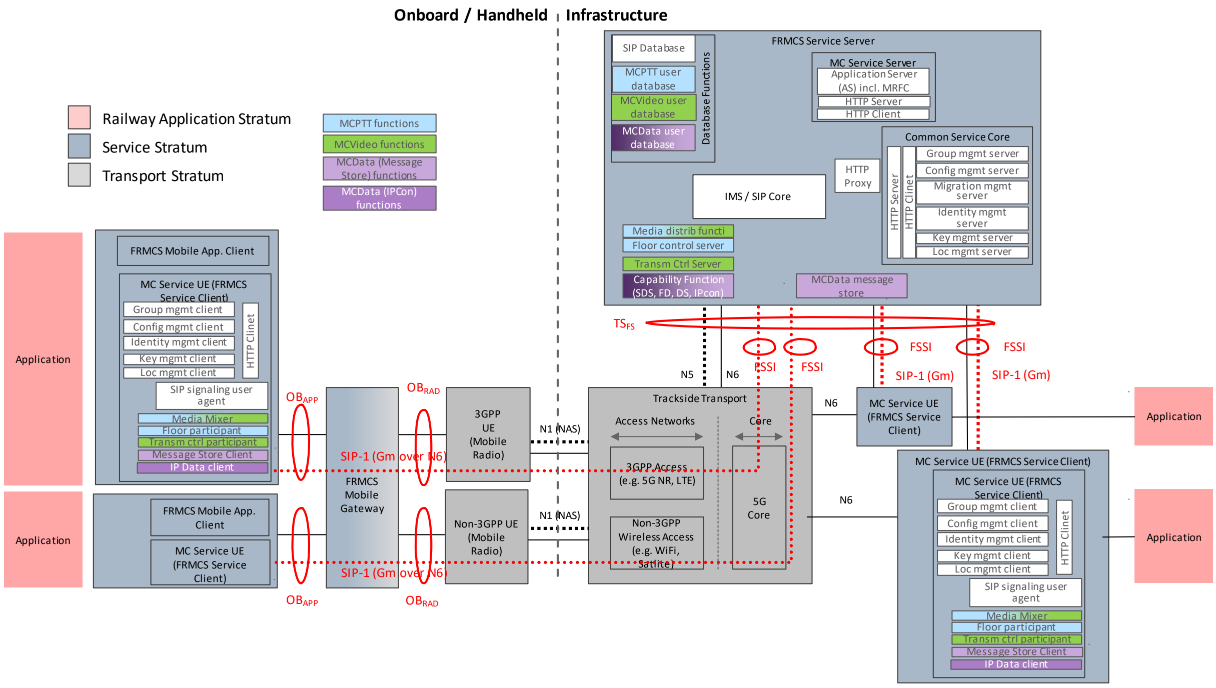
**Table 3-1 Mapping of the relevant specifications and functions (common and specific) of MCX to DB reference applications.**

# 4 MCX Building Blocks and Reference Points Mapping to FRMCS Logical Architecture

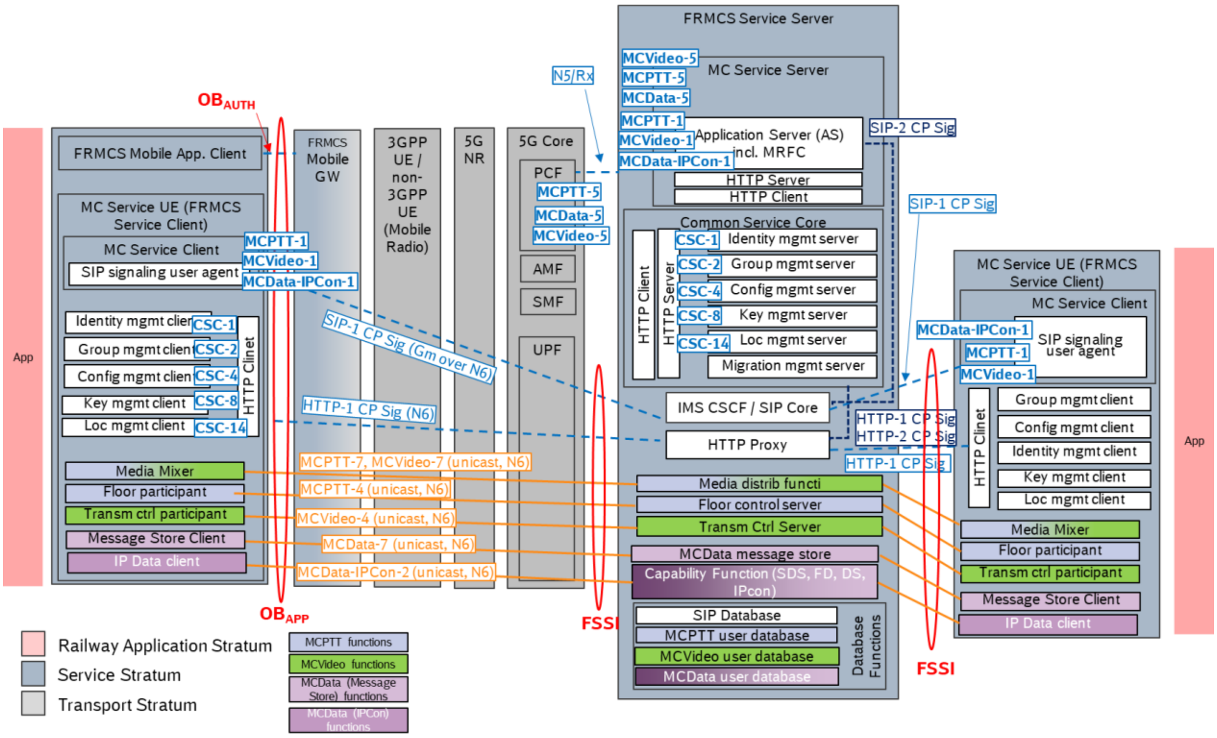
The MCX Architecture is used as vital building block for the FRMCS architecture. FRMCS Architecture is currently under definition and the actual status is described in ETSI TR 103 459 V1.2.1, "Rail Telecommunications (RT); Future Rail Mobile Communication System (FRMCS); Study on system architecture" [1].
Specifically, a mapping of the 3GPP building blocks, including a version of the MCX building blocks is included in Chapter 8.1 of ETSI TR 103 459 [1]. The following sections aim to detail the required MCX building blocks for the specific Railway reference applications described in Chapter 2 embedded in the overall FRMCS logical system architecture as technical realization option. In addition, the elected reference railway applications defined in Chapter 2 are mapped to the respective MCX Service.

Furthermore, the mapping of MCX reference points to FRMCS reference points defined in ETSI TR 103 459 [1] is provided.

## 4.1 Overview




a) MCX building blocks mapped to the architecture view defined in TR 103 459 [1]




b) MCX building blocks and reference points

**Figure 4-1 Generic MCX Building Blocks included in FRMCS Architecture with independent wireless and wireline transport domain.**

Figure 4-1 shows the complete generic view of all MCX related functions embedded in the FRMCS logical architecture. The FRMCS Service Server details now all MCX building blocks which are specified in MCX 3GPP Architecture. Similarly, the FMRCS Service UE (FRMCS Service Client) details all building blocks for the MCX client.
Not all MCX building blocks are required for all different MCX Services, namely MCPTT, MCData and MCVideo. White filled building blocks in Figure 4-1 are generic MCX building blocks which are potentially required for all MCX services (both on FRMCS client and FRMCS server side). These are specifically the following MCX blocks:

- FRMCS Service Server
  - SIP Database
  - MC Service Server including Application Server, HTTP Server/Client
  - MC Common Service Core including Group Management, Configuration Management, Migration Management, Identity Management, Key Management, Location Management and HTTP Server/client functions
  - SIP Core / IMS
  - HTTP Proxy
- FRMCS Service Client
  - SIP Signalling User Agent
  - Group Management, Configuration management, Migration Management, Identity Management, Key Management, Location Management and HTTP Server/client functions

For the other service specific MCX building blocks a color-coding scheme was introduced in order to highlight the requirements per MCX Service. This will be described in the following sections.

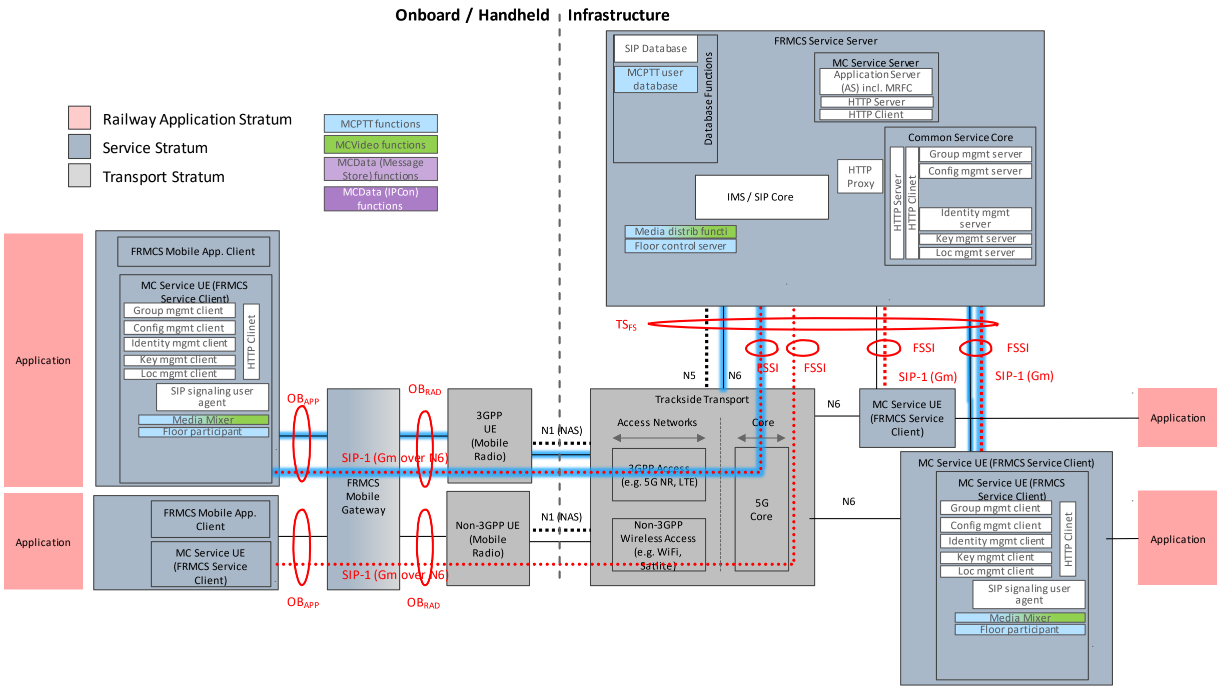
**Reference Points:**
The FRMCS reference point $OB_{APP}$ is the reference point between an onboard or handheld application and the FRMCS. It is composed of the reference points of FRMCS Service Session

Interface (FSSI) and $OB_{AUTH}$. $TS_{FS}$ is the reference point between the Trackside Transport and the FRMCS Service Server. The detailed mapping is provided in Section 4.5.
The reference points for common MCX building blocks are listed below:

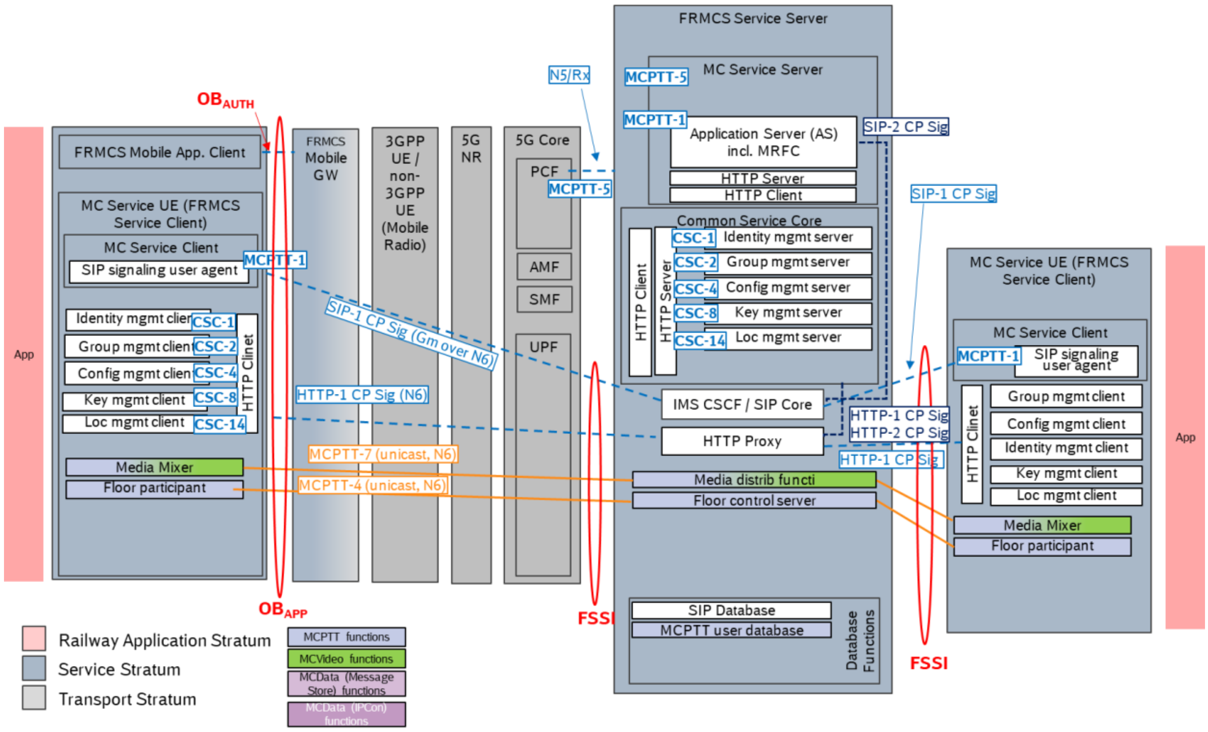
- **CSC-1** is between the identity management client and identity management server. It is used for MC-PTT user authentication between identity management client and server over secure HTTP/TLS
- **CSC-2** is between the group management client and group management server. It is used for configuration of group management data between server and client. HTTP is used for non-subscription/notification related signalling and SIP is used for subscription/notification related signalling
- **CSC-4** is between the configuration management client and configuration management server. It provides configuration information for MC services. HTTP is used for non-subscription/notification related signalling and SIP is used for subscription/notification related signalling
- **CSC-8** is between the key management client and key management server. It provides key material over HTTP/TLS from key management server for end-to-end communication security (keys for SRTP and SRTCP)
- **CSC-14** is between the location management client and location management server. It provides location information for MC services

## 4.2 MCPTT FRMCS logical architecture

As outlined in the previous chapter, for a specific service not all standardized MCX building blocks are required. In this section only the MCX building blocks required for MCPTT service are depicted.




a) MCX building blocks mapped to the architecture view defined in TR 103 459 [1]




b) MCX building blocks and reference points

**Figure 4-2 MCX Building Blocks required for MCPTT Service included in FRMCS Architecture with independent wireless and wireline transport domain.**

The service specific MCX building blocks for MCPTT are the following:

- FRMCS Service Server
  - MCPTT user Database
  - Media distribution function (MDF)
  - Floor control server
  - *NOT required from the common Service Core:* Migration Management,

- FRMCS Service Client
  - Media Mixer
  - Floor participant

**Reference Points**

- **MCPTT-1** is used for MC-PTT session establishment. MC-PTT may also provide location information with respect to multicast service availability. MCPTT-1 shall use SIP (through SIP Core or IMS CSCF) and may use the HTTP-1 and HTTP-2 reference points
- **MCPTT-5** reference point is between PCF (5G)/PCRF(4G) and MCPTT application server. It is used for policy control (QoS)
- **MCPTT-7** is for media distribution over unicast bearer using SGi interface or unicast PDU session using N6 interface. Secure RTP (SRTP) is used for media
- **MCPTT-4** is the reference point for floor control over unicast bearer. Secure RTCP (SRTCP) is used for floor control

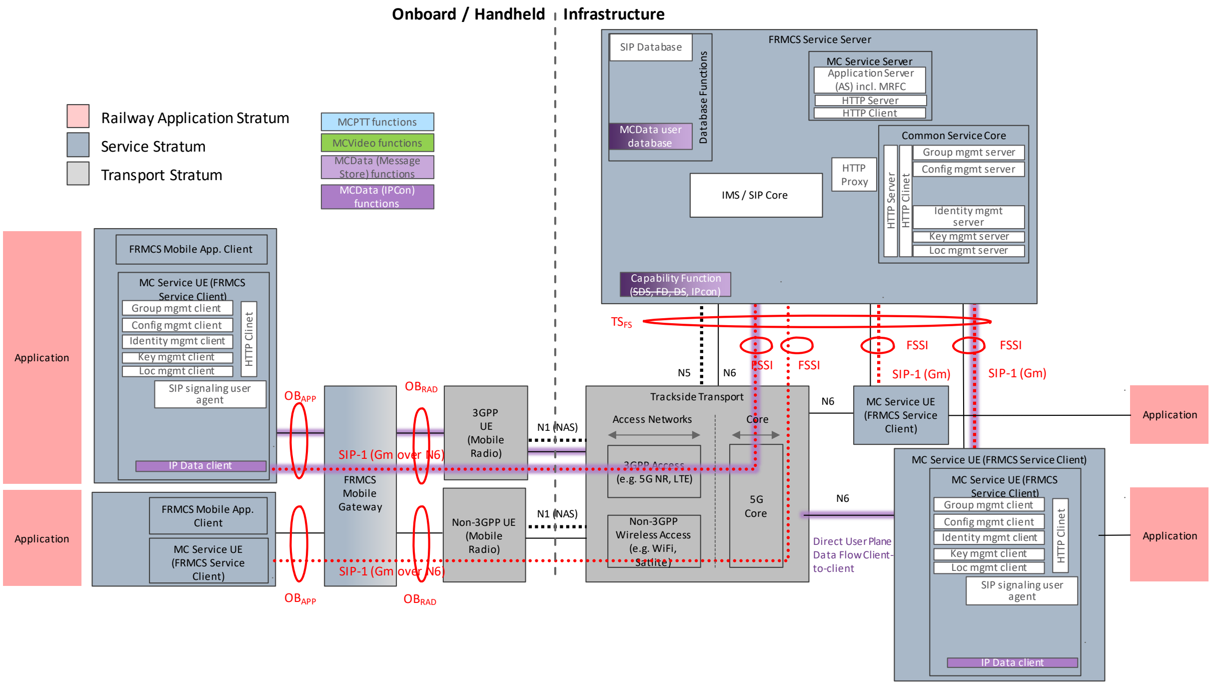
**Mapping to reference Railway applications:**

MCPTT FRMCS Service maps to following Railway reference applications:

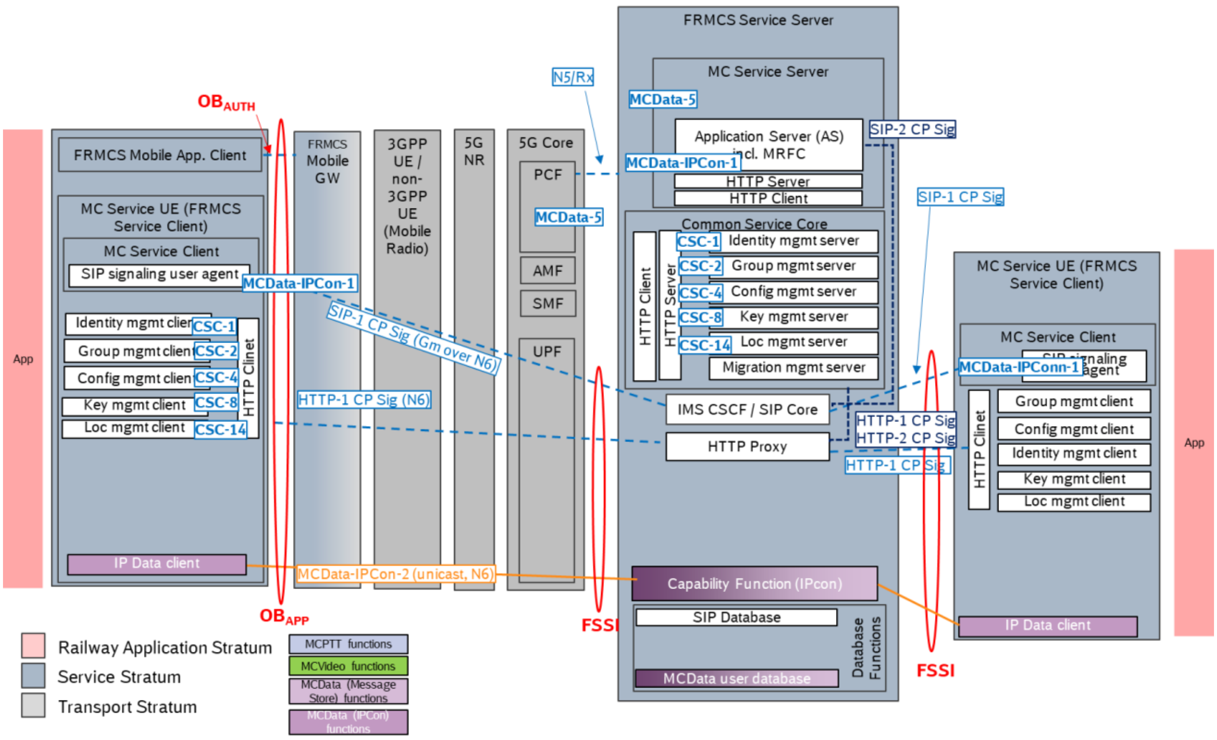
- Voice Railway Service

## 4.3 MCData-IPcon FRMCS logical architecture

In this section only the MCX building blocks required for the IP connectivity service are described because the IP connectivity is the main service required for data transmission in Railway Reference Applications described in Chapter 2. For other MCData services (e.g. message store, SDS or FD as shown in Section 3.3), different service specific MCX building blocks are required.




a) MCX building blocks mapped to the architecture view defined in TR 103 459 [1]



b) MCX building blocks and reference points

**Figure 4-3 MCX Building Blocks required for MCData-IPcon Service included in FRMCS Architecture with independent wireless and wireline transport domain**

As shown in Figure 4-3, the service specific MCX building blocks for MCData-IPcon are the following:

- FRMCS Service Server
  - MCData user Database
  - Capacity Function (for IPcon)
  - *NOT required from the common Service Core:* Migration Management
- FRMCS Service Client
  - IP Data client

**Reference Points**

- **MCData-IPcon-1** is used for a session establishment in support of MCData IP Connectivity service. It shall use SIP (through SIP Core or IMS CSCF)
- **MCData-5** which exists between the MCData capability function and the PCF(5GC)/PCRF(EPS), is used by the MCData capability function of the MCData server to obtain unicast bearers with appropriate QoS from the 5GC/EPS. It utilizes the N5/Rx interface of the 5GC/EPS.
- **MCData-IPcon-2** exists between
  - IP Connectivity distribution function in the MCData server and the client of IP Connectivity function in the MCData client(s) (defined in Rel-16)

**Video Service over MCData-IPcon**

As MCData-IPcon provides a transparent IP Service between two different FRMCS clients with a specific QoS, the IP Data path may be also used for transmission of Video Data. In this scenario the FRMCS Application (using the underlaying MCData-IPcon Service) must take care for itself on the video specific part of the video transmission, which means rate-control, Video-transmission-control (e.g. RTCP like signalling), codec negotiation, setup of video stream, etc.

In case MCData-IPcon is used for transmitting Video Data, the FRMCS Application must be ready to operate in this way and cannot rely on MCVideo specific call functions.

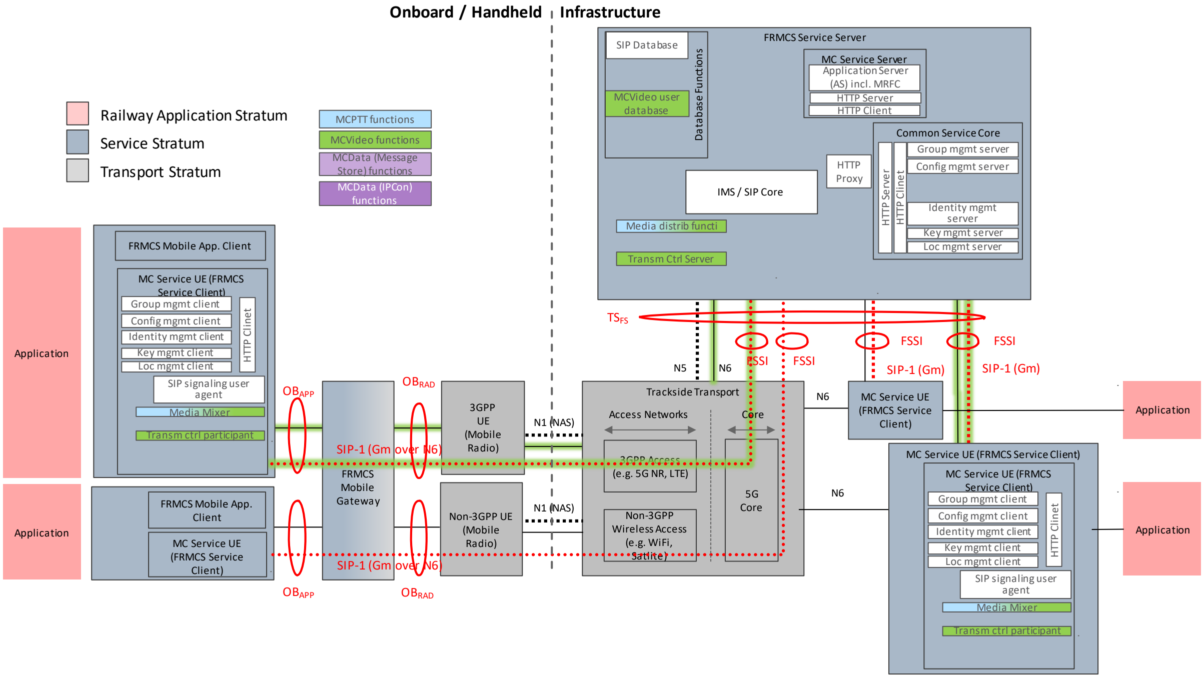
**Mapping to reference Railway applications:**

MCData-IPcon FRMCS Service maps to following Railway reference applications:

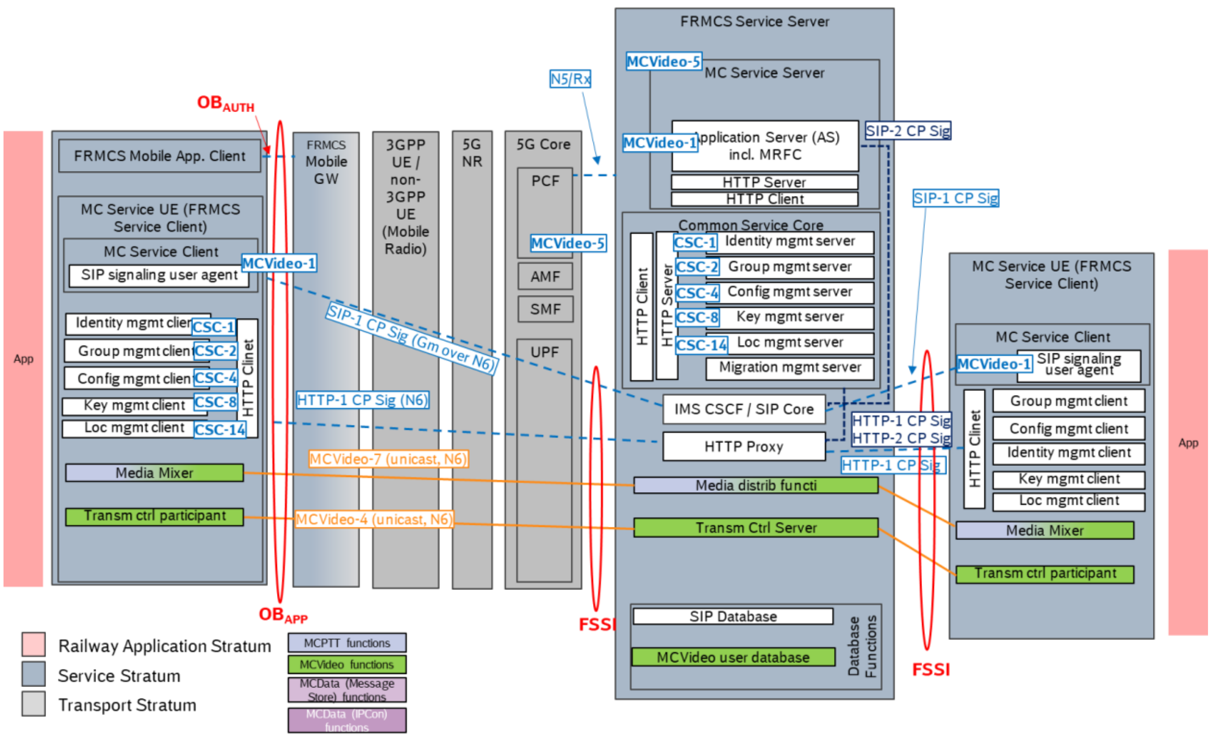
- ATO
- ETCS/APS
- Perception of Environment: Video Surveillance *(see comment for Video Service over MCData-IPcon above)*
- Incidence management: Remote Driving *(see comment for Video Service over MCData-IPcon above)*

## 4.4 MCVideo FRMCS logical architecture

In this section only the MCX building blocks required for MCVideo service are included.




a) MCX building blocks mapped to the architecture view defined in TR 103 459 [1]




b) MCX building blocks and reference points

**Figure 4-4 MCX Building Blocks required for MCVideo Service included in FRMCS Architecture with independent wireless and wireline transport domain.**

As depicted in Figure 4-4, the service specific MCX building blocks for MCVideo are the following:

- FRMCS Service Server
  - MCVideo user Database

  - Media Distribution Function (MDF)
  - Transmission Control Server

  - *NOT required from the common Service Core:* Migration Management,

- FRMCS Service Client
  - Media Mixer
  - Transmission Control Participant

**Reference Points**

- **MCVideo-1**, which exists between the MCVideo client and the MCVideo server, is used for MCVideo application signalling for establishing a session in support of MCVideo service.
- **MCVideo-5** reference point is between PCF (5GC)/PCRF(EPS) and MCVideo server. It is used for policy control (QoS). It utilizes the N5/Rx interface of the 5GC/EPS.
- **MCVideo-7**, which exists between the media distribution function and the media mixer, is used to exchange unicast media between the media distribution function of the MCVideo server and the media mixer of the MCVideo client. The MCVideo-7 reference point uses the N6(5GC)/SGi(EPS) reference point
- **MCVideo-4**, which exists between the transmission control participant and the transmission control server, is used for MCVideo transmission control signalling over unicast. The MCVideo-4 reference point uses the N6 (5GC)/SGi (EPS) reference point.

**Mapping to reference Railway applications:**

MCVideo FRMCS Service maps to following Railway reference applications:

- Perception of Environment: Video Surveillance
- Incidence management: Remote Driving

# 5 Integration of 5G and MCX in FRMCS: Challenges and Standardization Status

This chapter discusses the integration of 5G and MCX in terms of technique challenges and standardization status. Firstly, a 3GPP study item, TR 23.783 on MCX over 5G is presented in Sec 5.1. As many of MCX functions are derived from the IMS (IP Multimedia Subsystem), Sec 5.2 explores the 3GPP study item on the IMS and 5G integration studied, which could be a good indication for the future work on MCX and 5G integration. Finally, Sec 5.3 investigates the separation of control plane and user plane for MCX when integrating with 5G distributed 5G deployment.

## 5.1 MCX over 5G: status study of MCX over 5G

- Name: Study on Mission Critical services support over 5G System
- TR: 23.783 [7]
- Study item has been initially approved at SA#80 in 13.-15-June 2018
- Study has been revisited at SA 82 in 12 – 14 Dec 2018
    - Add Proximity based Services
    - Add multicast-broadcast services in 5GS
    - Completion date has been changed from Sept 2019 to Sept 2021 as a result of the wider scope
- Objectives
    - Identify subclauses in the existing stage 2 Mission Critical specifications that should also apply to the 5GS, but which currently contain 4G specific terminology and therefore would require terminology changes.
    - Develop a common approach (e.g. terminology) for changes in stage 2 Mission Critical specifications that apply to the 5GS.
    - Review and identify the 5GS aspects (e.g. 5QI, network slicing) to support Mission Critical architecture.
    - Identify key issues and develop solutions to ensure support of Mission Critical services over 5GS.
    - Evaluate the solutions and make recommendations for normative work.
    - Study where and how to integrate solutions in the stage 2 Mission Critical

- The following key issues got identified in TR 23.783 V 0.10.0
    - Key issue 1: Service continuity between on-network MC services and UE-to-network relay MC service
    - Key issue 2: 5GC level roaming
    - Key issue 3: Use of multicast
    - Key issue 4: ProSe
    - Key issue 5: APN
    - Key issue 6: Resource control
    - Key issue 7: Deployment scenarios
    - Key issue 8: Determine impacts of 5GS network slicing to MC services
    - Key issue 9: IP-based wireline access to MC System located on 5GS
    - Key issue 10: Low latency and user/media plane capabilities
- It has been commented in ETSI RT(20)000022 that
    - Key issues 2, 5, 6 of TR 23.783 should be sufficient for a first step in using the 5GS for MCX service system. It was made clear that this only addresses unicast mode. Other modes and functions e.g. multicast will follow in a later phase.

- In order not to complicate key issue 6, the low latency aspect in TR 23.783 [1] is addressed by a separate key issue independent of key issue 6.
- The basics as listed under 1.) may be made available in Rel-17 and the topic of low latency with Rel-18. This is all is to be viewed with caution in agreement with 3GPP SA6.

- Besides the terminology changes the following key issues got solutions provided in the last meeting:
  - Key Issue 2 on 5GC level roaming
    - pCR S6-200203 proposes some changes to 3GPP TS 23.280 (MCCore), adding that for MC services over 5GS, roaming is supported using 5G System roaming or IMS-level roaming.
  - Key Issue 5 on APN (system connectivity)
    - pCR S6-200308 consists of 2 main parts:
      - Explanation of the main differences between EPS and 5GS
      - Resulting proposed changes to 3GPP TS 23.280 (MCCore)
- Key issue 5 on APN
  - Explanation of the main differences between EPS and 5GS
    - 5GS Data Network (DN) access
    - EPS versus 5GS QoS model (please refer to section 6.2 for further details)
    - APN allocation
    - Changes to the functional architecture
    - Data Network (DN) AAA Server authentication/authorization
    - Observation and conclusions
  - Observation and conclusions
    - DNN(APN): 5G has more flexibility regarding QoS handling vs 4G, particularly, in 5G, one PDU session (mapping to one DNN/APN) has multiple QoS flow with QFIs (QoS Flow IDs). Use plane traffic with same QFI has the same QoS profile. In LTE, one EPS bearer links to corresponding APN associated with certain QoS profile
    - Functional Model: Due to the adapted 5GS interaction between AF and PCF via the reference point N5, an adjustment is proposed in the functional model for application plane and signalling plane in 3GPP TS 23.280.
    - QCI/QI values: The individual values for latency, packet reliability etc. of the 5G QI definitions for MC services correspond to those of the EPS QCI definitions, with the exception that the priorities are only noted as integer values (multiplied by 10).
    - Secondary authentication: Secondary authentication may be required using DN-AAA server (3GPP TS 23.501) using EAP according to 3GPP TS 33.501.

## 5.2 IMS and 5GC integration: provide a view on current standardization status

### 5.2.1 Overview

The aim of TR 23.794 (v17.0.0) [8] is to study and specify potential enhancements to the IMS architecture to enable IMS FE to integrate with the 5GC network functions to enable IMS applications to directly leverage the features and capabilities of 5GC.
The specific capabilities of 5GC included in this study:

- In regard to 5GC network slicing; what enhancements (if any) are necessary for IMS to efficiently support devices and networks with multiple slices and different IMS services per slice?
- Should (and how does) IMS leverage the 5GC's support for localized routing of traffic and placement of IMS elements? How do such optimizations impact IMS media bearers, IMS signalling bearers, and IMS functions? How is service continuity provided in presence of localized routing?
- Whether and how can IMS applications and network functions utilize the service based capabilities and service based interfaces of the 5GC (for interactions between the IMS and the 5GC)? Which 5GC functions should be interfaced with IMS using service based interfaces?

Key issues:

1. Routing of IMS traffic via localized UPF
    - **Not finalized, no solutions agreed**
    - Valid use-case – but anyway needs to consider FRMCS (MCX) specifics e.g. MRF/MDF anchored voice/video communication.
    - Note that this would be needed in the potential CUPS solution for MCX. Please refer to Section 5.3.1 for further details.
2. Placement of IMS AS in localized environments
    - **Not finalized, no solutions agreed**
    - Valid use-case – but anyway needs to consider FRMCS (MCX) specifics e.g. MRF/MDF anchored voice/video communication.
3. Network slicing and IMS
    - **Not finalized, no solutions agreed**
4. Discovery of Network Functions
    - PLMN driven use-case. FRMCS MCX will interact with FRMCS PCF and have specific/predefined slice (no PCF interaction) from PLMN.
5. Enabling SBA based Cx
    - N/A – considering assumption (recommendation) to keep FRMCS 5G transport stratum independent of FRMCS service stratum (i.e. keep DBs separated).
      Nevertheless, rather simple evolution path to support SBA based interface to a HSS/UDM.
6. Enabling SBA based Sh
    - N/A – considering assumption (recommendation) to keep FRMCS 5G transport stratum independent of FRMCS service stratum (i.e. keep DBs separated).
      Nevertheless, rather simple evolution path to support SBA based interface to an HSS/UDM.
7. How can IMS utilize services provided by Npcf
    - Valid use-case. Implementation question if used by P-CSCF or via MCX-AS.
8. How can IMS utilize services provided by 5GC other than PCF
    - **Not finalized, no solutions agreed**
    - PLMN driven – but potential use-cases also for FRMCS (e.g. location).

Summary:

- The study was closed in Rel16
- Inputs for Rel17 normative work for issues 4,5,6,7

### 5.2.2 Key issues and solutions

<u>Key Issue 4. Discovery of network functions</u>

- Solution 18: Discovery of Network Functions - explores options for discovery of network functions exposed to IMS e.g. discovery of PCF services, as well as discovery of IMS functions e.g. P-CSCF.

- Solution 24: IMS Utilizes BSF services and operations for PCF discovery and selection, as defined in TS 23.501 [9] clause 6.3.7 and TS 23.502 [10] clause 5.2.13.2.4
- SMF can utilize the services of the NRF to discover/select the P-CSCF - solution 18 is used as the basis for normative work.
- Solution 24 is used as the basis for normative work to address discovery/selection of PCF by IMS CSCF.
- HSS discovery/selection will be resolved during normative phase.

Key Issues 5. Enabling SBA based Cx & 6. Enabling SBA based Sh
For Key Issue #5 and Key Issue #6 the following is concluded:

- Solution 22: The principle of this solution is to define specific IMS services while reusing the principles of the UDM services specified in Rel-15 (i.e. SDM, UECM, UE Authentication) where service operations are interface agnostic (e.g. reusable between Sh and Cx) and hence can be used by any IMS NF.
  The IMS related service operations are prefixed with "Nhss_ims_XXX" (it is assumed that the IMS data are managed by the HSS part of combo UDM/HSS or by a standalone HSS).
- Solution 23: For Sh – same principle as above.
- The IMS service logic is performed by the IMS-HSS. Whether the IMS Service Logic is deployed as a combined UDM/HSS is an implementation option.
  - New SBA services are defined for IMS services exposed by the IMS service logic, with CSCF and IMS-AS as consumers.
  - For interactions with the CSCF Solution 22 is the basis for normative work, Stage 3 will need to investigate if whether implicit subscription from solution 12 or explicit subscription (solution 22) are required.
- For interactions with the IMS-AS Solution 23 will be used as the basis for normative work. Stage 3 will investigate the data split in solution 16 into operational and subscription data, if deemed necessary.
- These new SBA services will support transport of IMS AS transparent data (as the Sh interface does in diameter-based solutions) - to avoid unnecessary impacts to existing IMS ASs. Stage 3 will need to investigate if for transparent data the IMS-AS can use existing services, or enhancements to existing services to store this type of data in the UDR.

Key Issue 7. How can IMS utilize services provided by Npcf
In IMS network, the P-CSCF needs to be notified of some events related to access network, e.g. UE location information and other access network related events. This information will be used in IMS network for billing, LI, service trigger and so on. In VoLTE network, the P-CSCF subscribes to notification of these events over Rx interface. Since 5GC supports SBI, this solution proposes that the IMS utilizes services provided by Npcf to subscribe to notification of these events.

- IMS can utilize the services of the PCF as a AF using existing Npcf services.
- Solution #9 and #14 are adopted as the basis for enhancing Npcf to support IMS specific functions.
- A note will be added to TS 23.228 [2] clarify that the selection between Rx and N5 will be based on configuration in the IMS.

## 5.3 CP/UP Separation: including distributed/edge deployment

Edge computing plays a critical role in enabling the railway applications which require ultra-reliable low-latency communication. Understanding the impact of deploying an Edge computing system into FRMCS is crucial for railway operators in order to carefully plan their network. As a key technology in FRMCS, 5G has a key architectural option, namely Control & User Plane Separation (CUPS), which allows multiple levels of user plane gateways (UPF) corresponding to multiple levels of distributed Edge compute platform and applications placement. As another key technology in FRMCS, MCX specified in Rel16 does not yet apply CUPS concept to the architecture design. We will investigate in this section how MCX could be integrated with 5G to be compatible with Edge computing system.

In the ETSI TR 103 459 [1], there are two different variants of FRMCS system architecture with different setup for FRMCS Trackside transport network between FRMCS Server and the Trackside FRMCS Client. Accordingly, the compatibility study of allowing distributed Edge compute platform deployment with FRMCS using MCX and 5GS will be described for these two variants.

Furthermore, for studying the above mentioned topic, it is assumed that the MC Server can be divided into Control Plane (CP) and User Plane (UP), namely MC Server CP and MC Server UP[8]. Please note that there is no definition of CP and UP in MCX 3GPP specifications. For the consistency of terminology, the application plane and the signalling plane defined in MCX are both mapped to the CP used in 5G. Similarly, the media plane defined in MCX is mapped to the UP used in 5G. Similar to 5GC deployment strategy, the MC Server UP is deployed in the Cloud and Edge for hosting the MC client in the Cloud and Edge, respectively, while the MC Server CP remains in the Cloud.
The separation between CP and UP in MCX could be done in a similar way as defined in IMS (at least for MCPTT services), but needs to be further worked in standardization bodies.

As a summery, the different Edge MCX client connectivity options are the following:

- Independent trackside wireline transport domain
    - FRMCS signalling via separate fixed network connection
    - No FRMCS signalling for FRMCS Edge Client - User plane only

    In this variant a UPF discovery via 5G NEF or direct UPF selection via MCX-AS is possible, whereas the transport outside of the 5G domain is provided
- Trackside transport domain controlled under a 5G Core
    - Connectivity via W-AGF or via TNGF
    - Connectivity via N3IWF

    Here a 5G Data connection and thus a 5G signalling based UPF selection can be used.

The selection of the UPF in the 5G for MCX services depending on the Edge application and Edge location can be done via standardized 5G means which are available for IMS over 5G.

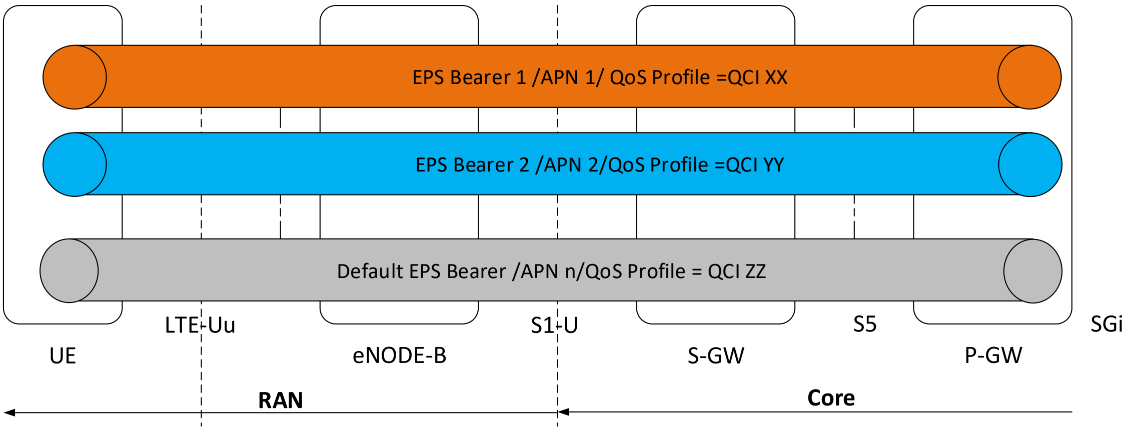
The details of the investigation results are part of the internal report version.

# 6 QoS in FRMCS using 5G (LTE) and MCX

Quality of Service interaction between the MCX service plane and the transport layer (4G/LTE or 5G) is important to ensure end-to-end Quality of service for the requested MCX service by the user. This chapter provides a short overview of the 4G/LTE QoS Model, the 5G QoS Architecture and its usage and finally the brief description of the interaction between MCX and the FRMCS Transport Stratum regarding QoS.

## 6.1 4G/LTE QoS model

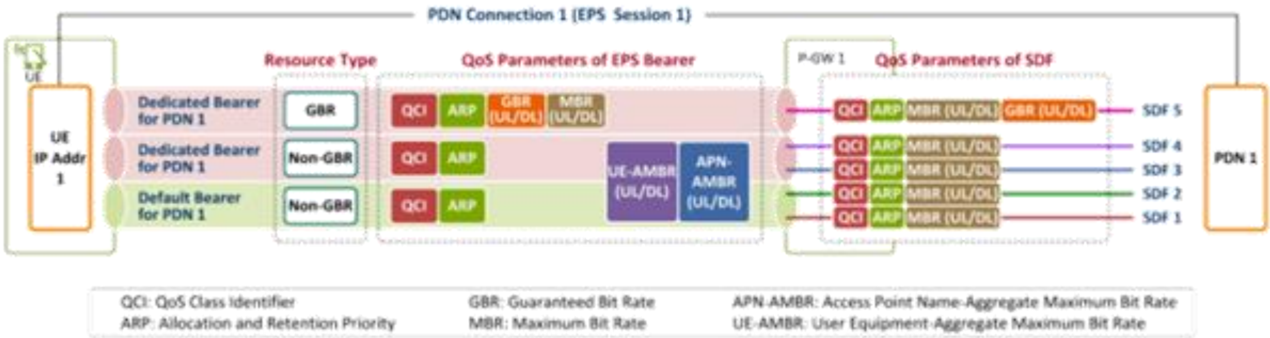
In the 4G/LTE QoS Model the EPS bearers are defined from the UE up to the P-GW. Each UE can have more than one EPS Bearer. The first EPS Bearer is always the default bearer. Every other EPS bearer is called dedicated bearers. An EPS Bearer is using a GTP Tunnel. See following graph from [7] for an illustration.




The LTE QoS Parameters are defined in 23.203, the main parameters are the following:

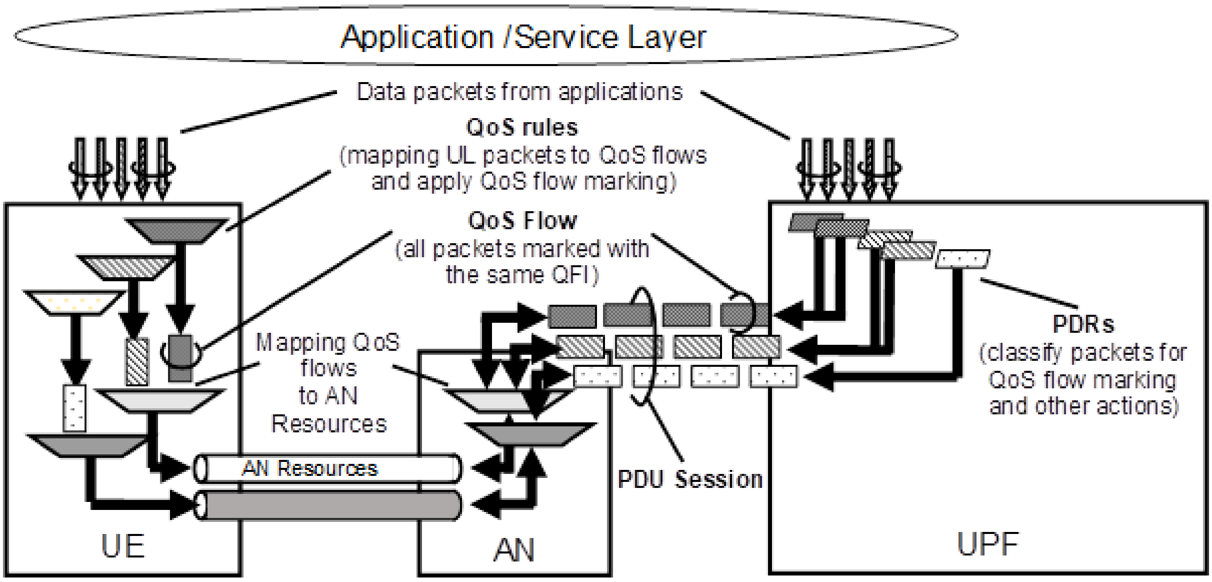
- Resource Type: GBR or Non-GBR
- QoS Parameters
  - QCI: QCI, in an integer from 1 to 9
  - ARP
  - GBR
  - MBR
  - APN-AMBR
  - UE-AMBR

Each bearer can have different QoS Parameters. The IP Flows connected beyond the Core network towards the external PDN network are mapped to Service Data Flows (SDF) in the P-GW. The Flows are then mapped to Dedicated or Default Radio Bearers (DRBs) which are the responsibility of the RAN [11].



## 6.2 5G QoS architecture

The 5G QoS Architecture is defined in 3GPP TS 23.501 [9]. In principle the 5G QoS Architecture is a Service Flow based architecture. The Service Flows are controlled by the Core Network.




Each PDU Session can have several QoS Flows. The service Data Flows from the applications or the external PDN network can be mapped on same or different QoS Flows. The Access Network (AN, i.e. mainly the gNB) maps the QoS Flows to the Data Radio Bearer (DRB). The DRB can have more QoS Flows associated. The distinction between different QoS Flows is done with the QFI (QoS Flow Identifier). The QFI can be based on various parameters like Source IP Address, Destination IP Address, Incoming Port, Outgoing Port etc.

The QoS Parameters are in a similar way defined as for 5G – with some differences. The Main QoS Parameters are the following:

- QoS Parameters:
  - 5QI (table similar to 4G QCI)
  - ARP
  - RQA (optional, reflective QoS)
  - Flow Bit rates
  - Aggregate Bit rates
  - Maximum packet loss rate
  - …

The 5QI parameter defines the main QoS parameters in a similar way to the 4G QCI parameters. A comparison for the MCX related QoS parameters QCI vs. 5QI is available from 3GPP TR 23.783 [7].

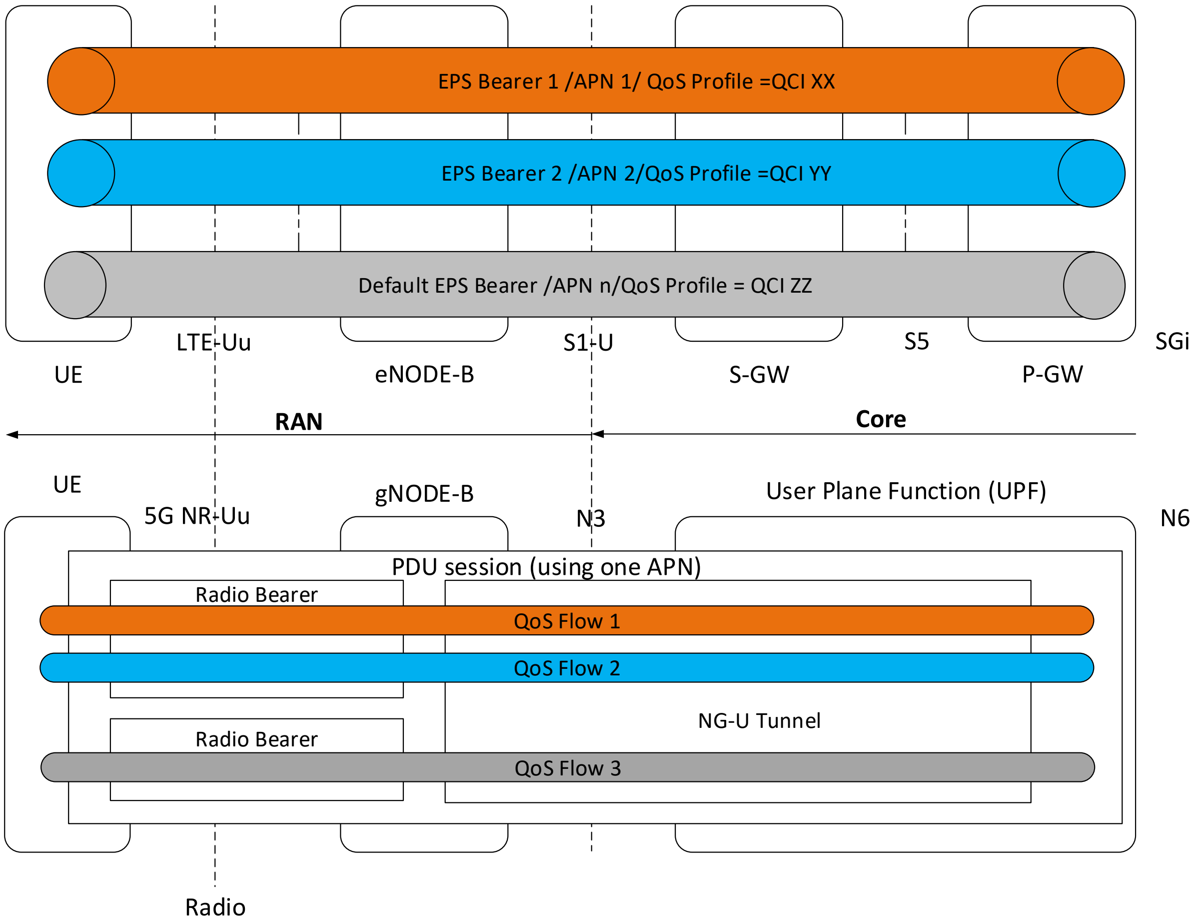



**Figure 6-1 Differences between EPS and 5GS QoS model (Figure 7.1.1.3-1 in TR 23.783).**

| EPS QCI value | EPS Resource Type | EPS Priority Level | EPS Packet Delay Budget | EPS Packet Error Loss Rate | 5GS 5QI value | 5GS Resource Type | 5GS Default Priority Level | 5GS Packet Delay Budget | 5GS Packet Error Rate |
|---|---|---|---|---|---|---|---|---|---|
| 65 | GBR | 0.7 | 75 ms | $10^{-2}$ | 65 | GBR | 7 | 75 ms | $10^{-2}$ |
| 66 | GBR | 2 | 100 ms | $10^{-2}$ | 66 | GBR | 20 | 100 ms | $10^{-2}$ |
| 67 | GBR | 1.5 | 100 ms | $10^{-3}$ | 67 | GBR | 15 | 100 ms | $10^{-3}$ |
| 5 | Non-GBR | 1 | 100 ms | $10^{-6}$ | 5 | Non-GBR | 10 | 100 ms | $10^{-6}$ |
| 8 | Non-GBR | 8 | 300 ms | $10^{-6}$ | 8 | Non-GBR | 80 | 300 ms | $10^{-6}$ |
| 69 | Non-GBR | 0.5 | 60 ms | $10^{-6}$ | 69 | Non-GBR | 5 | 60 ms | $10^{-6}$ |
| 70 | Non-GBR | 5.5 | 200 ms | $10^{-6}$ | 70 | Non-GBR | 55 | 200 ms | $10^{-6}$ |

**Table 6-1 Comparison EPS QCI values versus 5GS 5QI values (Table 7.1.1.3-1 in TR 23.783).**

The table above included services explicitly used for MC services (cf:23.783, where it is stated: "This consideration is limited to the common signaling referenced by 3GPP TS 23.280 [3] and QCIs/QIs explicitely used for MC services"). Note that there is mismatch between provided QCI/5QI and the performance requirements for railway scenarios defined in TS 22.289. The disadvantage of not having standard QCI/5QI value defined for railway scenarios is the vendor products very often are optimized with defined QCI/5QI value. This should be addressed in the future in the SRS.

### 6.2.1 Policy control function

The Policy Control Function in 5G is defined in Detail in 3GPP TS 23.503, Section 6.2.1 – see following short extract:

> The PCF provides the following session management related functionality:
> - Policy and charging control for a service data flows;
> - PDU Session related policy control;
> - PDU Session event reporting to the AF.
>
> The PCF provides authorized QoS for a service data flow.
> The PCF uses the service information received
> - <u>from the AF</u> (e.g. SDP information or other available application information)
> - and/or the subscription information received from the UDR
> - to calculate the proper QoS authorization (QoS class identifier, bitrates).
> - The PCF may also take into account the requested QoS received from the SMF via N7 interface and the Analytics related to "Service Experience" received by NWDAF
>
> Policy Control subscription Management
> - The PCF may request subscription information at PDU Session establishment and during the UE Policy Association Establishment procedure.
> - The PCF may receive notifications on changes in the subscription information. Upon reception of a notification, the PCF shall make the policy control decisions necessary to accommodate the change in the subscription and shall update the SMF and/or the AMF if needed.

**Interaction with MCX (text underlined above):** For the MCX case the PCF will then use the information received from the Application Function (AF) and the subscription information stored in the UDR. The UDR usually stores the default QoS parameters (used at 5G data session setup mainly) which can then be modified via the AF (which is the MCX application server in the FRMCS case).

### 6.2.2 Usage of priorities

The usage of priorities for common functions in MCX is defined in TS 23.280 (Common functions for MC-Services). Please see the cited text below:

| Clause in TS 23.280 | Cited Text |
|---|---|
| 5.2.11 Use of Priority<br>→ 5.2.11.1<br>Requested priority | *"The MC service system may allow the MC service client to request the priority of a communication by selecting the corresponding priority level. The MC service server can enforce the selected priority level in determining the application priority for resource allocation during communication establishment. The use of the requested priority may vary depending on MC service provider's policy"* |

| | |
|---|---|
| Annex C Application Priority (Informative) → C.1 usage of application priorities | *“Communication priority involves a combination of the type of call/communication, the role of the requesting MC service user, and the predefined/requested priority of the initiating MC service user and/or group.”* |

For the MC-PTT part the priority definition is included in TS 23.379 (Functional Architecture & Information flows to support MC-PTT).

(Almost) all call requests include the parameter “requested priority”.

- E.g. group call requests:
  - 10.6.2.2.1 MCPTT emergency group call request
  - 10.6.2.2.5 MCPTT imminent peril group call request
  - 10.6.2.2.7 Group call request (MCPTT client – MCPTT server)
  - 10.6.2.2.8 Group call request (MCPTT server – MCPTT server)
- …
- Private call requests:
  - 10.7.2.1.1 MCPTT private call request (MCPTT client to MCPTT server)
  - 10.7.2.1.2 MCPTT private call request (MCPTT server to MCPTT server)
  - 10.7.2.1.5 MCPTT emergency private call request (MCPTT client to MCPTT server)

## 6.3 Bearer control options

As outlined in the previous chapters the control of the QoS of the associated EPS or 5G bearer should be controlled via Rx Interface in EPS networks or N5 Interface in 5G networks. According to 3GPP TS 23.280 “Common functional architecture to support mission critical services” [3] two different scenarios are in principle defined (Clause 9.2.2.3 in 3GPP TS 23.280).

a. Access to Rx Interface via SIP-Core (Clause 9.2.2.3.2 in 3GPP TS23.280)

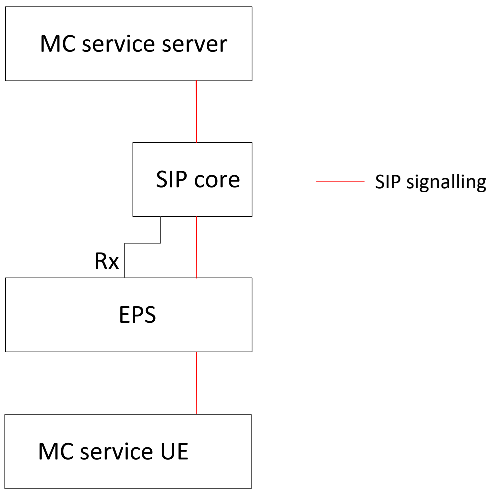



**Figure 6-2 Bearer control by SIP core (Figure 9.2.2.3.2-1 in 3GPP TS 23.280).**

b. Access to Rx Interface via MC service server (Clause 9.2.2.3.3 in 3GPP TS23.280)

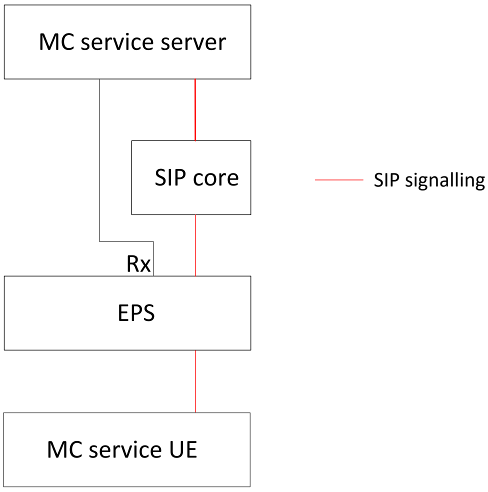



**Figure 6-3 Bearer control by MC service server (Figure 9.2.2.3.3-1 in 3GPP TS 23.280).**

Both Scenarios have Pros and Cons which we try to outline briefly in the following:

**Scenario a. Access to Rx Interface via SIP-Core:**

- The CSCF controls the interface to RX – according to IMS standards (which are derived mainly from VoLTE requirements)
- QoS control is provided according to SIP identity and SIP session setup level (i.e. at the base communication flow). However, in order to ensure that all MCX specific attributes are taken into account at the QoS Control, more details are required like:
    - MCX ID
    - Functional Alias,
    - MCX service configurations (e.g. for MC-Video)
    - ....

  This would **require customization on the SIP-Core/IMS part.**
- The MCX AS would be unaware of the QoS Procedures – or it would need specific (potentially proprietary interaction between CSCF and AS)

**Scenario b. Access to Rx Interface via MC service server**

- The MC service server has all information and parameters directly available and thus can issue the QoS control request to the EPS or 5G Core directly with the right QoS level
- The SIP-core/IMS can be used directly out of the box as standardized without any modifications
- If there are other services using the SIP-Core (outside of MCX), there might be the requirements for an additional RX Interface between SIP-Core and EPS (or N5 Interface between SIP-Core and 5GC). **The CSCF thus cannot control the QoS level between MCX requirements and other SIP Services**. However, this will be done finally anyway the EPS or 5GC according to standards as multiple Rx or N5 Interfaces towards a single core system are common practice.

**Conclusion**: From current viewpoint the Scenario b (Access to Rx Interface via MC service server) is in the long run the preferred option due to the above outlined arguments.

# 7 Standardization Timeline and Gap

This chapter summarizes the current standardization timeline and identifies work items which still needs to be completed to close the functional gaps in current 3GPP standards for FRMCS deployment. Please note that this chapter focuses mainly on the FRMCS Service Stratum.

## 7.1 Standardization timeline

3GPP announced a correction of the timeline in Q1 2020. Release 17 completion was moved from September 2021 initial planned date to new completion date of End 2021. The current valid time plane is shown in the figure below (from www.3gpp.org).

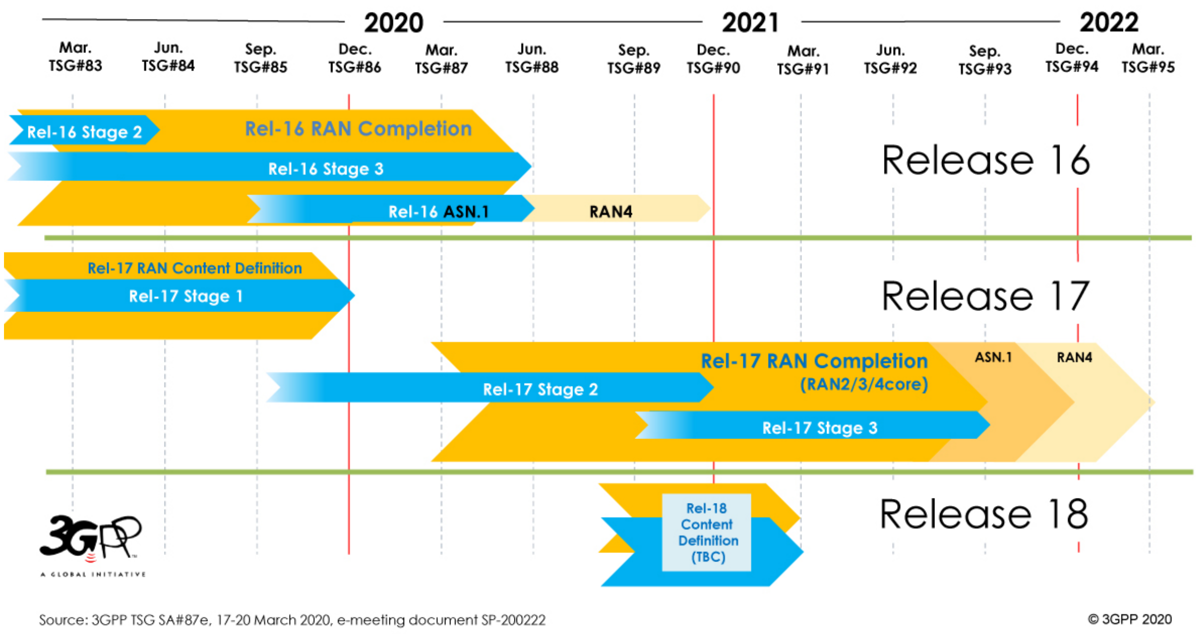



**Figure 7-1 Time plan of 3GPP Release 17 (from www.3gpp.org)**

With following more details in the next figure:

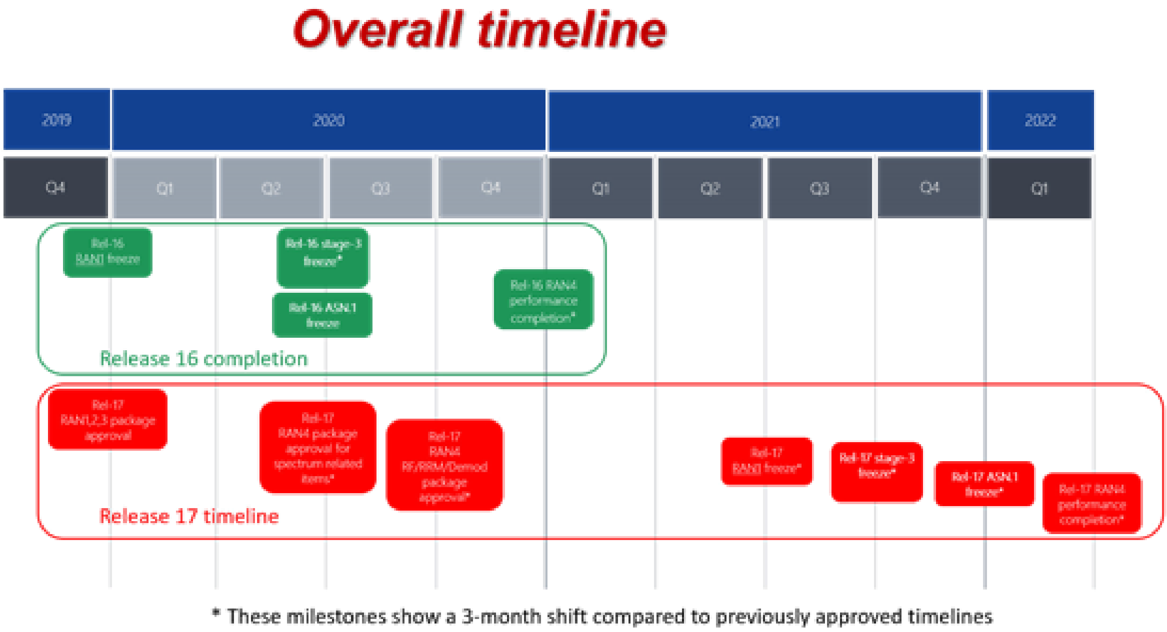



**Figure 7-2 Detailed time plan of 3GPP Release 17 (from www.3gpp.org)**

**However, during discussion at TSG#88-e Plenaries in July 3rd 2020 a high risk of further delays for Rel-17 was identified. This was further discussed in September 2020 during TSG#89-e. The September meeting stated again a high risk of shifting AGAIN for 6 or 9 months. A decision will be probably made in December.**

A mapping of the relevant Standards for the Mission Critical Service (MCX), IMS and FRMCS towards the different 3GPP releases is shown in the next figure:

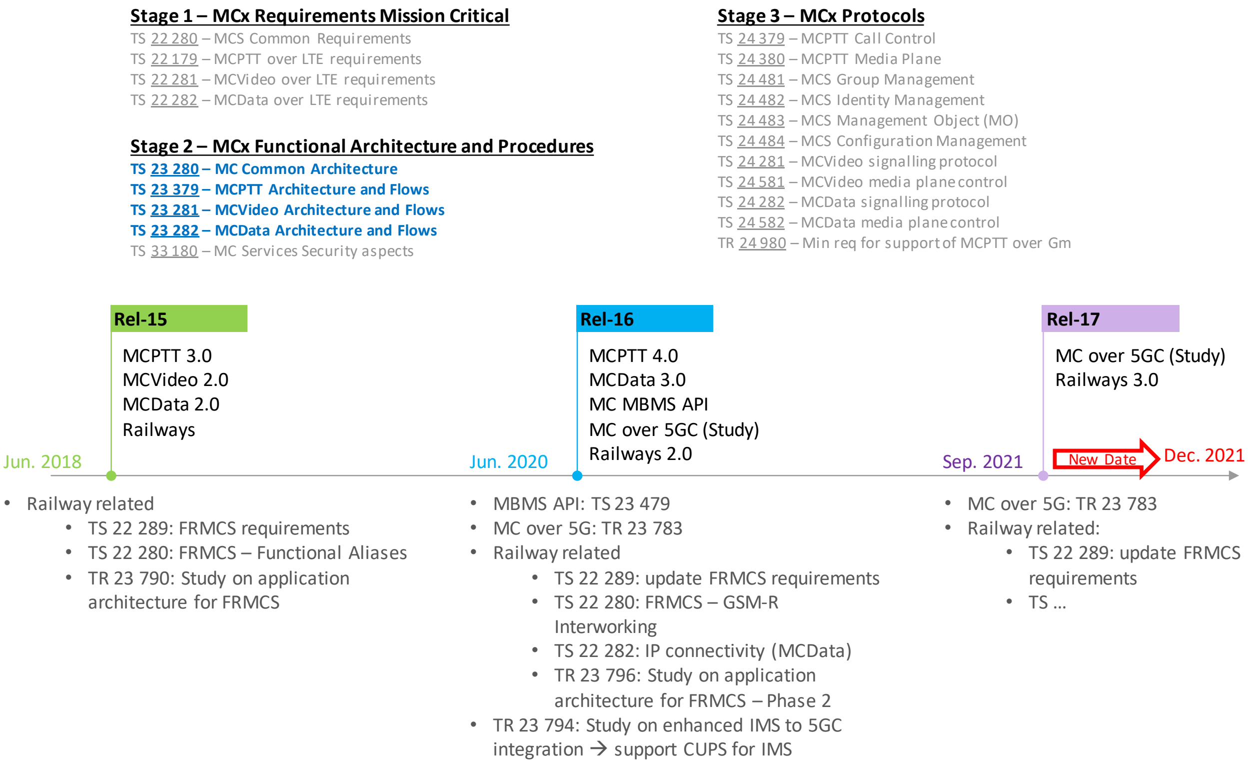



**Figure 7-3 Mapping of the relevant Standards for the Mission Critical Service (MCX), IMS and FRMCS towards the different 3GPP releases.**

To provide the global picture of additional relevant standardization bodies regarding FRMCS the standardization activities of ETSI TC-RT and UIC FRMCS are shown in parallel to the 3GPP timeline in the next figure:

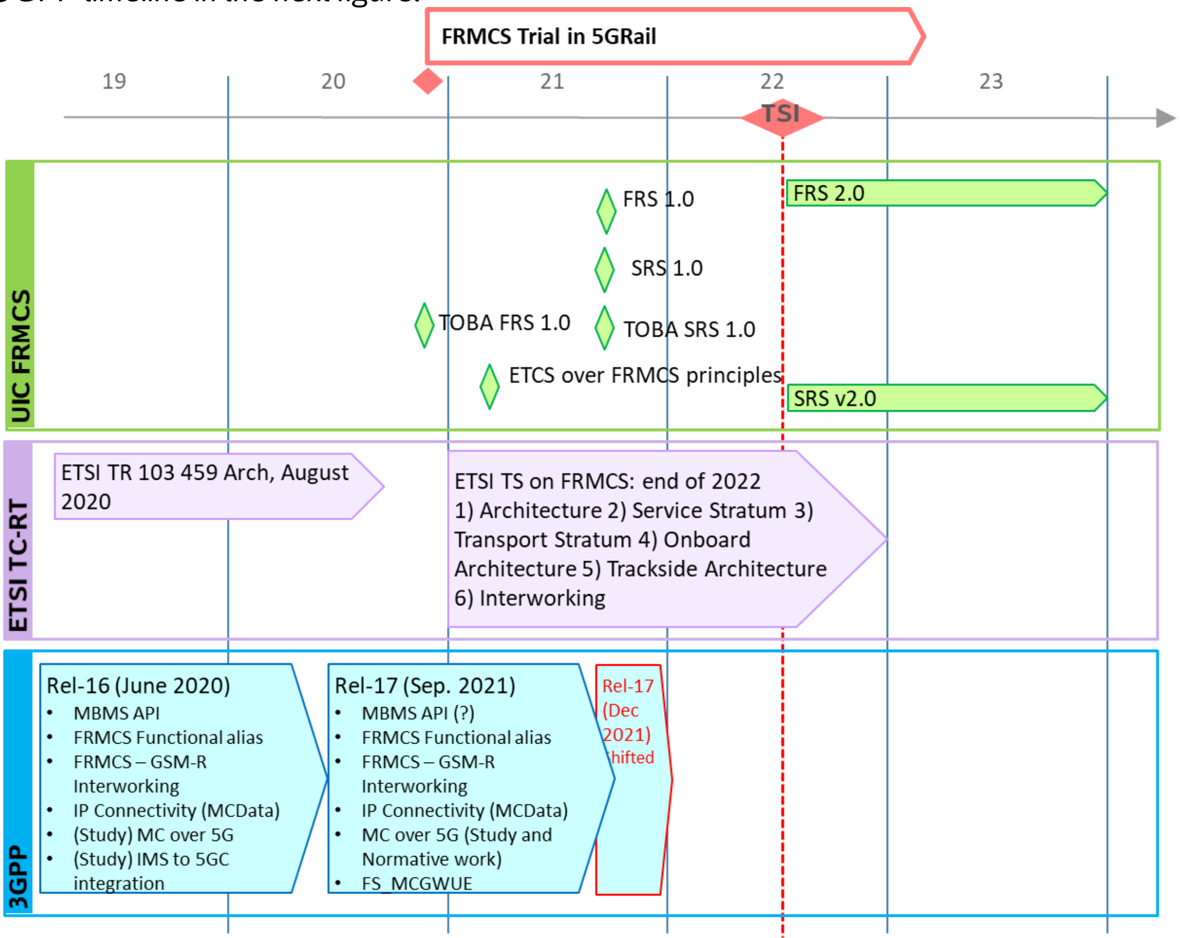



**Figure 7-4 Timeline of FRMCS standardization activities from different standardization bodies, namely 3GPP, ETSI TC-RT and UIC FRMCS.**[9]

ETSI provides the technical specification for the FRMCS Architecture and UIC will provide User Requirement specification (URS), standards on SRS (Service Requirement Specification) and FRS (Functional Requirement Specification) for FRMCS as well as the Onboard Architecture TOBA.

## 7.2 Standardization gaps in 3GPP

Still some requirements for FRMCS are not yet covered in 3GPP specification or are still worked on. The following list aims to provide a current view on functions and work items which are currently ongoing or expected to be standardized in the course of standardization work for 3GPP Rel-17.

### 7.2.1 Work/Study items of MCX in Rel-17 (including ones started in Rel-16)

**Stage 2** (most important ones)

[9] FS_MCGWUE is Study of Gateway UE function for Mission Critical Communication. Regarding MCOver5GS, mission critical services over 5GS has the work item been started (with limited scope)

- eMONASTERY2: S6: Enhancements to Application Architecture for the Mobile Communication System for Railways Phase 2
- FS_MCOver5GS: S6: Study on Mission Critical services support over 5G System
- MCOver5GS: S6: Work item covering a sub-set of Study FS_MCOver5GS covering unicast communication for MC services in a 5G system.
- FS_enhMCLoc: S6: Study on location enhancements for mission critical services
- FS_MC5MBS: S6: Study on Mission Critical services over 5G multicast-broadcast system
- enh3MCPTT; S6: Enhanced Mission Critical Push-to-talk architecture phase 3
- FS_ATSSS_Ph2: S2: ATSSS in the 5G system architecture
- FS_eLCS_ph2: S2: 5GC Location Services

**Stage 3**

- Follow up for MONASTERY2 called eMONASTERY2

**Others**

WID are in preparation (Rel-17 just starts for stage 3). Other features that are prioritized for Rel-17 likely relevant for FRMCS:

- NR_POS: R1: Positioning enhancements
- plus follow up of stage 2 SIDs/WIDs: MCOver5GS, FS_enhMCLoc, FS_MC5MBS, enh3MCPTT, FS_ATSSS_Ph2, FS_eLCS_ph2

### 7.2.2 MCx functions which be available until Rel-17 (till Rel 16 incl.)

**Expected content covered in Rel-17 – Stage 3**

- Registration: yes (already in Rel-16)
- Configuration management procedure: yes (already in Rel-16)
- Affiliation (only relevant for group communication?) yes, only for GC.
- Railway specific group functionality: Functional aliasing and location: Client based automatic group affiliation-based combination of location+speed+heading and functional alias is already available in Rel-16.
- QoS Policing: using Rx interface, yes, in Rel-17 Rx is still possible
- Location management
- Functional Aliasing: FA Management and origination side for MCPTT available. Termination side for MCPTT currently in progress. Will be completed in Rel-17
- IP Connectivity: currently in progress, basic functionality for P2P expected to be in release 16. Further enhancements will be in Rel-17
- Interworking with GSM-R: Not part of Rel-16. Expected to be included in release 17.

**MCData-IPcon specific status**

- MCData IP Connectivity is specified in stage 2 in 3GPP TS 23.282: http://www.3gpp.org/ftp//Specs/archive/23_series/23.282/23282-g61.zip mainly in the Clauses 5.11, 6.8, 7.12.2 (is outdated) 7.14, A.3.
- In stage 3 MCData content is spread across multiple specifications:
  MCData Signalling protocol:
  https://www.3gpp.org/ftp/Specs/archive/24_series/24.282/24282-g41.zip
  MCS Management Object (MO):
  https://www.3gpp.org/ftp/Specs/archive/24_series/24.483/24483-g40.zip
  MCS Configuration Management:
  https://www.3gpp.org/ftp/Specs/archive/24_series/24.484/24484-g60.zip

The IPcon contribution for Rel 17 focuses currently on the possibility to have an interconnection of IPcon MCX Clients without going on the central IPcon distribution function – i.e. distributed IPcon distribution function. A potential discussion is also going into the direction of CP/UP separation to have the possibility of central and/or local IPcon distribution function.

# 8 Conclusion

The assumption in ETSI TC-RT for FRMCS normative work is the utilization of 3GPP 5G and Mission Critical Services (MCX). One of the main findings of the collaboration between Kontron Transportation and Digitale Schiene Deutschland (Deutsche Bahn) was that a proactive approach to the standardization of FRMCS is very important due to the fact that the standardization activities are still ongoing. This is especially important because the 3GPP building blocks planned to be used in FRMCS are not finalized yet, and their standardization needs to be steered together in the direction of the final planned solution. Therefore, the study aims to investigate potential MCX technologies to be maximally leveraged in FRMCS for future railway operation.

As a starting point, a set of key MCX/FRMCS services, required for representative Deutsche Bahn railway applications, namely Voice, ETCS, ATO, Remote Driving and Video Surveillance were identified. Table 3-1 provides a summary of detailed common and specific MCX functions (including the relevance of 3GPP specifications and how these functions are required for corresponding representative DB railway applications).

Potential technical realizations of the FRMCS system using MCX building blocks were further elaborated. Furthermore, we identified whether the reference points between logical entities in the FRMCS logical architecture may adopt interfaces already standardized in MCX or be further standardized. In particular, we made some recommendations on the reference points between 5G and MCX, which are currently not yet standardized.

Specific topics as results of this collaboration were addressed such as Control and Use Plane Separation (CUPS) for MCX, Integration of MCX and 5G System and further work on MC Data IP Connectivity related to low latency User Plane Connection. These topics are being standardized or to be further standardized in stage 2 and stage 3 of the 3GPP standardization work. The analysis of the potential technical solutions provides good basis to steer the FRMCS standardization work.

Finally, standardization gaps were identified which showed that the current defined 3GPP building blocks still needs to be enriched either by detailing the specifications in 3GPP or through additional specifications done by ETSI. Active contributions to 3GPP/ETSI work items are essential to steer the standardization to the envisaged final solution. For instance, in 3GPP SA6, Kontron based on the collaboration results proposed a stepwise approach regarding basic media plane procedures for IP Connectivity going forward to a distributed media plane architecture approach.

# 9 References

[1] ETSI TR 103 459 V1.2.1 - Rail Telecommunications (RT); Future Rail Mobile Communication System (FRMCS); Study on system architecture.

[2] 3GPP TR 22.889 - Technical Specification Group Services and System Aspects; Study on Future Railway Mobile Communication System; Stage 1. (Release 17).

[3] 3GPP TS 23.280 - Technical Specification Group Services and System Aspects; Common functional architecture to support mission critical services; Stage 2 (Release 17.

[4] 3GPP TS 23.281 - Technical Specification Group Services and System Aspects; Functional architecture and information flows to support Mission Critical Video (MCVideo); Stage 2 (Release 17).

[5] 3GPP TS 23.282 - Technical Specification Group Services and System Aspects; Functional architecture and information flows to support Mission Critical Data (MCData); Stage 2 (Release 17).

[6] 3GPP TS 23.379 - Technical Specification Group Services and System Aspects; Functional architecture and information flows to support Mission Critical Push To Talk (MCPTT); Stage 2 (Release 17).

[7] 3GPP TR 23.783 - Technical Specification Group Services and System Aspects; Study on Mission Critical Services support over 5G System (Release 16).

[8] 3GPP TR 23.794 - Technical Specification Group Services and System Aspects; Study on enhanced IP Multimedia Subsystem (IMS) to 5GC integration (Release 17).

[9] 3GPP TS 23.501 - System architecture for the 5G System (5GS) (Release 16).

[10] 3GPP TS 23.502 - Procedures for the 5G System (5GS) (Release 16).

[11] Netmanias Tech-Blog, Dr. Michelle M. Do, 2013, https://www.netmanias.com/en/post/blog/5933/lte-qos/lte-qos-part-2-lte-qos-parameters-qci-arp-gbr-mbr-and-ambr