EUROPEAN UNION AGENCY FOR RAILWAYS

Making the railway system work better for society.

Report

Evolution of Railway Radio Communication: System Definition

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1.   Introduction

1.1.   Purpose of the Report

The purpose of this Report is to provide high-level information on the main elements of the System Definition for the successor system of GSM-R. The information contains conclusions that will be the basis for further development of system as well as for the preparation of the CCS TSI update which will be necessary to allow the use of other systems than GSM-R.

The development of the future radio system is one of the "game changers" identified in the ERTMS Longer Term Perspective document, presented to the Rail Interoperability and Safety Committee in 2016.

The main elements considered as relevant for a system definition are functionality, technology, spectrum and conditions for migration; these elements determine the scope of this document. The possible redefinition of the ETCS onboard architecture to allow modular communication is not in scope of this report.

The conclusions for the System Definition included in this Report are based upon the information available as per mid December 2018.

1.2.   Problem description

In Europe, the EU legal framework for railways – in particular the Control Command System Technical Specification for Interoperability (CCS TSI) - defines GSM-R as the radio system to be used for train-to-track voice communication and for ETCS data communication.

While GSM-R is widely spread across Europe as well as in other parts of the world, some vendors of the supply industry have indicated that obsolescence of GSM-R (e.g. due to aspects like component availability) might be a risk on the longer term, and replacement has to be prepared. The current situation is that general support of GSM-R will be guaranteed until at least 2030, while some tenders and individual contracts require extensions till 2035. The Railway sector expects that the full migration from GSM-R to the successor system may take at least 8 to 10 years, depending on the size of the network and the impacted rolling stock. Hence, replacement of GSM-R should start mid next decade in order to prevent risks for the continuity of GSM-R based communication.

Another trigger for considering a successor to GSM-R is the expected increase in communication demands due to further implementation of ETCS, notably in large station areas, and the digitalisation of railways. Although GSM-R has the possibility to increase its capacity by using packet switching technology (GPRS), the overall capacity of GSM-R will be too limited.

The Commission has tasked the Agency, in its role as system authority for ERTMS (Article 28 Regulation 2016/796) to prepare the introduction of new radio systems, in addition to, and, in a later stage, as replacement for GSM-R, for communication functions as defined in the CCS TSI. It has been agreed that ERA project provides a status report on the definition of the new system in 2018 and timely prepares input for an update in the CCS TSI planned for 2022.

1.3.   Scope of the System Definition

The scope of the ERA project covers solutions/systems related to the essential requirements and basic parameters of the radio part in the CCS TSI: the main applications of the current radio system, as defined in the CCS TSI, are considered as reference, and co-existence with these applications has to be ensured. However, the new system shall be capable to support future changes and extensions of the applications covered by the CCS TSI, as well as applications covered in other TSI's. Also voice and data applications outside

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TSI's, in particular those related to further digitalisation of railways, will be taken into account, as these could contribute to the business case for the introduction of the successor of GSM-R.

Note that in this report the term FRMCS (abbreviation for Future/Flexible Railway Mobile Communication System) is used for the successor of GSM-R. This term is already widely accepted and used inside and outside railways (e.g. 3GPP, ETSI).

1.4. Methodology

1.4.1. Organisation

In 2015, ERA started its project on evolution of railway radio communication in order to prepare the system definition and the CCS TSI update. As part of this project, a specific working group has been established, in order to facilitate the overall coordination of multiple initiatives and activities related to the evolution of railway radio, and to monitor the progress. This working group is attended by representatives of the rail sector organisations (CER, EIM, ERFA, UITP), the ERTMS User Group, the supply industry (UNISIG, ROC IG), UIC, ETSI and Shift2Rail IP2. Each of these working group members contribute e.g. by position papers, technical papers and progress reports.

Annex 2 contains a brief description of the main contributors and the interworking between them.

1.4.2. Results

This Report reflects the overall conclusions ERA has extrapolated from the information gathered in the working group and takes into account the feedback from the members of this group on the draft conclusions.

The draft report (without annexes) was distributed to the Coordination Radio WG members for their feedback on October 29. Comments in writing have been received from UNISIG, EIM, ROC IG, CER and UIC and S2R. The feedback was intensively discussed in the Coordination radio meeting on 22/11. The results of this meeting have been included in the final report.

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2. Opportunities and constraints

2.1. Opportunities

The GSM-R system is relying on a technology that was defined in the mid 90's. Although very robust and very convenient in terms of interoperability, performance and functionality, and satisfying the current operational needs of railways, GSM-R and its allocated spectrum has a couple of intrinsic limitations, such as limited capacity and scalability. GSM-R has some embedded railway specific features, which, from a functional perspective, makes it complicated to create extension of capacity by using public networks maintaining the functionality; also, the use of commercial off the shelf equipment (e.g. smartphones) is problematic. In this way, GSM-R can be seen as a niche market, which leads to a small market for users and suppliers and thus suboptimal economic situations.

On the other hand, the use of mobile communication, both terrestrial and satellite, has evolved dramatically during the last decade. In particular, the uncoupling of functionality and radio bearer technology has resulted in an extremely flexible and expandable ecosystem of hundreds of types of user devices and thousands of apps, which are capable to use any kind of radio networks. In many domains, mobile communication and innovative applications are in use or under development.

The technical developments in radio communication, as included in 3GPP roadmaps and the EU ambitions and strategy as laid down in the EU 5G Action Plan[1], are intended to facilitate functional improvements in terms of capacity, latency, performance and efficiency for data communication in different verticals markets, such as Internet of Things, Critical communications and Intelligent Transport. Railways, when defining the successor of GSM-R, can benefit from these developments.

Specific for Railways, expansion of the deployment of ERTMS, further digitalisation and automation are the expectations from EU and many infrastructure managers and railway undertakings. Considering the - yet unknown - increase of mobile communication demands in railways, the system concept shall be very flexible, in terms of bearer technology independency in such a way to be immune from the dramatic evolution of the telecom sector, scalable, expandable, and finally more sustainable from the economic point of view. This requires a state-or-art architecture which does not only include the latest technologies, but also allow the introduction of future technologies. The anticipated update of the radio system is also an opportunity to introduce a clear split between applications and radio systems, in particular for the current ETCS and voice applications, in order to achieve independency in the respective long term technical and implementation roadmaps and life cycles. It would also enable the paradigm shift from "network as an asset" to "network as a service".

The overall architecture of the radio system should support the use of dedicated railway communication networks, as well as commercial public networks in situations/areas where these networks can fulfil the railway requirements for e.g. service availability, without functional, performance or even safety degradation. This is in line with the EU 5G Action Plan, which encourages all stakeholders to consider 5G, and to use commercial networks also in support of Public Safety and Security Services (e.g. TETRA or GSM-R). In addition, in specific cases, the use of non-3GPP systems such as wifi and satellite communication could be beneficial.

The definition and introduction of FRMCS will cope with these trends, providing sufficient flexibility in terms of functionality, capacity and performance, and allowing cost reduction by using commercial mainstream telecom technologies, products and/or services, while keeping interoperability.

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[1] Brussels, 14.9.2016 COM(2016) 588 final: An Action Plan {SWD(2016) 306 final}

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2.2.   Constraints

Due to the large implementation of GSM-R, the time needed to update on-board and trackside installations and the related investments, a fast switchover from GSM-R to FRMCS will be virtually impossible; hence the EU wide transition to the new system may take up to a decade. The window for migration is related to the earliest possible availability of new products, expected around 2023, and to the latest possible guaranteed support for GSM-R for both on-board and trackside systems, somewhere between 2030 and 2035. However, in the meantime, infrastructure managers are considering how to equip new railway lines, because there is little point to invest in a nearly obsolete technology. This may lead to the situation that the start of implementation of FRMCS and decommissioning of GSM-R in different MS or on different lines may differ more than 10 years.

Related to the potential to use commercial public networks, the railway stakeholders currently lack certainty on if third party service suppliers (e.g. MNO) could meet on all railway lines the quality of service requirements that critical railway applications require. Nevertheless, the system definition will not exclude the possibility for IMs to use this option, at least for non-critical applications and/or secondary lines.

Another constraint is related to the financial impact of the introduction of new dedicated networks while maintaining and supporting the existing ones. For IM's, the reuse of existing assets (e.g. base station sites) can reduce the costs for implementation of the new system dramatically. For RU's, following the economic/technical life cycles of the current on-board radio equipment, as well as combining other vehicle upgrade activities (in particular related to ETCS and ATO) with radio upgrades, can prevent additional costs.

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3. Conclusions on System Definition

Based upon the input and achievements as per Q4 2018, such as rail sector position papers, requirement specifications, studies, research results, technical developments in 3GPP and ETSI, spectrum regulation and economic impact analysis, ERA is able to conclude on high level conclusions on System Definition for FRMCS. In particular the UIC FRMCS project, S2R IP2 TD2.1 and ETSI TC RT have delivered essential input for this report. Annex 1 contains a list of reference documents used for this Report.

The conclusions, endorsed by the involved stakeholders, are given in the subsequent sections below; it covers four fields of interest, being functionality, technology, radio spectrum and migration.

3.1. Functionality

The conclusion is that FRMCS should offer, as a minimum, functionality for voice and data applications similar to the functionality offered by GSM-R. This includes e.g. telephony functions, voice group and broadcast communication, location dependent addressing, use of functional numbers (e.g. train-number) for addressing, communication priority and pre-emption. FRMCS shall also be capable to support demanding data applications with high quality of service requirements and/or high bandwidth demands. The correct level of harmonisation of functionality should be determined and a minimum set should be included in the CCS TSI. This approach will facilitate a smooth migration from operational point of view, with minimal impact on existing applications such as driver – signaller voice communication, emergency communication and ETCS and the related operational rules.

Analysis of the current use of GSM-R[2] and collection of user expectations for future applications[3] using mobile communication have shown that the use of voice applications and emergency communication (Railway Emergency Call) will remain stable or will decrease slowly, but the amount of data-applications will increase. Some data applications will be relatively low-profile in terms of bandwidth or quality of service, other data applications will require high bandwidth and high quality of service. An example of the last category is automated train operation (ATO), which is getting increased attention and will require a significant bandwidth in the case of autonomous driving (GoA4) or remote controlling, enlarging significantly the performance requirements of the critical functions, e.g. due to the use of real-time video transmission.

3.2. Technology

The conclusion is to continue with the usage of radio systems as specified in 3GPP roadmaps in order to benefit from global developments and standards, economies of scale and mature products. This approach has been proven to be successful with the introduction of GSM-R. The ongoing work on ensuring that rail specific requirements are "supported by design" by the generic specifications of 3GPP roadmap will ensure that a high level of compliancy with railway needs will be achieved. The preferred solution at the start of the introduction of FRMCS is based on a 5G platform. It would be beneficial if this platform can also support non-3GPP radio technologies.

It has to be noted that the 3GPP roadmap specifications are not only covering the needs of the global consumer and commercial operators' market, but also include the specific requirements from the critical

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[2] Evaluation of the use of GSM-R for operational voice and emergency communication, ERA, April 2018
[3] User Requirement Specification v 3.0.0, UIC, January 2018

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communication market, such as Public Protection and Disaster relief (PPDR, the "blue light" sector) and Railways, starting within 3GPP Release 15 and going further steps in 3GPP Release 16 and 17[4]. The inclusion of railway requirements in 3GPP ensures the native management of the railway needs in various future evolutions of 3GPP.

It is expected that during the migration from GSM-R to the new system, 5G will replace 4G (LTE) as the global dominant technology. Hence the proposal is to consider 5G as the preferred technology at the start of the introduction of FRMCS, both for generic architecture (on-board and trackside) and for radio technology. The – maybe temporary - use of 4G radio technology could be allowed too, unless it is demonstrated that there are unacceptable non-compliances to functional requirements, technical complications or economic impacts.

The proposal is to provide IP technology for all types of communication, based upon known protocols. Priority and pre-emption must be supported for certain types of communication to ensure the prioritisation of certain types of communication (i.e. critical applications such as ETCS). This is in line with the global trends in mobile communication.

The clear separation of applications and communication services and networks, as well as the migration to a full IP based communication architecture, offers the possibility to develop and maintain independently applications (such as voice, ETCS, ATO and all kind of applications in the context of digitalisation of railways) on one hand, and for the radio networks and radio devices on the other hand.

In order to achieve this flexibility for ETCS, a couple of options are currently under investigation. One of them is the possibility to connect the legacy ETCS BL3 on-board with FRMCS on-board, to allow a smooth migration. Another option is to introduce changes in the in the ETCS (non-safe) communication part. With these concepts, it would not be required to re-certify ETCS on-board when the radio system is changed.

High level principles of the generic architecture for systems with CCS TSI relevance will be discussed with the involved stakeholders in specific workshops organised by ERA. Research on a generic architecture for on-board and trackside to demonstrate this concept is performed by Shift2Rail IP2 TD2.1.

Further investigation of the impact of the need to support multiple radio technologies on the on-board equipment and antenna-system is addressed to identify the optimal catalogue of technologies.

3.3.   Radio Spectrum

The conclusion is to promote the allocation of additional harmonised radio spectrum for railway specific radio networks, which is sufficient to support the short and longer term railway radio communication needs and technologies as described in the previous sections. This implies that the spectrum has to be available in time to start the migration and has to enable the use of 5G or, where applicable, 4G radio technologies. In order to limit the economic impact, the 900 MHz band is preferred. Additional spectrum may be required to extend the system capacity where required. Although not all railways or Member States may have the same spectrum needs, a certain degree of harmonisation ("catalog") would be helpful for creating a coherent Single European Railway Areas as well as to minimise the technical complexity and costs for supporting all spectrum options on CCS TSI compliant trains

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[4] 3GPP uses a system of parallel "Releases" which provide developers with a stable platform for the implementation of features at a given point and then allow for the addition of new functionality in subsequent Releases.

EC has mandated ECC[5] to report on the railway needs – applications, operational conditions, capacity, performance, availability - and the potential spectrum options. The current main option is to allow railways to use a part of the 900 MHz band (2x1.6 MHz, following a Decision on SRD[6]) in addition to the existing spectrum (2x4 MHz already assigned to and used by GSM-R), to facilitate the introduction of FRMCS. However, as the preferred 5G radio technology requires currently at least 2x5 MHz bandwidth, the proposed additional spectrum does not allow the introduction of 5G from the beginning, unless 3GPP will adopt the railway request to support smaller spectrum bandwidth, or specific technical solutions can be found to allow the coexistence of GSM-R and 5G.

Although 4G/LTE is also defined for the use of the part of the spectrum planned (2x1.6 MHz is sufficient for a 2x1.4 MHz LTE system), the scenario of starting with a 4G system and, after decommissioning of GSM-R, migration to 5G, is raising questions on migration efficiency.

Other frequency bands which are under investigation by ECC, the 1900 MHz or the 2300 MHz band, can provide sufficient spectrum for a 5G system, but using these higher frequencies may require a densification of radio sites, creating a considerable economic impact when used for a complete network. On the other hand, these bands could help to enhance the overall capacity on specific locations, e.g. in dense railway networks, border areas and high-density areas.

An ECC Decision on the harmonised spectrum allocation for railways is expected around November 2020.

The potential spectrum options for dedicated railway networks mentioned above, and the potential use of public networks, which may be different for MS, require a clear definition of frequencies to be supported by on-board (and other radio) equipment in MS. It is worth considering to perform an analysis of the inclusion of a list of intended frequencies, to be used in an MS, in the FRMCS section of the National Implementation Plans (see section 3.4 below).

The railway sector has expressed their concerns about the significant negative economic impact of some of the spectrum options (e.g. limited spectrum, higher frequency bands) or conditions (e.g. limitation of transmitted power, improvement needed on the receivers to avoid interferences). These aspects could not only have short term effects, such as jeopardising the pure reuse of the current GSM-R site for FRMCS (where a decrease of inter-site distance would have a critical deployment cost impact), but also for the longer term, referring to the Commissions' incentives to promote railways as one of the solutions for CO2 reduction. Lack of sufficient radio spectrum could conflict with these ambitions.

3.4.   Migration

The conclusion is that the expected scenario for the technical migration is to use the general principle of multimode on-board, supporting GSM-R and FRMCS as this migration scenario has the lowest economic impact for the railway sector as a whole. This scenario needs coordination between the IM and the concerned RUs to define the most optimal migration planning. This coordination of optimal migration planning will be enforced within the future TSI CCS (chapter 7) and with some additional specific migration rules to enforce the balancing of migration costs for all impacted RUs (minimising the retrofitting costs for existing GSM-R equipped vehicles) and costs for IMs (minimising the costs to maintain multiple radio trackside systems).

The planned TSI CCS 2019 revision is expected to introduce some elements for the migration towards FRMCS (as one of the ERTMS game changers) with following 2 references:

>   (1)   If draft release specifications of the ERTMS game changers, as identified within ERA-REP-150, are included in an Agency Opinion before the legal release planned in the year 2022, suppliers

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[5] RSCOM18-05 rev3 Final EC Mandate to CEPT on spectrum for FRMCS

[6] Commission Implementing Decision (EU) 2018/1538 on the harmonisation of radio spectrum for use by short-range devices within the 874-876 and 915-921 MHz frequency bands

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and early implementers shall use these draft release specifications in their pilots and shall inform the Agency.

(2)   The update of the national implementation plans shall take into account the introduction of the next generation communication system(s), e.g. by indicating the date of start of operation and, when applicable, the date of decommissioning of GSM-R on (parts of) the Network.

The planned introduction of FRMCS legal release specifications is foreseen within the TSI CCS 2022. The proposal is that notification of GSM-R decommissioning towards RU's is made available well in advance, e.g. minimum 5 years, in order to give sufficient time for RU's to prepare the migration. The example of a minimum retrofitting period of 5 years is defined with the assumption that there is no impact on the existing ETCS B3R2 OBU equipped vehicles (link to on-board system architecture work stream).

Deviation from the minimum retrofitting requirement would only be allowed if an agreement is made between all the impacted stakeholders (e.g. including potential use of financial compensation schemes).

Actually, there will be no obligation yet in the TSI CCS 2022 to install the successor of GSM-R on new or upgraded lines or in new or upgraded vehicles without sufficient return of experience of first FRMCS deployments and considering the expected different GSM-R implementation periods across Member States. A generic obligation across Member States may cause a non-optimised economic impact.

4. Risks

The current status of development of in particular technology and spectrum aspects is not in such a stage that final conclusions on these aspects can be made. Hence, a couple of risks are identified by the different stakeholders.

4.1. Risks related to availability of specifications with relevance for the CCS TSI

One of the main risks for the timely availability of technical specifications for the radio part of the successor of GSM-R is that their finalisation can only start after the publication of an ECC Decision on radio spectrum (expected end 2020), as it would have an influence on the definition of radio characteristics of FRMCS and on some of the architecture aspects of on-board equipment. In order to mitigate this risk, it is recommended that CEPT/ECC communicates with ETSI/3GPP as soon as possible to shorten this period. In addition, EC should encourage transport administrations to validate with the National spectrum authorities the scenarios considered for the migration.

There is also a risk that the functional and technical requirements, as set by the railways, will not be fully covered by 3GPP specifications, or, due to heavy processes, will be delayed. In the case this risk occurs, which will be known mid 2019, additional standardisation work – specific for railways – may be required. .. In order to potentially limit the possible delays in standardisation, it is recommended to plan an assessment of the railway requirements and, in parallel, to investigate technical alternative solutions. It is recommended if EC issues a standardisation request to ETSI to develop specific technical specifications for FRMCS in ETSI TC RT, covering this gap. This would also provide a better visibility on the availability of Standards to be considered in the CCS TSI.

Until now, there is no clear identification of items which require specific activities for test and validation to demonstrate compliancy to the requirements. It could be assumed that for many generic functions and services, as defined in 3GPP and ETSI, no or minimum railway specific test activities are needed. However, test and validation of railway specific items, such as applications, interfaces, interworking with GSM-R, operational conditions, etcetera, - in particular those requirements with CCS TSI relevance - will be required. Funding for these activities is not yet addressed, or not completely open to all supply industry. In the case that validation (by demonstration and trials) is required for – a subset of - requirements, there is a considerable risk of delays. EC should consider funding mechanisms for supply industry and stakeholders to issue clear plans for test and validation.

In general, delays in the overall specification, standardisation and validation work will lead to delays the delivery of reference documents for the CCS TSI and in commercial availability of products.

4.2. Risks related to deployment of the successor of GSM-R

Considering the scenario where the railway communications would rely partly or entirely on services offered by third parties (e.g. public radio networks), there could be a risk to have additional requirements for on-board equipment, or that those requirements would need to evolve to cope with the dynamics of the public market.

In some of the spectrum scenarios, the anticipated spectrum will not be sufficient to allow railways to start with a 5G based radio system, and temporary a 4G based system has to be deployed; thus a second migration step would need to be performed after decommissioning of GSM-R. This scenario could lead to negative impact on the overall business case for the introduction of FRMCS.

In general, it is currently not clear what are the possibilities and limitations of the modularity and upgradeability of on-board equipment; this may create a risk of economic impact for RU's in different migration stages.

4.3.   Recommended actions

Related to the mitigation of the identified risks, ERA would like to address the following actions to EC:

1. EC to issue a standardisation request to ETSI to develop FRMCS specifications
2. EC to encourage transport administrations to validate with the national spectrum authorities the scenarios considered for the migration and for the longer term.
3. EC to investigate funding mechanisms for test and validation

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5. Next steps

In the period 2019-2021, the work on the requirements, specifications, standards and solutions will be continued by all involved stakeholders. The objective for ERA is to timely receive stable versions of documents with relevance for the CCS TSI.

One of the specific topics which will be integrated in this work is the outcome of the discussions on a generic ERTMS architecture, which covers also the game changers.

ERA will initiate the Identification of necessary test and validation activities and the involved actors.

ERA will continue with monitoring and, where needed, coordination of relevant activities from Shift2Rail, UIC, ETSI, the signaling and telecom supply industry, ECC.

Further investigation of the migration strategies and migration plans of IM's and RU's will be performed by ERA, in close cooperation with the railway stakeholders. Specific attention will be paid to the radio spectrum, both at ECC level and on MS level.

Intermediate reports on progress of the work on the evolution of railway radio and the identified risks will be available end of 2019 and end of 2020. These progress reports will provide input for the Report on System Definition in June 2021, to be issued by the Commission. This report will include the conditions and possible strategies for the migration to the next generation communication system with the due considerations for the coexistence of the system and spectrum requirements.

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Annex 1   Reference documents

Ref Nr	Title	Source	Date
1	Position Paper on Future Radio Communication System	CER	June 2014
2	Future Railway Mobile Communication System, EIM expectations and key challenges	EIM	December 2016
3	User Requirement Specification URS FU-7100 v 3.0.0.	UIC	January 2018
4	Functional Use Cases FU 7110	UIC	ongoing
5	System Use cases AT 2504	UIC	ongoing
6	Draft Functional Requirement Specification FU 7200	UIC	ongoing
7	Survey on operational communications	ERA	February 2014
8	Study on Evolution of GSM-R; network models	ERA	March 2015
9	Study on Migration from GSM-R to other solutions	ERA	May 2016
10	Study on Coexistence of GSM-R with other systems	ERA	July 2016
11	Study on Feasibility of Satcom for railway communication	ERA	February 2017
12	Study on Implications of bearer independent communication concept	ERA	July 2017
13	Study on the architecture of on-board radio communication	ERA	September 2018
14	Ex-post analysis Operational requirements of railway radio communication systems	ERA	October 2014
15	Evaluation of the use of GSM-R for operational voice and emergency communication	ERA	April 2018
16	ETSI TR 103 333 SRDoc	ETSI	
17	ETSI TR 103 459 Technical report on Architecture	ETSI	November 2018
19	ETSI TR 103 554 Simulation 1.4 LTE railway conditions	ETSI	October 2018
20	High level impact analysis of FRMCS on Euroradio	UNISIG	February 2017
21	Radio Spectrum Committee mandate on FRMCS	EC	July 2018
22	Commission Implementing Decision (EU) 2018/1538 on the harmonisation of radio spectrum for use by short-range devices within the 874-876 and 915-921 MHz frequency bands	EC	October 2018
23	ECC Report 294 (FM56)	ECC	December 2018

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Annex 2   Involved organisations

General

The development of FRMCS requires a close cooperation between several organisations with different backgrounds, scopes and objectives. The general approach is given below.

Based upon position papers and other inputs from the sector organisations, in particular CER and EIM, the UIC FRMCS[7] Project (where railway experts in the field of radio communication and railway operation are participating) drafts a set of requirements. These requirements consists of URS (User Requirement Specification), FRS (Functional Requirement Specification), SRS (System Requirement Specifications). UIC contributes also with documents on specific subjects, such as capacity/traffic analysis as input for spectrum discussions, architecture concepts as input for ETSI work, and a complete set of functional and system use cases, which are important input for the identification of railway requirements in the 3GPP work.

Specific for ETCS related aspects, both ERTMS user Group and UNISIG are involved and consulted.

ERA has performed studies on specific subjects which were not covered by other organisations, such as network models, migration aspects, feasibility of satellite communication and technical architectures.

With reference to these requirements and other documents, in ETSI TC RT[8], the telecom supply industry and railway experts are drafting contributions for the technical details on architecture (building blocks, interfaces) and potential solutions. Where applicable, these contributions are forwarded to 3GPP in order to cover the railway needs in their Work Items.

In 3GPP, both railways and telecom supply industry are participating in the relevant working groups (e.g. SA1).

In a later stage, ETSI will draft the required standards, mainly based upon 3GPP specifications.

Shift2Rail IP2 TD2.1 is performing research on the Adaptable Communication System, which is intended to demonstrate solutions for connecting all kind of railway applications (including voice and ETCS) to several radio systems (including GSM-R and FRMCS), both on-board and trackside. S2R is collecting requirements from heavy rail (in particular from UIC FRMCS project) and urban rail. Where applicable, outcomes from the research will be used as input for standardisation by ETSI. Coordination with UIC and ETSI is ensured by means of MoU's.
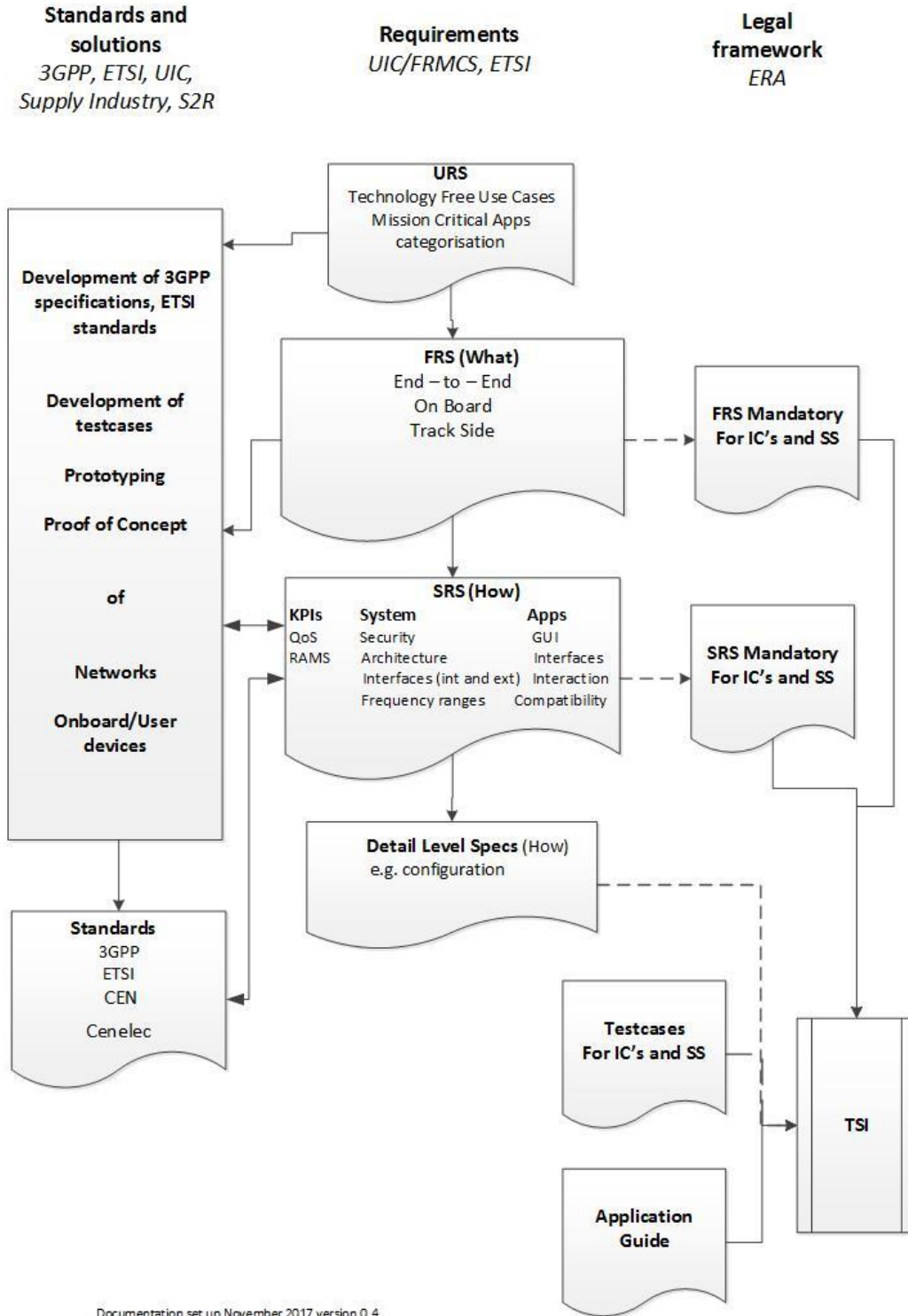
In addition, S2R has contracted a consortium (including EUG, UIC and supply industry) for the support of ERA. This contract covers also research on an evolution of ETCS train-to track communication.

In the ERA Coordination Radio working group, all organisations mentioned above are reporting about planning and progress of deliverables and activities. This enables a good exchange of information in an early stage.

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[7] Future Railway Mobile Communication System, project started end of 2013
[8] ETSI Technical Committee on Railway Telecommunication

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The figure below describes the overall approach.

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Specific for Radio spectrum

Specific for the topic of radio spectrum, the formal procedures for obtaining spectrum are followed, with involvement of DG CNECT/RSC (Radio Spectrum Committee) and CEPT/ECC. Railways, UIC, ETSI have addressed the need for additional spectrum to DG CNECT and have contributed with Position Papers and System Reference Documents[9]. In several MS, information exchange between railways and Administrations has been initiated.

In parallel, DG CNECT has mandated ECC to work on a report on railway spectrum needs and options. In this FM56 working group, Railways, UIC, ETSI and telecom industry are involved and contributing. Railways are also participating in other ECC working groups (e.g. on co-existence between FRMCS and public networks, such as ECC PT1 and SE7).

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[9] ETSI TR 103 333 SRDoc

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Annex 3   Functionality aspects

Context

During the first development of GSM-R, specific attention was paid to the inclusion of railway specific features which were at that time not available in the "telephony-oriented" GSM specifications. These features supported, for example, group communications, location dependent addressing (e.g. a driver can address a call to the appropriate signaller, depending on the location of the train), the use of functional numbers to address calls (e.g. to call a driver of a train using the train running number) and the possibility to introduce different priority levels for handling the calls. These features are available for both voice and data applications.

The railway sector has indicated that GSM-R contributes to the safety and performance of rail operation and is still fit for use[10]. Consequently the successor of GSM-R shall at least offer similar functionality and performance as GSM-R. In the responses to a questionnaire sent by ERA to its stakeholders on the usage of GSM-R[11], this conclusion has been repeated, although some specific functional improvements have been requested. The railway sector also has stated that the introduction of the new system should have very limited impact on the current operational rules.

Although not directly related to functionality, a railway specific requirement for the new system is to achieve a very high level of availability of the communication services and, in particular for ETCS, a high level of – guaranteed performance related quality.

One specific item inherent to the design of GSM-R is that the overall system is a complex integration of "user applications" and network properties and functions. This makes it very difficult to change or add functions or to create the optimal configuration for train operation: there are several dependencies between IC's (on-board equipment, sim-card) and the trackside subsystems. As changes can impact the whole system (not only the on-board or trackside elements), and there is no clear separation of the safety relevant and non-safety relevant parts of each subsystem, re-certification may be required in many cases after a modification.

Although many of the envisaged new applications could have been already developed to be used with GSM-R (with GPRS), this has not happened in most of the cases: some of these applications do not require a high amount of bandwidth, such as the monitoring of trackside workers, sending of data alerts, etc.

Another issue is that the "R" features (covering railway specific requirements) are implemented in GSM-R networks only and are generally not supported in public networks, either because they are described as optional features for GSM or because they are specifically developed for railway use. Hence, the use of public networks does not provide compliancy to the functions required in the CCS TSI. In addition, public networks are not designed to provide similar availability as achieved by dedicated GSM-R networks.

The disadvantages of the GSM-R concept, and the dynamics of mobile communication technologies evolution, require the uncoupling of applications and bearer services. This is essential to offer sufficient flexibility in the long term for future developments, not only related to applications, but also related to the use of any dedicated and/or public network.

There shall be a shift towards a model where the railway specific functionalities are provided by the application layer, allowing the use of multiple bearers to transport the information. An "apps based approach" as used in consumer smartphones and app-stores, is an excellent example of how this could be achieved. Although it is not the intention to make all railway applications available in an commercial "app-store", the way how flexibility and bearer-independency is achieved in the current environment for public

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[10] Ex-post analysis Operational requirements of railway radio communication systems, ERA, October 2014
[11] Evaluation of usage of GSM-R for operational voice and emergency communication, ERA, April 2018

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network subscribers and how user equipment is updated, can be considered in the railway domain, which may impact the way development and certification is currently done.

Special attention has to be paid to include in the overall design an architecture that allows the desired flexibility.

The sources of information for the description of the functionality are coming from the following initiatives:

› Agency's participation in the UIC FRMCS Project (Functionality Working Group)
› Position papers from the sector (EIM[12], CER[13], combined paper from CER, CIT, EIM and UIC[14])
› Ex-post analysis of the use of GSM-R (issued by the Agency)
› Questionnaire on operational use of GSM-R (issued by the Agency)

The common objective of these initiatives is the analysis of the functionality currently in use by railways, thanks to the capabilities offered by all the transmission networks available (not only GSM-R, but also other critical communication networks, the commercial public networks or private networks) in order to describe it and to later identify which of these functionalities shall be harmonised.

Both voice and data functionalities are considered in this analysis.

Objectives

The objective of the Agency is to identify in the different initiatives ongoing for the successor of GSM-R (UIC FRMCS project, Shift2Rail TE 2.1 Adaptable Communication) the essential requirements for interoperability (on-board and trackside) with respects to functionality that should be retained and defined in the update of the CCS TSI.
The description of the functionalities that are needed for all the trains to run safely shall be included in the CCS TSI. The Agency expects to rely on the content of technical specifications or standards from UIC, ETSI, or Shift2Rail defining an overall system for railway telecommunications, and in case it is needed, to create specific documents based on the specifications, adapted to the purpose of the CCS TSI.

In addition, the Agency fosters the assurance that interoperability will be maintained during the transition phase. The functionality described in the CCS TSI shall be as "technology neutral" as possible.

Only a minimum set of requirements should be included in the CCS TSI, therefore, an assessment of the proposed improvements or additions should be made by the Agency and its stakeholders within a specific task group: some of the currently used functionalities may not be needed and other applications may be introduced to support future needs. Examples of the latter may be the support of the functionality to allow virtual coupling or train integrity verification systems, the use of data messages for alerts and emergency situations, etc.

The discussion on which of the desired functionalities shall be present in all trains is key to achieve a set of requirements that balance the operational needs and the implementation costs of the system. Harmonisation may not only be limited to the functionalities included in the CCS TSI: a high level of harmonisation will help the deployment of other functionalities.

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[12] http://www.eimrail.org/uploads/news/2016-12-EIM-FRMCS%20position%20paper.pdf
[13] http://www.cer.be/sites/default/files/publication/FRCS_Position_Papers_2014.pdf
[14] http://www.cer.be/sites/default/files/publication/A%20Roadmap%20for%20Digital%20Railways.pdf

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Special care should be taken by the Agency to ensure that if a new functionality is introduced in the CCS TSI, it is accompanied by a set of operational rules.

Options

Different organisations are collecting the functional needs of the sector (UIC, S2R). Each of these functionalities may be seen as an application, and a decision has to be taken with respects to its level of harmonisation (defining the interfaces, the messages exchanged with the communication system and with other applications) and the need to include it in the CCS TSI.

Baseline scenario: the applications used in GSM-R will be kept. According to the ex-post analysis of the use of GSM-R performed by the Agency, the use of the different features offered by GSM-R in all the countries that have deployed the system was studied.

Option 1: baseline scenario plus a few additional harmonised functionalities, restricting to those agreed by the Agency stakeholders as needed by all trains, with their corresponding harmonised operational rules.

Option 2: option 1 plus an additional set of harmonised applications described as optional in the CCS TSI.

Impacts of the options

The inclusion in the CCS TSI of a wider range of optional applications may go against the overall desire of stability and simplicity of the legal framework. Harmonisation is possible outside of the frame of the CCS TSI, therefore it is not seen by the Agency as a must that all the applications defined should become part of the TSI. Option 2 is seen as a non-optimal solution.

The applications selected for the Option 1 should permit the access to all the networks in the Single European Railway Area without additional requests for the compatibility with the different routes. Option 1 is the preferred one.

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Annex 4   Technology aspects

Context

Sources of information for the main elements of the System Definition are coming from the Agency's participation in the following initiatives:

› UIC FRMCS Project (Architecture and Technology Working Group)
› ETSI Technical Committee Rail Telecommunications
› Shift2Rail Technical Demonstrator 2.1 (X2Rail-1 WP3)

The common objective of those three initiatives is the independency between radio/transport technologies and voice & data applications, facilitating use of radio telecommunications services (railway and non-railway networks)between on-board and trackside. This is referred to as bearer flexibility, and relies on IP based communication over standardised interfaces (including protocols on the different communication layers). This approach favours the possibility to use services provided by dedicated railway radio networks, public networks or hybrid solutions, depending on specific requirements (e.g. availability) and economic considerations (e.g. wider ecosystem than for GSM-R). Relying on 3GPP/IETF Standards is a common assumption in the three initiatives, to reuse to the highest extent already available technical specifications. However, some rail specificities could require amendments to those specifications.

> Note: Although the main trend amongst the three initiatives is to build up on 3GPP/IETF existing capabilities, the ERA on-board study considered possible future introduction of so-called Over-The-Top applications. This option is however not sufficiently covered by the above-mentioned initiatives.

> Note 2: The impact of the signalling game changers (ETCS L3, ATO) onto the general radio architecture are not sufficiently covered by the above-mentioned initiatives, as they are seen as applications that could cope with any type of data communication. It remains to be clarified if the level of Quality of Service required (e.g. ETCS over FRMCS) could have a strong influence on the radio architecture.

The UIC FRMCS project Architecture and Technology Working Group is developing technical conditions of the FRMCS System (in parallel of the applications and Use Cases drafted by the UIC FRMCS project Functional Subgroup). Later, System Principle Use Cases are provide to 3GPP (via ETSI TC RT). Currently, almost all those Use Cases have been drafted by the Architecture and Technology Working Group and transferred to 3GPP[15]. This group is now working on the development of a System Requirement Specification for the FRMCS system. The target date of availability of the SRS is

ETSI Technical Committee on Rail Telecommunications is performing relevant studies for the future system. Amongst those studies, the Technical Report 103 459 (publication expected Q4 2018) provides a reference model of FRMCS system architecture from a functional point of view, and a high level description of the functions that address FRMCS requirements (as specified in URS and Use Cases issued by the UIC FRMCS project). This feasibility study does not yet preclude of implementations of FRMCS, and a second phase drafting requirements complementing the FRMCS SRS will be needed. The target date of availability of this SRS is not known.

> Note: in TR 103 459, voice and data applications are considered differently and the rail specific requirements for ETCS could be fewer than for voice (e.g do not necessarily require MCX framework)

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[15] In 3GPP, railway topics are not dealt with the highest priority, therefore having all rail specific features within a specific timeframe (e.g. Rel-16) is not guaranteed

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Shift2Rail Technical Demonstrator 2.1 "Adaptable Communication" X2Rail-1 WP3 developed in the deliverable D3.3 "Specification of the communication system and Guideline for choice of Technology" a draft technical specification of a communication system (including overall architecture, definition of interfaces, addressing, QoS requirements, security); and a guideline to identify suitable technologies to be used for the prototypes. X2Rail-3 WP3 foresees in a second stage the finalisation of the prototype development and the testing and integration of prototypes into demonstrators, with the aim to validate the concepts and demonstrate the capabilities of the adaptable communication system for different railway environments (tests results expected Q2 2020).

> Note: It is not clear from the Grant Agreements in X2Rail-1 and 3 when output specifications could be transformed in ETSI Standards.

According to the information gathered in the three above-mentioned initiatives, it is difficult to conclude when Standards would be available for inclusion in the CCS TSI. The time needed by the Industry to develop products based on a Standard is usually in the range of 18 months. Therefore, in case Standards would be available for an update of the CCS TSI in 2022, deployments could be expected around 2023.

The Railway Operational Communication (ROC) Industry Group (formerly known as GSM-R Industry Group) indicated that they are committed to support GSM-R technology and GSM-R products at least until 2030. After this date, it will become technically more difficult to sustain product and technology based on the second-generation cellular technology (2G), especially as all other telecom stakeholders will discontinue the support of 2G. There is therefore, at least for obsolescence mitigation, the need to identify a new technology platform for railway telecommunications.

The expected ramp up of digitalisation in railways is an additional factor explaining the need for a more up to date technology. Applications like Automatic Train Operation, remote control of engines, and monitoring of infield sensors requires currently too much capacity for GSM-R. Reusing mainstream telecom technologies and development in other sectors (e.g. Public Protection and Disaster Relieve, automotive) would enable railway sector to support new applications and develop innovative maintenance methods.

Taking into account the operational impact of the deployment of a new telecom system for railways, as well as the very different timelines for migration in Europe, rail stakeholders indicated that coexistence of GSM-R and the successor system during a period of migration that could last for 8 to 10 years. The design of the successor system should consider this.

Objectives

The objective of the Agency is to identify in the different initiatives on going for the successor of GSM-R (FRMCS project, Shift2Rail TE 2.1 Adaptable Communication) the essential requirements for interoperability (on-board and trackside) that should be retain and defined in the update of the CCS TSI. Technologies to be prescribed could be one, bearing in mind that the concept of bearer flexibility should be introduced to work around the technological lock-in effect (i.e. GSM-R).The Agency expects to rely on technical specifications or standards from UIC, ETSI, or Shift2Rail defining an overall system for railway telecommunications.

In addition, the Agency promotes migration patterns, in cooperation with Infrastructure Managers and Railway Undertakings, ensuring that interoperability is maintained during the transition phase. A constructive dialogue will be key to ensure a balance between the objectives of IM to minimise the length of transition period and of RU to avoid replacement of existing asset already compliant to an older version of the CCS TSI.

Options

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From the initiative working on a successor to GSM-R, the assumption that 3GPP/IETF based telecommunication systems can provide for railway requirements is shared. However, some rail stakeholders would prefer to see non-3GPP solutions being adopted as well, referring to the Over-The-Top approach. Such an approach would enable use of railway applications irrelevant of the telecom technology deployed. Although this model is in theory possible, it is currently not sufficiently documented in UIC, ETSI or S2R.

ETSI TC RT is finalising a Technical Report 103 459 "Study on architecture" where a high-level view of what could be an architecture for FRMCS is presented. In this report, the 3GPP ecosystem is a prerequisite, and the merits of the different options are discussed.

A distinction can be made for voice and data applications, as the latter require less specificities in a railway context. For example, railway voice applications such as the Railway Emergency Call described in the FRMCS URS rely on group of users, and this concept requires specific 3GPP features (e.g. Mission Critical Service framework). Conversely, point-to-point data communications could be realised through more common methods or earlier 3GPP releases.

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Annex 5   Spectrum aspects

Context and problem definition

In order to be able to implement GSM-R networks, railways have obtained radio spectrum in the 900 Mhz frequency band, which is harmonised in EU. In all MS, 2x4 MHz bandwidth is available for railways, in some MS additional 2x3 MHz is assigned to railways.

As GSM-R is a circuit switched based system, the overall capacity is limited. Some IM's have implemented (or will implement) an additional packet switching system (GPRS) to increase the capacity.

Taking into consideration the achieved level of availability and performance of GSM-R networks and the limitations of the public networks in terms of availability (see previous sections), many IM's want to continue with the concept of dedicated railway networks, giving them full control on availability and performance.

A study performed by ERA[16] has shown that, with the available technologies as per today, it is not possible to introduce a new (LTE/4G) radio system in the same radio spectrum as GSM-R simultaneously without a severe impact on the legacy GSM-R network. As a consequence, additional spectrum is required.

The EC Radio Spectrum Committee has mandated ECC[17] to identify the railway needs and to identify potential frequency bands. Also the technical implications, such as co-existence with GSM-R and other radio systems including public networks, have to be investigated. A dedicated working group (ECC FM56) is tasked to deliver a final report in 2020.

ECC FM 56 is regrouping experts from the railway and telecom side, as well as National Regulatory Administration (i.e. spectrum regulators). The group is aiming at defining, in two phases, the amount of spectrum required by the railways for critical applications during and after the migration from GSM-R to it successor, and the spectrum scenarios for having a harmonised allocation at CEPT level. The conclusions of this group will quite probably lead to an ECC Decision for allocating harmonised railway spectrum. A complementary EC Decision could also result from the answer to the FRMCS Mandate.

> Note: The FRMCS Mandate also tasks FM 56 to study and assess the technical feasibility and scenarios of using commercial mobile networks, taking into account wireless coverage and reliability needs of the railway system.

The most credible scenario currently is to harmonise 2 X 1.6 MHz in addition to the existing 2 X 4 MHz already allocated to GSM-R for the introduction of the new system. This scenario offer the possibility to have after the migration 2 X 5MHz, a frequency channel arrangement that is supported by both 4G and 5G. Additional frequency bands, such as the 1900 MHz band, would also be required in dense railway networks, border areas and high density areas.

The first report on the railway needs (draft report A) is published in September 2018, the second report on the spectrum options (report B) is expected in 2020. Report B will also cover the definition of conditions for co-existence with other systems including prevention of interferences, as discussed in other ECC WG's (SE7 and PT1). Both reports will be input for an ECC Decision in November 2020 and an EC decision in 2021.

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[16] ERA Study by LS Telcom

[17] RSCOM18-05rev3 Final EC Mandate to CEPT on spectrum for FRMCS

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The UIC FRMCS project, in close cooperation with the railway sector, has performed a study on radio communication traffic and capacity which is needed to support the current and future applications using the dedicated railway radio network[18].

Based upon this traffic analysis, the rail sector, in particular the Infrastructure Managers, requires the allocation of a certain minimum amount of EU harmonised spectrum for harmonised (current and future) applications during and after the migration from GSM-R to its successor. In addition, the possibility to assign on national basis additional spectrum is also requested for specific, non-harmonised applications or for applications with a limited geographic scope.

A complicating factor is the fact that not all railways have the same needs (e.g. applications on top of the mandatory ones), the same train density (differs from line to line), or the same plans for further digitalisation of railways. In particular, the use of critical video communications for e.g. ATO or remote control of engines, could lead to a dramatic increase of capacity need for radio communication in the coming decades. Hence, a certain flexibility and scalability is required - without impacting interoperability.

Not only the critical applications, but also the robustness of the radio system in terms of availability (e.g. by using double coverage on ETCS lines) impacts the overall spectrum needs.

A specific element related to radio spectrum is the economic impact of the proposed frequency bands. A considerable part of the overall capex and opex of radio networks is directly related to the amount of radio sites and the subsequent costs for masts, power supply and transmission systems. This infrastructure represents the majority of costs for radio networks. The possibility to reuse of these sites for the successor of GSM-R, or even reduction of the overall amount of sites, leads to a limitation of the economic impact of the introduction of new radio technology. However, not only the frequency bands, but also the conditions for co-existence (e.g. maximum transmitted power levels) may create economic impact, e.g. due to the necessity to install additional sites.

The railway sector also documented their preferred spectrum target, e.g. an allocation of spectrum below 1 GHz, in order to be able to reuse to the greatest extent the existing infrastructure, such as masts, transmission systems and power supply;

ETSI TC RT has performed a relevant study in the Technical Report 103 554, simulating the capacity a 4G LTE system would achieve in a railway environment. Preliminary results are available for a 1.4 MHz LTE channel, and a second version of the TR will report additional results for 3 and 5 MHz channels. Although 4G LTE is only one candidate for the radio access technology to be used for FRMCS during and after the migration, the results are extremely useful to convert the traffic estimation from UIC Group for Frequency Aspects into a spectrum estimation.

An important aspect of spectrum is that 4G radio technology is able to work with 2x 1.4, 3 and 5 MHz bandwidth, where 5G technology requires currently a minimum of 2x 5 MHz. 3GPP is requested to investigate the possibilities to allow the use of smaller portions of spectrum than 5 MHz, in particular 1.4 and 3 MHz.

It has to be noted that even in the case that the candidate frequencies to be supported are covered in the 3GPP specifications, there is a certain risk that this will not lead automatically to availability of products supporting this spectrum.

Another aspect of radio spectrum is the impact on user equipment, in particular on-board radio equipment. In general, the amount of frequency bands to be supported will influence the costs of this equipment, in terms of complexity and the amount of radio modules. Also the risk of creating a niche market could lead to

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[18] FW-AT 2603 v2.1.1 FRMCS Traffic Analysis V2

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economic impact. Specific for trains, also impact on (amount of) antennas has to be taken into account, as the space for installation of antennas on the roof is limited.

In the absence of a commonly agreed spectrum migration plan at EU level, on-board radio equipment shall support all the harmonised railway frequency bands plus National specific allocation where required. In addition, on-board shall frequency bands enabling roaming to public networks as well.

The Agency will continue monitoring the railway spectrum work, in order to analyse the impact on the CCS TSI and to prepare the update of the CCS TSI.

Objectives

Main objectives: sufficient spectrum to allow the introduction of the successor of GSM-R and to facilitate the first migration step, possibilities to extent the spectrum after decommissioning of GSM-R, possibilities to have additional spectrum on hotspots, interference resilient, not interfering with GSM-R, limitation of economic impact, limitation of migration steps towards the target system, supporting interoperability.

A note on the relationship between interoperability and spectrum: following the basic principle of interoperability, the on-board equipment shall be able to operate at all frequencies which are available in MS networks. A limitation of the "catalog" of frequencies, e.g. by defining one single frequency band (like for GSM-R) or to agree on a set of mandatory and optional frequencies bands, reduces the costs of on-board. In order to create a stable and predictable situation for on-board, the catalog has to be defined and fixed at the time of publication of the new radio system in the CCS TSI.

Options

Although the final ECC report on radio spectrum is not finalised yet, the following options can be considered:

Baseline scenario: harmonised limited amount (2x1.6 MHz) of spectrum in the 900 MHz band, additional to the 2x4 MHz used by GSM-R. After decommissioning of GSM-R, 2x5.6 MHz is available. This scenario is based upon the SRD decision[19]. Note that some MS have already assigned 2x3 MHz (in addition to the 2x4 MHz) to railways.

Option 1: baseline scenario plus additional harmonised radio spectrum in the 1900/2300 MHz band (under investigation)

Option 2: option 1 plus additional non-harmonised spectrum outside the 900 MHz and/or in the 1900/2300 MHz. This provides the possibility to use the additional spectrum for non-interoperability related applications.

Impacts of the options

Baseline: this spectrum scenario allows railways to introduce 4G technology only. In general this spectrum is considered to be sufficient for the traffic currently using GSM-R (mainly voice and ETCS data), however, there are several hotspots (dense areas, shunting yards, big stations) which definitely require more capacity. It is questionable if this scenario can support the introduction of new applications, e.g. related to digitalisation of railways. This baseline is also not available in those MS where the spectrum is already used by GSM-R.

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[19] SRD decision

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When starting with 4G, further expansion of capacity and/or the introduction of 5G) are only possible after decommissioning of GSM-R. This requires a second migration. The current expectation is that a migration from 4G to 5G using (partly) the same frequency band is extremely complicated.

When the whitespace idea is feasible, it allows the introduction of 5G technology as first (and final) migration step. This baseline option also offers the possibility of reusing legacy sites, when the co-existence conditions allow to do so.

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Annex 6   Migration aspects

Context and problem definition

The introduction of the successor of GSM-R (called FRMCS radio system) raises the question if and which migration requirements should be considered into the CCS TSI revision. The overall order of magnitude of GSM-R assets in Europe are estimated around 10 BEUR.

The timeline of GSM-R implementations across Europe are significantly different and can be categorized between early (around the year 2000), medium (around the year 2010) and late (around the year 2020) GSM-R implementers. While some Member States report to be interested to migrate as soon as possible from GSM-R to FRMCS (e.g. Sweden, Switzerland) because there GSM-R assets have to be renewed soon, other Member States are still investing significantly in upcoming years in GSM-R assets either to renew their current GSM-R assets (e.g. NL, DE) or to roll out GSM-R for the first time on lines or even new networks (e.g. Poland, Spain). Therefore, it is expected that in the baseline scenario, the start and end of FRMCS implementation within the different Member States would follow the renewal cycles of the GSM-R networks. This may lead to a difference in start and end of FRMCS implementation in terms of 10-15 years as e.g. contracted lifetime of GSM-R in Poland reaches 2034, therefore it has been assumed that GSM-R will be in operation at least until then. Without further action, the migration towards FRMCS may create an unpredictable financial impact mainly for RUs and in some cases for IMs (e.g. one IM reported today not to be allowed to switch-off the Class B radio system after implementation and operation of the GSM-R system).

Objectives

The main objective is to analyse the requirements to be considered for chapter 7 of the TSI CCS in order to enable a cost efficient FRMCS migration and GSM-R decommissioning.

Options

1. Baseline scenario: similar radio specific implementation rules as in point 7.3 of CCS TSI 2016/919. Class A GSM-R radio system is replaced by Class A GSM-R/FRMCS radio systems, allowing the choice for trackside (and consequently on-board) installations between GSM-R or FRMCS implementation.

2. Baseline PLUS scenario: Baseline scenario including the obligation to update the National Implementation Plan (7.4.4) indicating the FRMCS implementation dates and GSM-R decommissioning dates.

3. Option 1: Baseline PLUS scenario with additional minimum period of 5 years between the notification of the start of FRMCS-migration and first decommissioning of GSM-R. Faster decommissioning of GSM-R is only possible in case of an agreement made between IM and all impacted RUs (e.g. by using financial compensation schemes to incentivise FRMCS on-board migration).

4. Option 2: Baseline PLUS scenario with fixed dates for FRMCS-implementation and earliest GSM-R decommissioning on European Railway Corridors or on complete European railway network.

Impact of the options

Under the assumption that the spectrum used for FRMCS-migration is in proximity to the current GSM-R spectrum, it is estimated that most GSM-R trackside assets (70%) can be fully re-used (e.g. GSM-R masts/power supplies) which would limit the FRMCS trackside migration costs.

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Besides the impact on the CAB-radios and EDOR radios (estimated asset value between 20 to 40[kEUR/radio]), a specific issue has been raised on the potential impact on the ETCS OBU. An analysis of the system architecture demonstrates that the impact on the ETCS OBU is limited to changes in the ETCS non safety part and further analysis is required to investigate if any ETCS OBU impact can be avoided when migrating from GSM-R to FRMCS.

2 suppliers indicated that also potential upgrades of cyber-security requirements should be considered in the migration model in order to optimize the overall on-board migration and avoid separate on-board revision cycles for FRMCS and for upgraded cyber-security requirements.   The appropriate allocation of upgraded cyber-security requirements will be taken into account in the overall future CCS system architecture. In order to avoid multiple impacts on the ETCS safe part, it has to be investigated if upgraded cyber-security requirements can be introduced outside the ETCS application. This would provide more agility in case of future potential upgrades/patches in case new cyber-security risks have to be mitigated in future. Under this system architecture assumptions, the suppliers reported an overall ETCS OBU low (below 20 [kEUR/OBU]) or medium cost impact (below 100 [kEUR/OBU]).

A questionnaire has been distributed to analyse the impact and preferences of the different migration scenarios. These scenarios are: baseline scenario, option 1 and option 2.

In the *Baseline scenario*, the requirements in chapter 7 of the CCS TSI would imply to request for an updated ERTMS National Implementation Plan taking into account the potential introduction of the FRMCS radio system.   The questionnaire asked if such baseline scenario would be sufficient to enable a cost efficient FRMCS migration and GSM-R decommissioning taking into account that Infrastructure Managers have an interest to avoid a long period of providing dual GSM-R/FRMCS trackside radio services, while RUs prefer a long overlapping period to avoid significant retrofitting costs for existing vehicles. Most of the answers reported that such baseline scenario would not be optimal as there are limited generic migration practices at national level to handle network changes which impact existing vehicles. Examples have been reported related to migration issues linked to network changes which impact vehicle changes (e.g. issues related to introduction of interference resilient radios, issues related to maintaining analogue radio systems in parallel to GSM-R and other examples outside the radio domain).   The Agency has to analyse further the need for EU-actions and generic financing and migration principles in case of network changes which impact vehicle requirements.

Option 1 is to mandate in Chapter 7 of the CCS TSI revision of 2022, in addition to the baseline scenario (NIP update), a minimum retrofitting period to be respected for FRMCS-migration of existing vehicles (e.g. between 5 to 10 years). This minimum retrofitting period shall start after the notification of the FRMCS-implementation plan by the Infrastructure Manager and ends with the decommissioning of GSM-R network. both start of FRMCS deployment and end of GSM-R shall be included in the NIP. This would allow to protect existing ERTMS on-board investments and provide a smooth migration for a substantial part of the existing vehicles taking into account the natural renewal cycle of the existing ERTMS on-board products. Deviation from this requirement would be allowed if an agreement is made between all the impacted stakeholders (e.g. including potential use of financial compensation schemes via funding or discounts to track access charges) which would allow the introduction of a shorter retrofitting period if this optimizes the overall business case at railway sector level.

Option 2 is a scenario where EU includes in Chapter 7 of the CCS TSI revision of 2022, in addition to Option 1 (minimal retrofitting for on-board), harmonized dates for start of FRMCS deployment and for GSM-R decommissioning. Most respondents to the questionnaire indicated that there is no evidence and less urgency to set mandatory FRMCS implementation dates for upgraded or new vehicles in the CCS TSI revision of 2022 in particular without any return of experience of the availability for FRMCS-on-board products. Taking into account the different GSM-R trackside asset lifetimes across Member States, there is no evidence

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yet to mandate trackside FRMCS implementation dates. Some answers from the questionnaire reported to analyse the introduction of mandatory trackside FRMCS implementation dates at EU-level in correlation with the potentially available EU-funding for FRMCS-implementation.

Comparison of options and preferred option

Few stakeholders reported to prefer the baseline scenario and in those cases, these Member States reported to have an effective process to handle network changes taking into account the interests from all the impacted stakeholders with potentially associated financial compensation schemes between IM and impacted RUs. For these Member States, this scenario is in fact similar to option 1.

Based upon the responses to the questionnaire and the additional preliminary qualitative assessment, Option 1 is the preferred scenario, creating a predictable framework for both IMs (e.g. guaranteed maximum period for maintaining operation of multiple radio systems) and RUs (guaranteed minimum period given to RUs after the notification of the start of FRMCS-implementation, e.g. covered in NIP or in network statements). This option also provides sufficient flexibility in case a faster migration is envisaged by allowing compensation schemes to be established between IM and RUs. This preferred option aims to reflect the current best practices across Member States for network changes which impact existing vehicles.

The main risk of this preferred option 1 is linked to early FRMCS implementers which prefer to adopt a fast migration based on a voluntary agreement between IM and RUs. In option 1, these Member States/IMs could be negatively impacted compared to the baseline scenario as financial compensation must be given to both national and international impacted operators. The potential prioritization and use of EU-funding in these cases shall be further analysed.

Option 2 can be considered in a later stage after the first return of experiences of FRMCS-implementations (expected around 2025).

Further work on the analysis of the potential upgrades of cyber-security requirements and potential impact on the CCS-, and in particular the FRMCS-, system architecture part has to be considered including its impact on FRMCS-migration.

The Agency will also need to analyse if a generic strategic framework should be developed across the Interoperability Directive, Access Directive and EU-funding programmes in order to handle future network changes which impact vehicle requirements as this FRMCS-migration is only one example of balancing IM and RU-interests.