FUTURE RAILWAY MOBILE COMMUNICATION SYSTEMS

Tomorrow's advanced connectivity for rail starts today

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DIGITALIZATION OF RAILWAY

Digitalization is increasing in rail, as old mechanical systems are replaced by highly interconnected digital alternatives. Such systems will require high-bandwidth communications, service-oriented architectures, and safety-critical cloud infrastructure to reduce trackside infrastructure and allow rail operators to deliver innovative services in an agile manner.

Advanced connectivity is fundamental to the digitalization that will enable more sustainable and intelligent transportation. This advanced connectivity will enable the deployment of advanced analytics, Artificial Intelligence (AI), and Machine Learning (ML) that will underpin innovative solutions, services, and applications. This will deliver operational, performance, and business use cases.

An example of a service that is currently being deployed is the European Rail Traffic Management System (ERTMS), which requires data transfer between the train and the track as part of the European Train Control System (ETCS) and Automatic Train Operation (ATO). The data transfer is currently based on the Global System for Mobile Communications (GSM-R) which requires extensive network upgrades to include the packet data capability of GSM (GPRS - General Packet Radio Service). However, GSM-R is based on 2G technology that was developed three decades ago. GSM-R, despite being a successful technology for railway operation, has limitations.

Challenges of legacy connectivity technology

2nd generation technology:

GSM was developed some 30 years ago, and primarily aimed to provide circuit switched voice and low speed circuit switched data services. GSM was later enhanced to provide packet data capability (shared channel) through the introduction of GPRS, which was followed by the introduction of EGPRS (Enhanced GPRS) to increase the data rate.

Narrow data pipe:

GSM provides a very limited pipe for data communication of about 4-6 orders of magnitude less than the latest generations.

Approaching obsolescence:

The GSM-R suppliers have committed to support this system until 2030 and on a contract-basis thereafter, which would potentially make it more expensive to maintain.

Such limitations will not allow the deployment of more advanced levels of ETCS and ATO, nor the many other services essential to a fully digital railway. This requires the railway industry to replace GSM-R with a more advanced connectivity network.

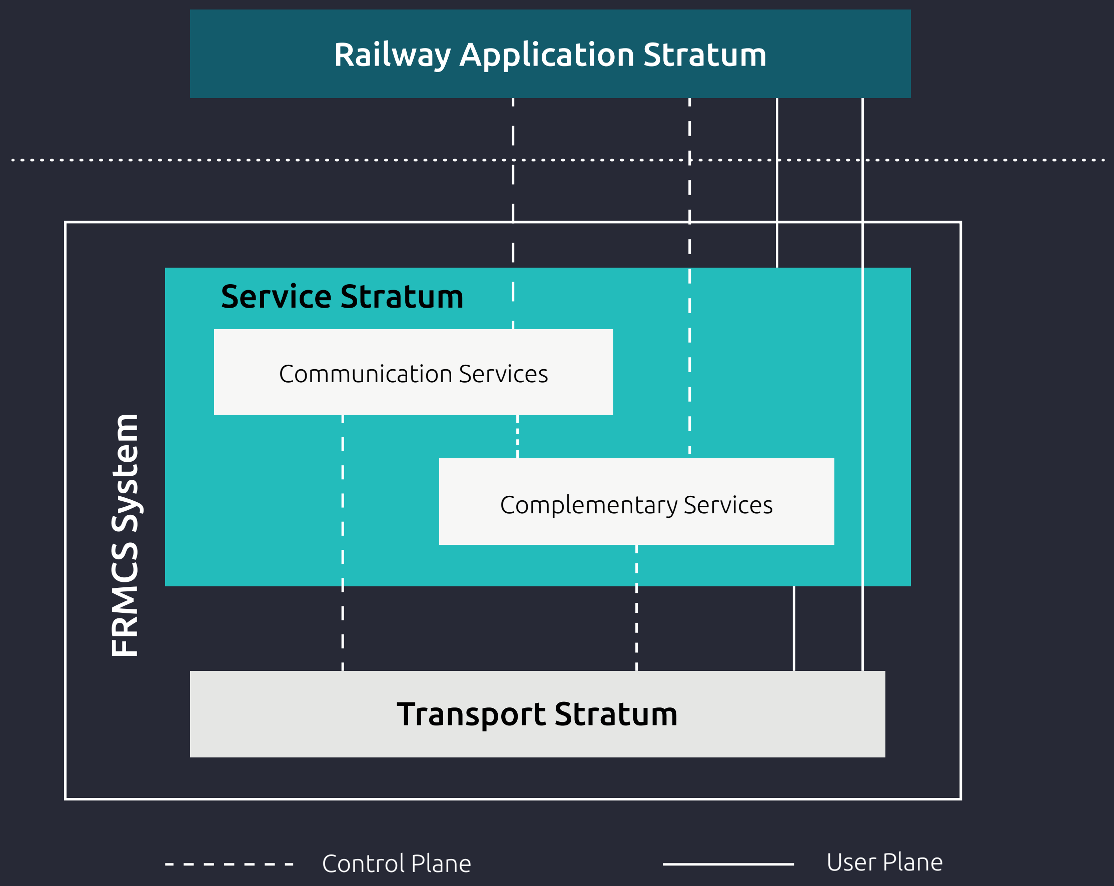
The railways are therefore looking to leapfrog straight to 5G under the Future Railway Mobile Communication System (FRMCS) standard.

WHAT IS FRMCS?

Designed by the International Union of Railways (UIC), FRMCS is being developed in close cooperation with stakeholders from the rail sector. FRMCS aims to become the worldwide standard, conforming to European regulations and responding to the needs and obligations of rail organisations outside of Europe.

FRMCS design is based on a clear separation between the railway application stratum, service stratum, and transport stratum. The FRMCS network architecture is designed to provide a software driven platform for the agile introduction of services. The transport stratum of the FRMCS system will be primarily based on 5G technology, whose network architecture is fundamentally redesigned to be open and accessible. It allows the creation, deployment, and upgrade of capabilities quickly, securely, and cost-effectively via cloud native and software driven network functions.

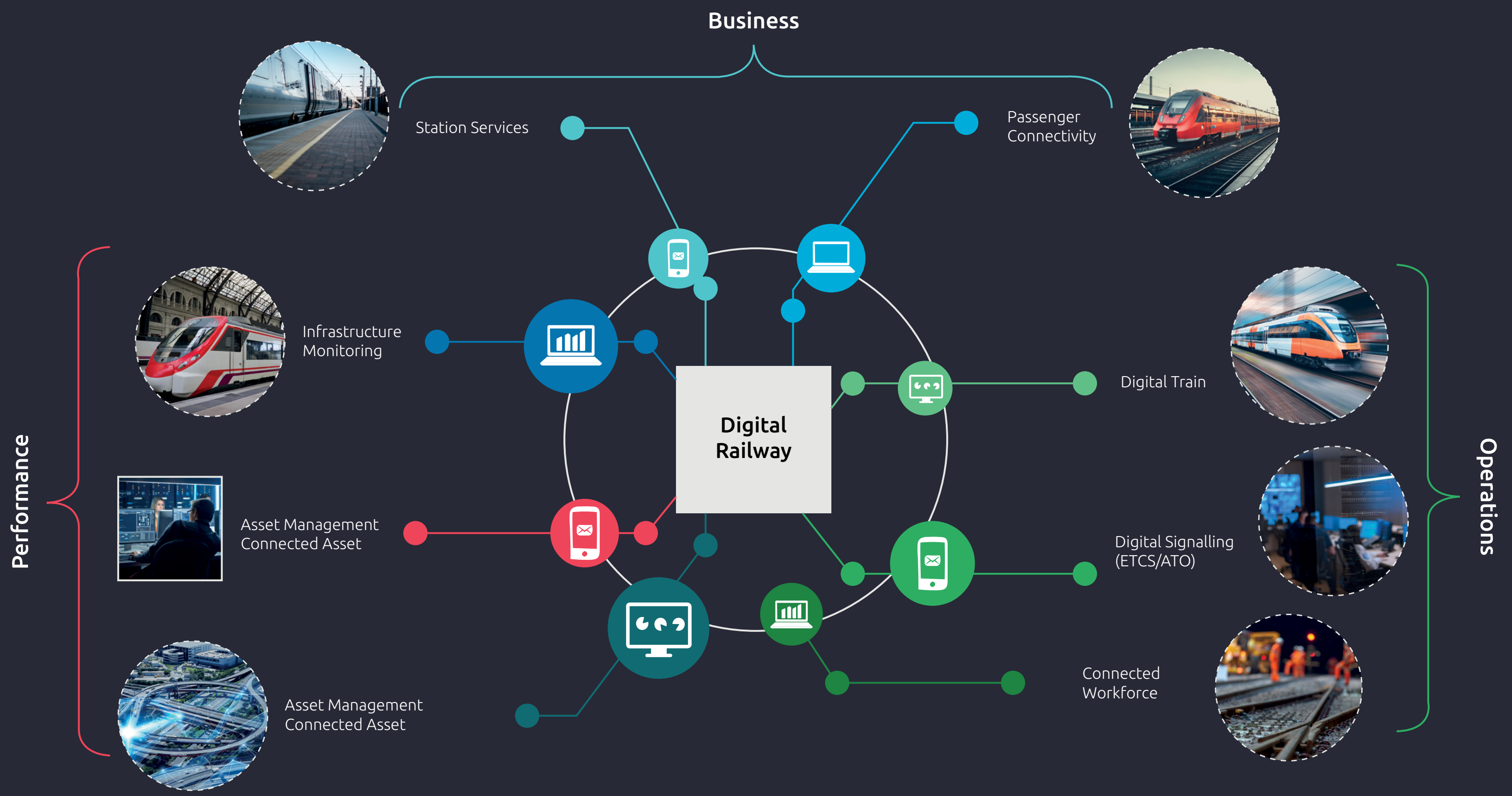
FRMCS provides advanced connectivity and a future-proof technology for railway digitalization that is targeted to replace GSM-R in the next 7-10 years. But it will be no easy task. The technological challenges are immense, including dual operation during the co-existence period, network type deployment – private or shared – and new security threats.



FRMCS Benefits

FRMCS will be instrumental in enabling the provision of services and applications that will benefit multiple stakeholders, including infrastructure managers (IMs), suppliers, freight customers, passengers, and ultimately the economy. FRMCS is critical in addressing future railway system elements of strategic importance, like trackside asset reduction to reduce cost by providing reliable, pervasive connectivity. Such benefits have already impacted other transport systems like aviation and roads, where more modern technologies provide more capable connectivity for various operational activities.

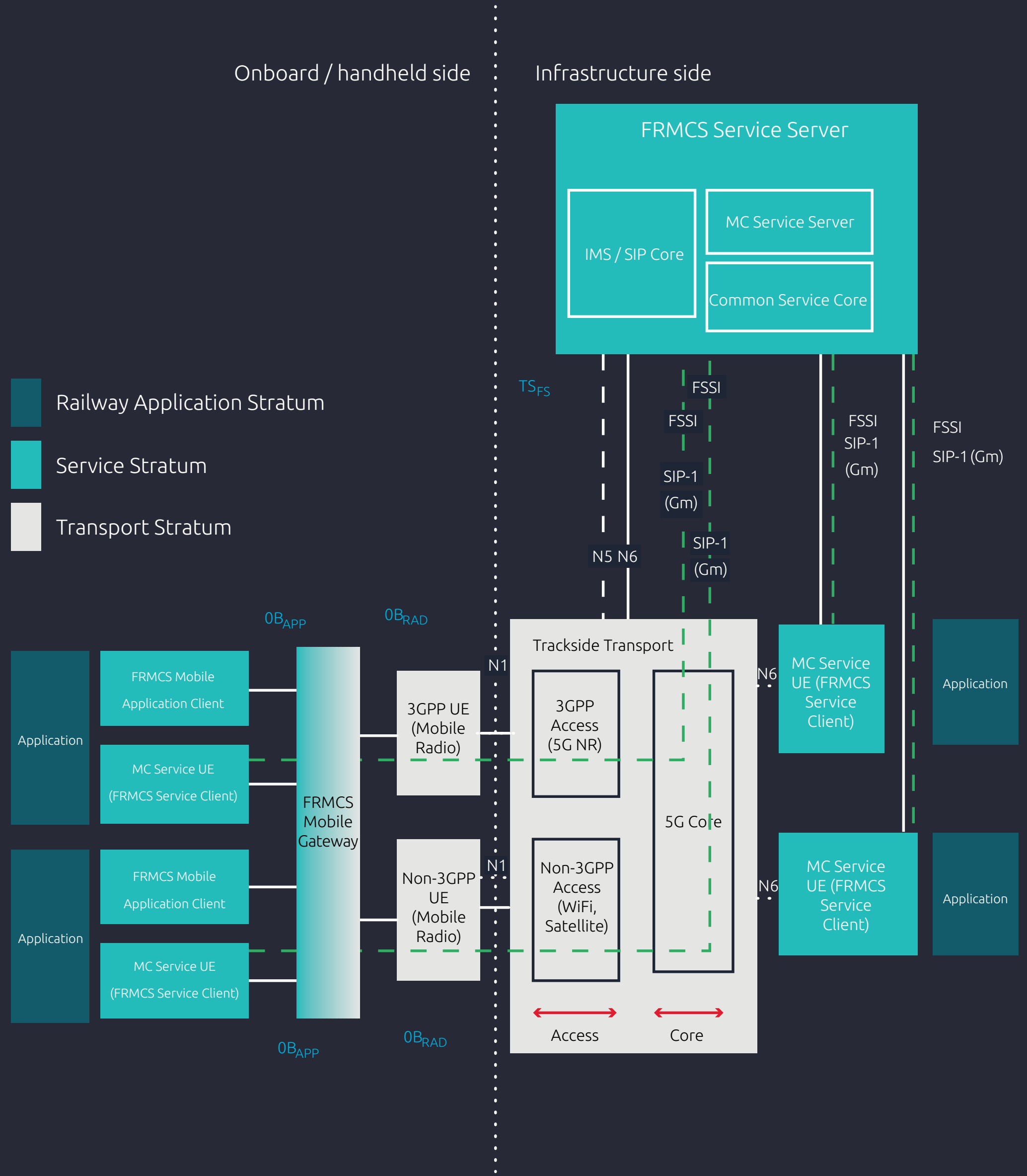
For railway IMs, FRMCS enables a scalable, future-proof infrastructure that will enable a host of use cases, like intelligent traffic management, intelligent infrastructure, automated shunting, and connected workers. The realisation of such use cases is crucial in the railway industry, because it is an intensive asset-based sector in which implementing modern communication technologies would make it more productive and drive down capital and operational costs.



WHAT ARE THE MAIN CHALLENGES OF FRMCS?

FRMCS is complex, just like systems in rail

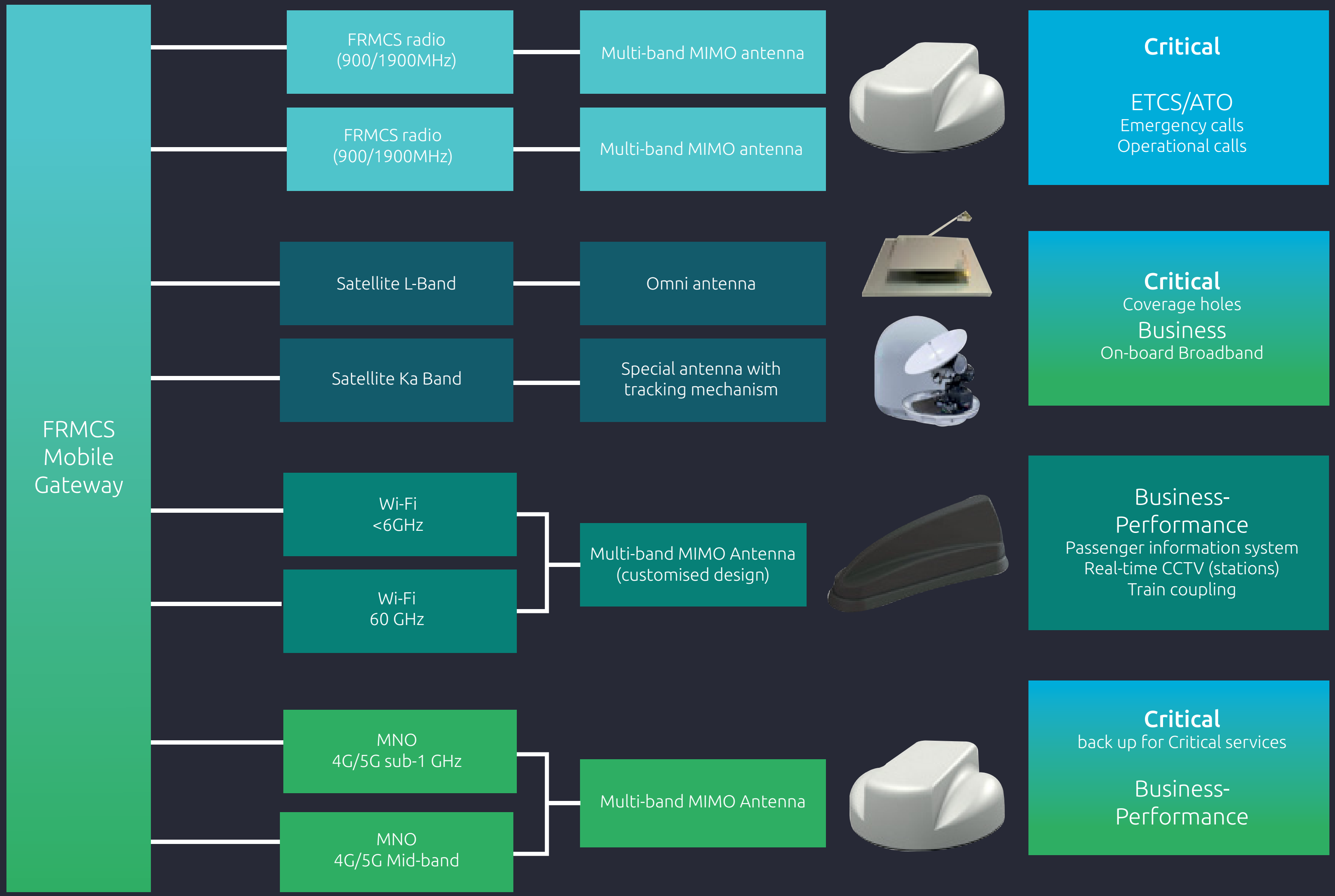
Railways are critical national infrastructure. They have complex systems to ensure the safe operation of trains and monitor the performance of the infrastructure. It is not easy to replace existing systems and/or introduce new systems and services. They take considerable time, because of extensive testing, verification, and stringent safety requirements. Additionally, the 5G transport stratum component of the FRMCS presents a range of technological challenges that are unique to 5G architecture. Despite the widespread deployment of 5G in public land mobile networks, many aspects of 5G remain untested. Moreover, FRMCS has its own features and functionalities, such as mission-critical services and bearer flexibility. The three most challenging FRMCS aspects are bearer flexibility, dual operation, and security, which share common overlapping challenges.



Bearer flexibility

FRMCS is being designed to be bearer flexible, which means that any technology, such as Wi-Fi and satellite, in addition to 5G, can be used as a data bearer. The challenge here is multi-fold, ranging from mapping use cases to suitable technologies, to determining what type of network – private, shared (different flavors), or infrastructure-as-a-service (IaaS) — the technologies should be mapped to. This is complex, however, it is very beneficial and will determine the end-to-end architecture options for each technology. Moreover, the onboard architecture and equipment arrangement are crucial to analyse, due to space constraints and EMC (electromagnetic compatibility).

An early understanding of the options, together with a cost-benefit analysis is crucial. This should include a more solid plan behind the GSM-R upgrade, engagement with suppliers and service providers, and a proof of concept. For example, an IaaS network deployment may be a more cost-effective option. The challenge, however, is the unproven nature of network slicing, which is one of the key innovative features of 5G, providing an independent logical channel over the same physical infrastructure - a more innovative network sharing mechanism. The challenge here is how safety critical use cases should be kept isolated and unaffected by other network slices.



Dual Operation

Based on our analysis, the most critical factors during the migration phase are the radio access network (RAN) deployment type, RAN design, and RAN planning, all of which are mainly governed by spectrum availability. Spectrum availability is the major challenge in the migration phase that should be addressed to create a firm network deployment upgrade strategy that can achieve the FRMCS target state.

The availability of the spectrum is tightly linked with the type of network mentioned earlier and the mapping of use cases to FRMCS technologies. The current 2x5.6 MHz FDD (Frequency Division Duplex) at 900 MHz used for GSM-R and the potential 10 MHz TDD (Time Division Duplex) at 1900 MHz earmarked for FRMCS, combined with unlicensed and shared access bands, pose a challenge in determining the optimal spectrum allocation during GSM-R coexistence and post-decommissioning. Once again, an early understanding of this will influence many aspects of the migration strategy.

	Site	Spectrum	Base Station	Transmission System	5G Core	NCX Core
Option NSD-1: Private	IM	IM	IM	IM	IM	IM
Option NSD-2: Dual	IM-MNO	IM / MNO	IM / MNO	IM / MNO	IM / MNO	IM
Option NSD-3: Hybrid ESN Core Sharing	IM	IM	IM	IM	IM-ESN	IM-ESN
Option NSD-4: Hybrid ESN CoreRAN Sharing	IM	IM / ESN / Shared	IM-ESN	IM-ESN	IM-ESN	IM-ESN
Option NSD-5: Hybrid MNO RAN Sharing	IM-MNO	IM / MNO / Shared	IM-MNO	IM-MNO	IM / MNO	IM
Option NSD-6: Hybrid MNO RAN Ownership	IM-MNO	Shared	MNO	IM-MNO	IM / MNO	IM
Option NSD-7: Hybrid MNO RANCore Ownership	IM-MNO	Shared	MNO	IM-MNO	MNO	IM
Option NSD-3: Full MNO Ownership	MNO	Shared	MNO	MNO	MNO	MNO

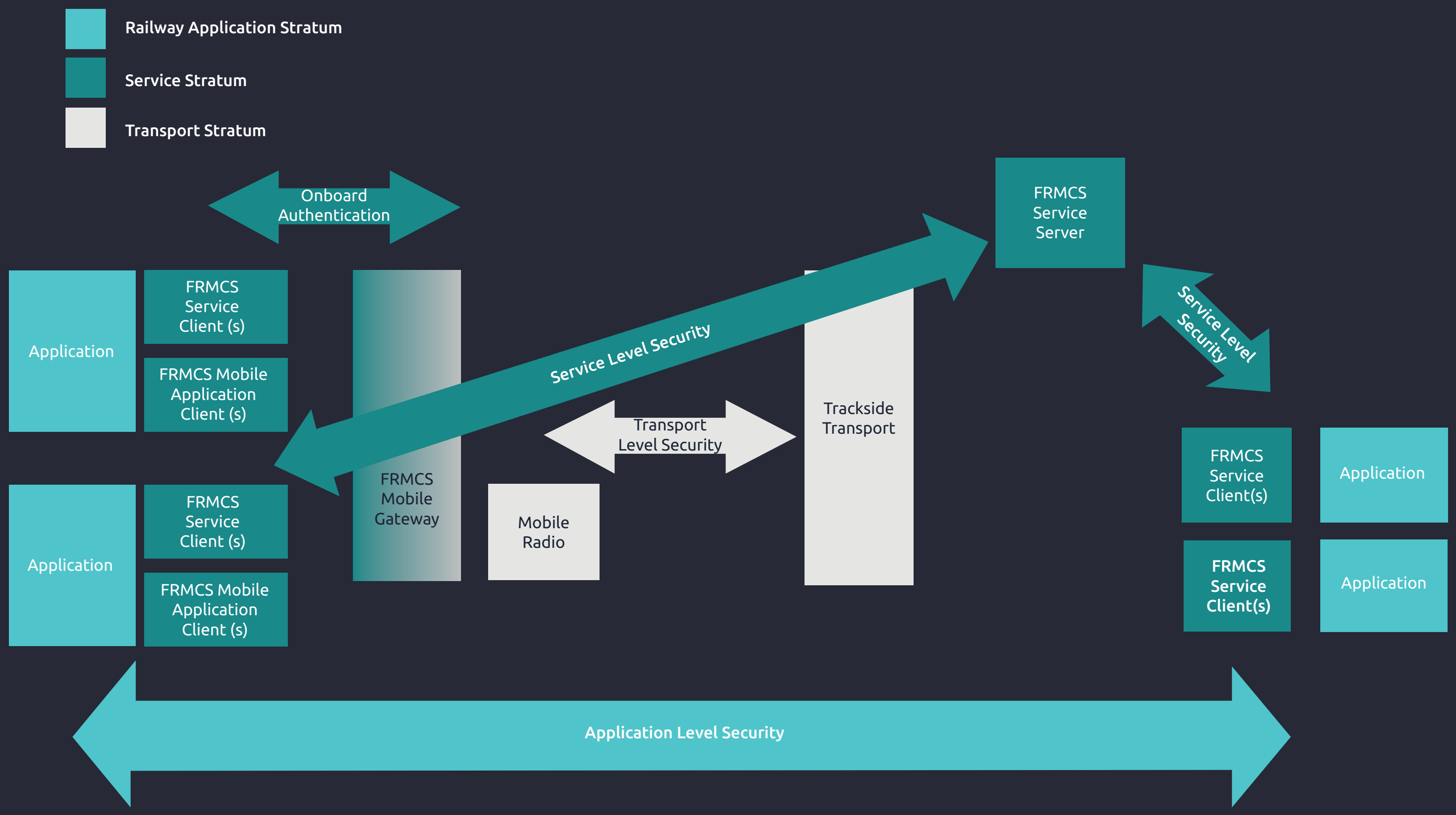
Security

Despite the huge technological benefits that FRMCS will bring, it introduces new security challenges that must be analysed and aligned with the minimum safety and security standards practised in the railway industry. It should continue to support the three safety-critical services that affect both safety and train performance, namely signalling, train detection, and driver-signaller voice communications.

There are specific security layers in different strata of the FRMCS system, with the major one being the transport stratum. The FRMCS transport stratum system security framework requirements are different from previous GSM-R standards, such as secure interaction between network functions and the prevention, detection, and response to software-based attacks.

The FRMCS system security framework by the UIC provides a high-level description of the security specifications and associated use cases to ensure security for end user devices. But the introduction of virtualization or cloudification in the transport stratum mainly around software-defined elements will increase the complexity for implementing governance, risk, and compliance.

There are challenging security threats during the GSM-R to FRMCS migration, depending on the chosen network deployment model, and FRMCS target architecture. It is especially crucial to analyse the security threats faced by the 5G based FRMCS network and controls. The focus should be on identifying the known security threats faced by 5G technology, together with threats to other components of networks that are part of the FRMCS architecture. Based on the threats, appropriate controls and standards can be determined and specified, which should consider the dual operation phase, FRMCS target architecture, as well as the chosen network deployment.



Source: ETSI TR 103459: FRMCS, study on system architecture, V1.21. August 2020

WHY NOW?

Time is short

It is of paramount importance that GSM-R operations remain unaffected while FRMCS is gradually rolled out and must interoperate with GSM-R seamlessly. So, despite a seemingly large time window of 7-10 years, IMs should act now to establish a cohesive approach to enable the identification of the building blocks, their interrelationships, and how they should plan for implementation.

As the FRMCS standards evolve, early clarity is needed on how to design, deploy, and manage such an advanced system, in harmony with GSM-R, within tight budgets and timeframes - all whilst meeting a substantial (and growing) number of use cases.

Early deployment is essential to driving the cost down

Despite the promise of the suppliers to support GSM-R until 2030 and beyond on a contract basis, the early deployment of FRMCS will be a critical factor in reducing the cost of operating railways. This is primarily due to GSM-R reaching obsolescence and the shortage of skilled workers to maintain the system, which will pose ever-increasing challenges over time.

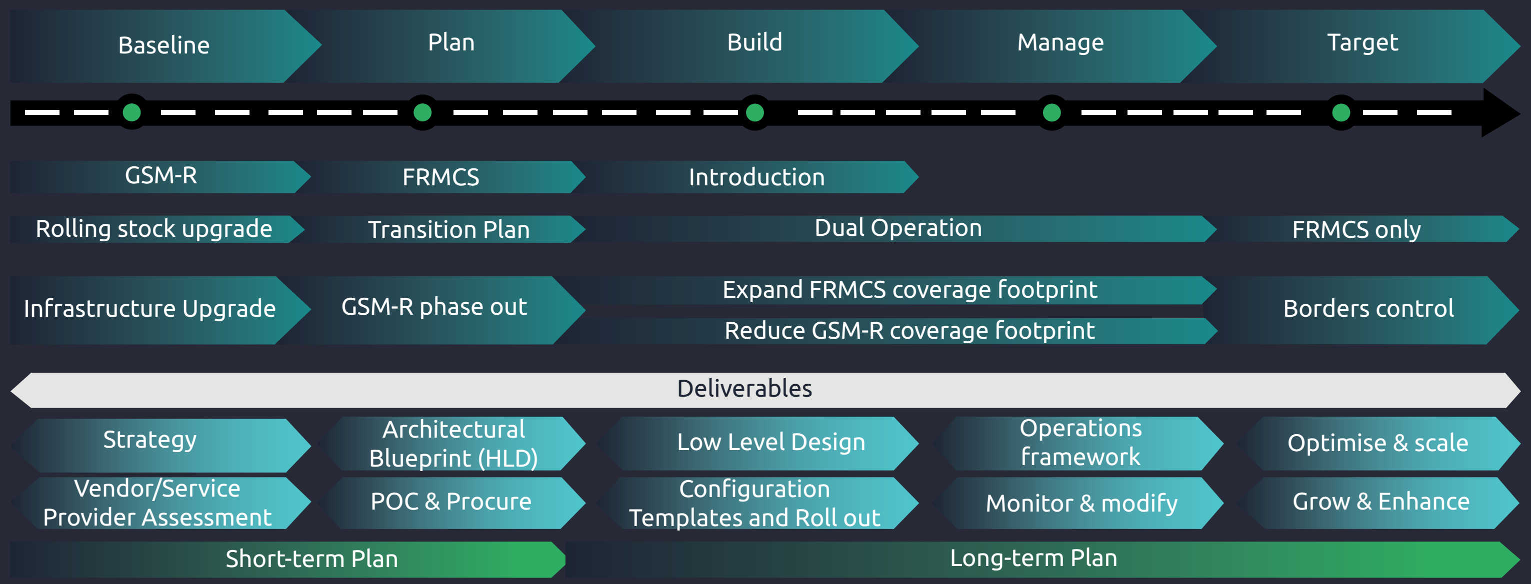
Lowering the cost of operating railways is critical to the economy and ensuring sustainability, by making rail travel affordable to the general public. As an example, Network Rail in the UK, under the programme known as Target190Plus has established numerous projects to bring down the cost of a signalling equipment unit by around 50%. A key project under this programme is Future Communications, which is looking into various aspects of modernising Network Rail's telecommunications infrastructure, which is a critical enabler for various signalling system upgrades and renewals. Under this project, our analysis of several R&D studies for Network Rail has revealed the underlying challenges and how they should be addressed, thereby paving the way for an early deployment of FRMCS through a structured approach in the next few years.

WHAT TO DO NOW?

A detailed migration strategy is key

It is crucial to have a short (e.g.,5-year) and a long (e.g.,10–15-year) plan now. This can only be accomplished by a thorough investigation of the challenges involved in developing a solid and comprehensive migration strategy. The migration strategy should contain the key technical, operational, business, and commercial elements that will be impacted, along with an integrated plan detailing how they should be addressed during various phases. In our analysis, there are a multitude of parallel, overlapping, and sequential activities that determine the building blocks of short and long-term plans. Such activities include spectrum analysis, RAN dimensioning, network sharing analysis, security threat and counter-measures analysis, and a network slicing proof of concept.

In addition, IMs, suppliers, and service providers must understand the changes required to plan the transition from GSM-R to FRMCS in a coordinated, timely fashion, both to the infrastructure (trackside) and rolling stock (onboard). Indeed, all stakeholders must work together to bring this fruition, agreeing on the key activities and deployment phases of the FRMCS.



GSM-R upgrade harmonisation with FRMCS infrastructure vision

The critical stage of the migration is the roll-out of the FRMCS and most importantly how smoothly it can be carried out to optimise the deployment cost. To that end, the migration strategy work items should be aligned, for example, with the ETCS deployment plan and other activities related to the GSM-R upgrade plan.

The on-going GSM-R upgrades should consider the FRMCS requirements, especially at the RAN level, and the transmission network. For example, to ensure full utilisation of 5G features such as smart antennas, existing GSM-R sites may have to be upgraded, e.g., a pole structure may have to be replaced with a lattice structure. In addition, suppliers' product roadmaps, especially their GSM-R upgrade programmes and how they overlap with their FRMCS strategies, play a crucial role in the readiness of both the infrastructure (trackside) and rolling stock (on-board).

CONCLUSION

While building an FRMCS network is a significant undertaking, it provides numerous transformative benefits towards railway digitalization. There are also significant opportunity costs of pushing forward; FRMCS will allow early adopters to differentiate their services and eliminate the huge cost of maintaining a GSM-R network.

We emphasise the importance of developing a clear migration strategy now, which investigates key elements to address the challenges and develop a clear business and architecture plan. This should be followed with early testing and trials. Based on our analysis, we have highlighted some of the key challenges and what should be done now to address them. There are other aspects, such as standardisation and supplier development plans, that should be equally considered in the migration strategy to collectively pave the way towards a graceful migration to FRMCS.

Finally, FRMCS should not be seen as GSM-R, but instead as a technological lever that will help usher in a data-driven transformation that changes how railway operators interact and do business. This will result in a multitude of services, leading to improved operational efficiency, performance improvement, and business-oriented value-added services.

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Davood Molkdar is a telecommunications executive with over 34 years of technical, managerial, and commercial experience. He has expertise in a broad range of telecommunication technologies, and spectrum management.

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Glossary

ATO	Automatic Train Operation
ESN	Emergency Services Network
ETCS	European Train Control System
GPRS	General Packet Radio Services
GSM-R	Global Systems for Mobile communication – Railway version GSM is a 2G system
IaaS	Infrastructure as a Service
IM	Infrastructure Manager
MIMO	Multiple Inputs Multiple Outputs
MNO	Mobile Network Operator
NSD	Network Sharing Deployment

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