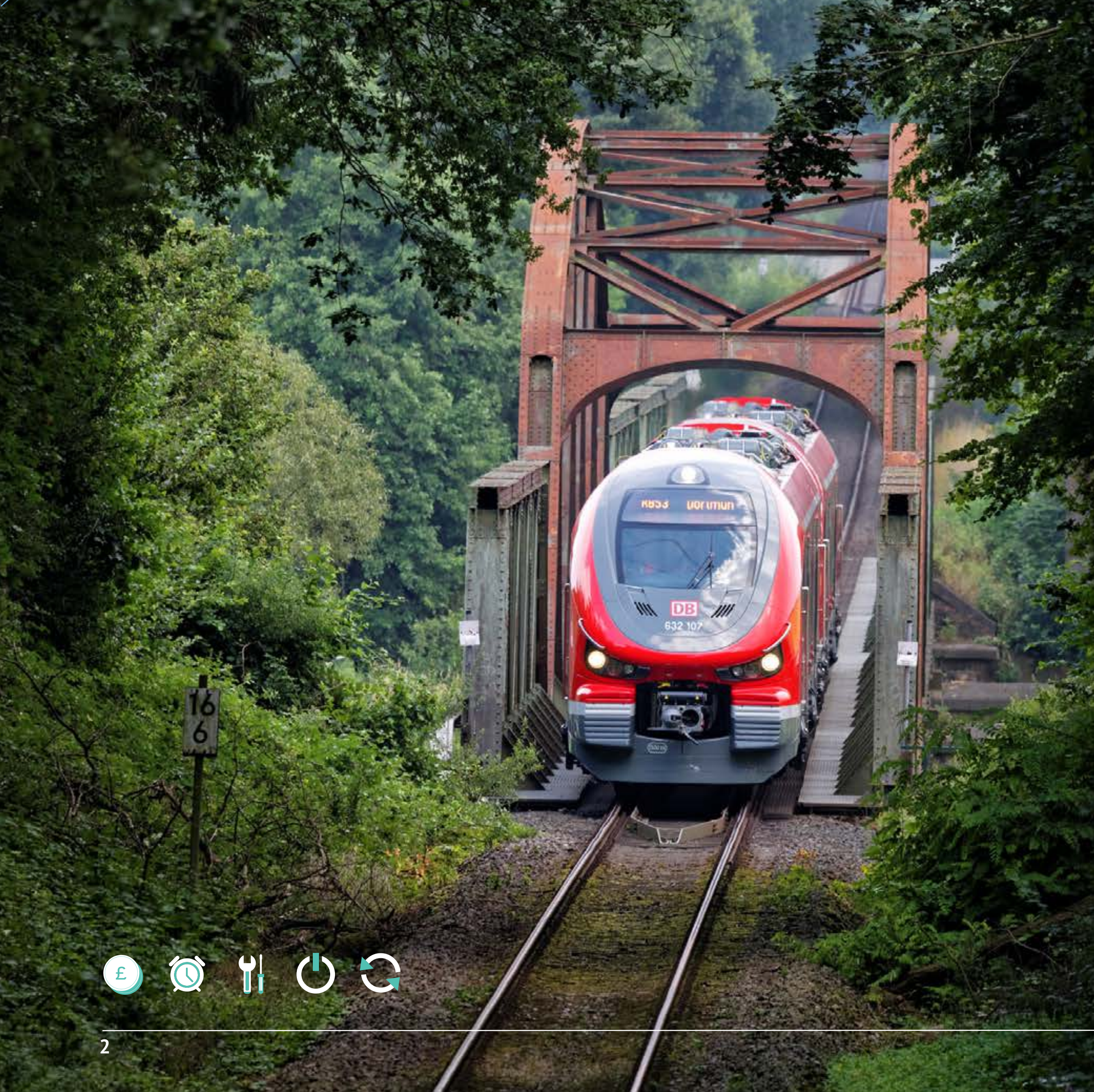
Overcoming the barriers to FRMCS adoption

The **Future Railway Mobile Communication System** has the potential to serve as a comprehensive enabler for the digitalisation of the railway sector, but its widespread adoption and rapid deployment across the industry are far from assured. This White Paper explores the challenges ahead and seeks to assess how far they can be overcome.



Introduction

The Future Railway Mobile Communication System, or FRMCS, has the potential to serve as a comprehensive enabler for the digitalisation of the railway sector, which in turn holds the key to unlocking many of the efficiency and reliability gains which policymakers are asking railways to deliver. Yet it is clear that in an era of macroeconomic instability and ongoing uncertainty related to war and pandemic, rail operators and infrastructure managers face a daunting challenge in balancing competing investment needs.

Understandably, when governments and transport authorities are asking railways to deliver tangible improvements in the next few years rather than decades, it is not surprising that spending on asset enhancement, infrastructure renewals, rolling stock and signalling systems may seem a higher priority than next-generation communications. Set against that, though, is the reality that current rail telecoms platforms are either already obsolete or facing obsolescence in the next few years, as is the case for the widely-adopted GSM-R.

In addition, many of the 'game changer' advances which the rail sector has identified through research and innovation programmes like Shift2Rail and Europe's Rail will be dependent on high-capacity communications to enable them to function. It is far from certain that existing bearer networks, which typically use 2G-era telecoms technology, will have the capability to support functions such as train automation, real-time video monitoring of infrastructure, or entertainment streaming for passengers.

Nevertheless, these arguments have not so far proved universally compelling; a number of railways and infrastructure managers suggest that as yet the case for migrating to FRMCS has not been made. That reticence makes the early technology trials now underway across Europe – either through Europe's Rail or more particularly as part of the *Digitale Schiene Deutschland* initiative in Germany – all the more important. Can the industry demonstrate as a matter of urgency that FRMCS is on a clear, viable path to technological maturity and affordability?

Photo: Deutsche Bahn

The story so far

'There are two main drivers behind the strategic decision to adopt FRMCS', explains Karsten Oberle, Head of the Rail Transportation Segment at Nokia. 'The first is the overarching trend in the rail sector to push for digitalisation. The second is that the 2G technology behind GSM-R simply won't be supported in any industry for much longer beyond what has been agreed by the industry. There certainly won't be any further investment into 2G platforms by the vendors, even though the rail operators will still need to invest into maintenance of GSM-R systems until FRMCS is deployed in a couple of years from now.'

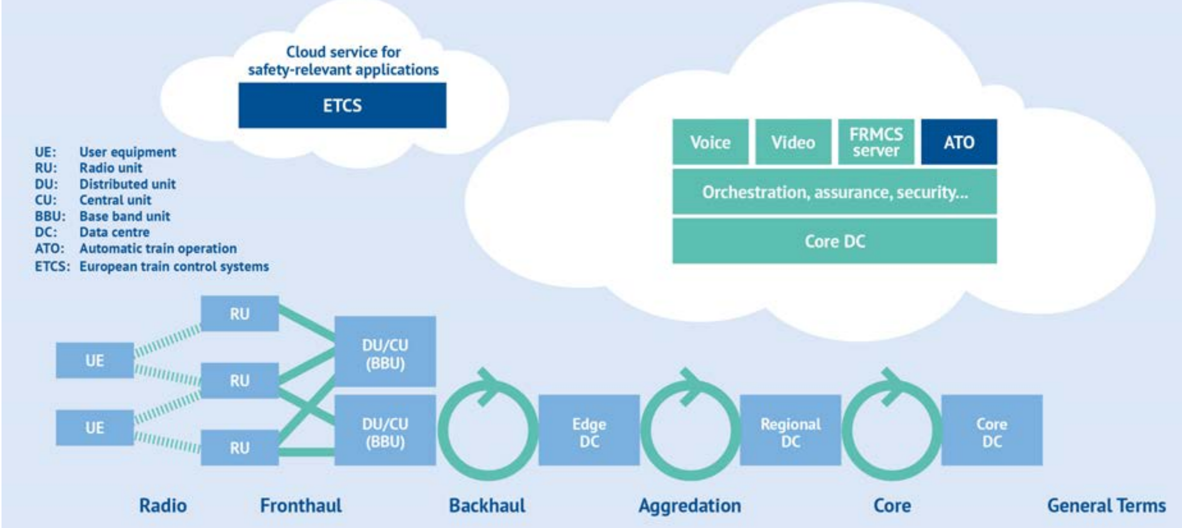
Development of FRMCS is being co-ordinated by the International Union of Railways. UIC has been drawing up plans for the next-generation platform for several years, recognising that the requirements of digital railway operations have steadily grown in importance. That said, the current telecoms technology, primarily the GSM-R mobile standard, is capable of delivering many of the core tasks required by train operators and infrastructure managers today, leading some to query the need to push for a radical shift in functionality.

The roll-out of GSM-R as a secure, operationally flexible ground-to-train communications medium using 2G mobile telecoms protocols has broadly mirrored the emergence of the European Rail Traffic Management System since 1997. Over the past 20 years, ERTMS has been deployed on numerous routes, first in Europe and then increasingly globally. GSM-R provides the communications link which supports the train control and signalling element, ETCS, although it is also used to handle a variety of other voice and data functions. Today GSM-R is deployed on around 150 000 km of railway in Europe and a further 100 000 km worldwide. GSM-R is the critical bearer underpinning ETCS Level 2, which displays movement authorities to the driver via an onboard unit rather than traditional lineside signals and can facilitate operation at shorter headways.

Rail operators will still need to invest in maintenance of GSM-R systems until FRMCS is deployed in a couple of years from now

Karsten Oberle, Head of the Rail Transportation Segment, Nokia

Reference generic architecture



Source: Nokia / DB Netze

The history of GSM-R should offer a template for the successful roll-out of FRMCS. But there is a catch: while GSM-R has been widely adopted, ERTMS deployment has not kept pace, at least in Europe where it was intended to facilitate an interoperable pan-European rail network. In 2022, that goal is still years from fruition, and policymakers are increasingly keen to ensure the pace of deployment picks up. But rolling out ERTMS across the core network in every European country will clearly come at a cost of many billions of euros.

While some nations, like Italy, have already made significant progress and have a clear plan to move from legacy signalling to an ETCS-controlled network, eliminating redundant train control equipment as quickly as possible, others, such as the UK and France, are more hesitant. Speaking in June 2022, SNCF Réseau's Europe Director Dariush Kowsar put the overall cost of a national ERTMS roll-out in France at €40bn.

What does this mean for FRMCS? Quite simply, it is fighting for the same funding. Indeed, senior representatives of RFI told the Smart Rail Europe conference in Rome in June 2022 that the Italian infrastructure manager had no intention of adopting FRMCS in the foreseeable future, citing unclear costs and a lack of technological maturity.

Is FRMCS affordable?

According to estimates by UIC, global investment in FRMCS could ultimately total €50bn. Yet this single figure almost certainly oversimplifies what will be an extremely lengthy and complex migration from legacy systems, region by region. The nature of this migration is likely to vary by geography – and perhaps the most significant distinction will be between Europe and the rest of the world. In Europe, the core focus must be on managing the transition from GSM-R to FRMCS in a harmonised, interoperable way, in line with the EU policymakers' goal of developing a Single European Railway Area. As we have already seen, there will be pressure to ensure the emergence of FRMCS does not hinder the already staccato implementation of ERTMS.

Outside Europe though, major rail markets such as India or Australia have more flexibility and arguably a greater need to upgrade their telecoms. Many routes are still dependent on traditional telephone working or simple 'dark territory' operating practices, where there is no voice or data connectivity at all. However, their need to move quickly poses a potential challenge to the economics of FRMCS; the European rail industry supplier association UNIFE has voiced concerns that this could lead to a two-speed rail telecoms migration, where some emerging markets opt to deploy an intermediate 4G technology as they lose patience with Europeans finalising the standards for a 5G platform.

'Considering the market situation outside Europe, and in some countries in eastern Europe, where the step from analogue radio systems to a digital GSM-R network was not done yet or only partially, a demand for introducing FRMCS in the short-term is vital', UNIFE argued in a position paper published in September 2021. 'Already today deployments or at least plans for early deployment in countries like Korea, Australia, India and Russia before 2025 are under consideration. This results in risk of segmentation of the market as well as the technology because such early adopters will most likely go for 4G rather than 5G technology as a basis for their railway communication networks. A discrepancy to FRMCS, which is targeted for 5G technology, will therefore arise.'

In terms of the cost of rolling out 5G-based systems, spectrum will be a major factor, although UIC reports that several hurdles have already been overcome. The first big win has been the gradual acceptance by 3GPP, the global telecoms standards organisation body, that the rail industry has sufficient use cases for 5G to justify the acceptance of FRMCS as part of the wider 5G release programme.

The second win is spectrum access, initially in Europe. The first requests to the various spectrum management authorities relating to FRMCS were made in 2017. At that time, there was a consensus that the likely outcome would be that the sector would receive only that same share of the spectrum already used for GSM-R, which is 4 MHz within the 900 MHz band. Following three years of intense lobbying by UIC and the GSM-R suppliers, the European Conference of Postal & Telecommunications Administrators ultimately agreed in November 2020 to allocate dedicated frequencies in both the 900 MHz and 1 900 MHz bands for railway use in Europe.

However, there are caveats. According to UNIFE, the harmonised spectrum now available to railways 'remains relatively small and may not be sufficient

Barrier 1

Funding

Global investment in FRMCS could ultimately total €50bn, which will be challenging for the sector to fund given competing investment needs, including ERTMS deployment, and the post-pandemic pressure on public funding in many countries.

Currently we have slow wifi or even no data connection at all

With FRMCS we'll have rapid onboard access to web and data

	Phase 1 2021-2023	Phase 2 2023-2025	Phase 3 2025-2028	Phase 4 2028+
	5GRail, Demos and PoC	5GRail, Demos and PoC	5GRail, Demos and PoC	General deployment, coexistence and migration projects
Functionality Focus	Limited	Reduced	BasicUse case: Critical voice, ETCS, ATO, TCMS, Broadband data application, GSM-R Interworking	Aligned with requirments and use cases defined in URS; IoT, Virtual Coupling, Shunting ATO GoA3/4 depending on ATO specification
3GPP	3GPP Rel 15/16 MCPTT, MCData (IPconn)	3GPP Rel 16/17 MCPTT, MCData (IPconn)	3GPP Rel 17 MCX over 5GS MCVideo for rail	3GPP Rel 18+ MCX Interconnect, Gateway UE MCX, %G Off Net
System Architecture	5G and MCX, TOBA	5G and MCX/FRMCS, TOBA Cross Border support	5G, FRMCS	Satellite, WiFi, Enhanced wireline, Off Net, Multi Cast
Deployment options	5G SA FRMCS prototype	5G SA FRMCS Precommercial	Reliability, 5NR functionability for coverage	Enhanced reliability and coverage functionality

Source: UNIFE

on its own for all the operational and business applications envisioned by railways in the FRMCS User Requirements Specifications'. This, it believes, may lead to constraints around the development of the onboard architecture for FRMCS and its associated rooftop antenna setup.

A further essential question to be answered as the migration gathers pace is how far existing telecoms infrastructure could be redeployed for 5G, and where new masts or base stations are needed, how cost effectively they can be installed, and who pays for this? The hope is that in many cases base stations and other legacy fixed assets from GSM-R could be reused, although this will depend heavily on the specific geography of a given railway network.

From its inception, the FRMCS concept has been influenced by developments in other industries, and in particular the mission-critical communication systems being specified by 3GPP. This was initially driven by the emergency service, security and disaster relief community, which needed to define a broadband-capable successor system for its TETRA or analogue communications systems. According to UNIFE, 'most benefits arise when synergies in products, markets and standardisation with other industries can be utilised – 3GPP 5G with the dedicated support for railway industry requirements as well as for mission critical communication provides this framework.'

Timescales

It is already clear that the mass roll-out of FRMCS across many differing geographies will be a phased process that will take at least 10-15 years, perhaps longer. However, the risk of GSM-R obsolescence and the resulting pressure from the telecoms industry means that UIC is keen to start deployment as soon as is practically possible, which it sees as 2025-26. If the sector is to achieve this, an initial set of FRMCS specifications will realistically have to be included in ERA's current revision of the Control Command & Signalling TSI, which is due for completion by the end of 2022. However, reports from Brussels suggest that at the time of writing, the formal inclusion of FRMCS in the CCS TSI revision is not yet assured.

A Version 1 of the FRMCS specifications would cover functionality for interoperability. But for these to be ready, some initial prototypes of the FRMCS ecosystem, both trackside infrastructure and onboard equipment, need to be deployed now. This work is being led through the 5G Rail partnership, supported by DG Connect, the European Commission's telecoms and digital services directorate. The initial test results would then underpin a further update to the specifications in preparation for formal European trials based on upgraded 5G equipment; these would take place around 2024.

Launched in November 2020 with a budget of €13·3m, the 5G Rail research project runs for 30 months. A key area of focus for the project partners is

Barrier 2

Timescales

The mass roll-out of FRMCS across many differing geographies will be a phased process that will take at least 10-15 years. Pressure is mounting to finalise the technical specifications so that the adoption process can begin soon.

Barrier 3

Installation

Railways and telecoms providers must assess how best to install FRMCS infrastructure, both fixed and onboard. How far will infrastructure managers seek to develop their own private networks, and to what extent can existing assets used for GSM-R and other legacy systems be redeployed?

the onboard equipment, where the aim is to reduce specific equipment costs and installation engineering time by combining all train-to-ground communications in a single onboard architecture based on standardised interfaces and including mainstream 5G components. This is known as Telecoms Onboard Architecture, or TOBA.

Overall, 5G Rail is divided into eight Work Packages, six of which will focus on research and development, testing, field implementation and evaluation, and two on co-ordination of the research and dissemination of the findings. A range of prototypes will be tested in simulated and real environments, with both laboratory pilots and field tests in various European countries, including France, Hungary and Germany. The 5G Rail consortium anticipates that these trials will ensure compliance with and validation of the FRMCS Version 1 specifications, and also contribute to realising a viable time to market for FRMCS products from the end of 2025.

German trials

However, 5G Rail is not the only initiative driving tangible trials of FRMCS in the real world. As part of Germany's national *Digitale Schiene Deutschland* programme, Nokia and Kontron are working together to build a 5G-based communication network in the Erzgebirge mountains. Infrastructure manager DB Netz is providing the testing zone, and facilitating infrastructure access. Eight radio sites are to be developed along a 10 km section of railway, featuring masts and optical fibre connections, while the main server infrastructure will be located at Scheibenberg station.

Installation of the FRMCS equipment started at the end of 2021. It has now been upgraded to a functional standalone 5G network and integrated with the MCx components. On February 23, the first Mission-Critical Push-to-Talk call was completed over the cellular network, which the partners considered a significant milestone. This basic functionality demonstrated successful integration of the different components of an FRMCS platform, paving the way for testing in a live railway environment for the first time.

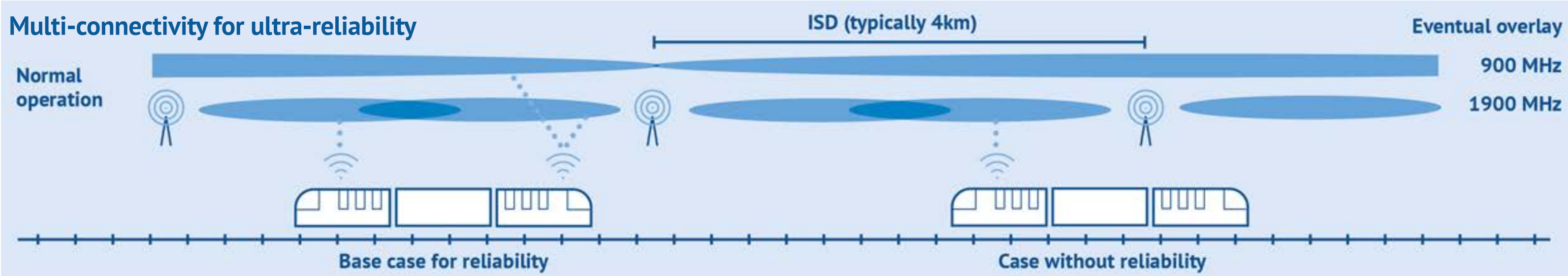
Looking ahead, the FRMCS test platform is to be expanded both geographically and technically. More antenna locations are to be established, and further components integrated, including the onboard equipment for rolling stock. Expanding the functionality of the existing test network will give the programme partners scope to trial more ambitious use cases. This is likely to include so-called hybrid network architectures, in which a public mobile telecoms network serves as a fallback layer or as a capacity complement to the railway's dedicated cellular network.

Deutsche Bahn has plans to develop its own private FRMCS infrastructure as part of DSD. However, it recognises that this may have to be complemented by the use of public networks, either as a fall back or to provide additional capacity. In a joint project, Vodafone and DB Netz have assessed the benefits of a hybrid FRMCS network architecture, offering redundancy in case the railway's own 5G network is not available. The partners suggest that a hybrid approach also offers possibilities for utilising both 5G networks in parallel to increase network capacity for non-critical rail applications.

The Erzgebirge FRMCS zone is intended to form the basis for further trials of automated main line operation, supported by workstreams from the pan-industry Europe's Rail research initiative. These are expected to include the

FRMCS will require a high degree of collaboration across industry, and perhaps to a greater extent than existed with GSM-R 20 years ago

Ian Maxwell, Head of Train Control Systems, ORR



Source: Nokia / DB Netze

Nokia and DB Netze have been working under the Digitale Schiene Deutschland programme to develop a highly reliable, resilient and redundant architecture for FRMCS deployment aimed at long-distance rail corridors

evaluation of ETCS Level 3 Hybrid Moving Block, which would use virtual blocks to permit a further reduction of headways on existing lines.

The need for knowledge

While welcome progress is being made on prototyping elements of FRMCS and launching field trials, it is clear that more buy-in will be needed across the rail sector, initially in Europe and then globally, for the technology to be firstly adopted and then exploited to its full potential. Leaving aside the question of the TSI CCS revision, outstanding questions remain in a number of areas. One of the biggest is the question of how far individual railways or infrastructure managers will seek to develop their own private 5G networks, as DB has said it intends to do.

Clearly, this would not be a straightforward or cheap option – even for major railways. We know this from the legacy of GSM-R, which is still only partially installed on the French network following a complex set of PPP deals involving public mobile network operators to extend coverage to more routes. The concept of network slicing offered by FRMCS means that the use of public telecoms networks for railway applications is going to become a more viable option in the future; this has already been cited by some in the rail sector as a major benefit of the migration from GSM-R. But UIC is cautious, noting that 'the current business model of mobile operators, whose strategy is predominantly focused on selling telecoms services to individuals, is nowhere near being able to offer the quality of service needed for critical railway communications'.

Assuming a viable business model can be reached over network access, railways and infrastructure managers will then face the task of implementation. It seems likely, although not inevitable, that the largely successful template of GSM-R roll-out since the late 1990s might be repeated again in many countries. Ian Maxwell, Head of Train Control Systems at UK rail regulator ORR, told *Railway Gazette* last year that the technical skills held by the infrastructure managers in markets with a high degree of vertical separation mean that they will take the lead in FRMCS deployment.

But this raises other potential hurdles and unanswered questions. 'FRMCS will require a high degree of collaboration across industry, and perhaps to a greater extent than existed with GSM-R 20 years ago', Maxwell suggested. 'Who is responsible for fitting out the trains? Will an infrastructure manager really lead that process? How could it be aligned with train maintenance cycles, and what will the role of a train manufacturer holding a whole-life maintenance contract be?'

The technology choice

The doubts over the commercial readiness of public telecoms companies to deploy 5G, the potential cost to infrastructure managers to develop their own private networks, and questions about the scale of coverage away from urban areas all mean that 5G itself, while serving as the backbone for FRMCS, is not the only 'game changer' available to help boost digital railway connectivity. Satellite and aerospace technology in particular is emerging as a possible candidate for train location and detection applications, especially in rural areas.

RFI has been an early leader in exploring these options, which could partly explain the organisation's reticence to embrace FRMCS as currently envisaged. The pan-European ERSAT programme is aimed at integrating satellite technologies into railway applications, and more specifically into ERTMS, and Italy is the first country in Europe to start the process of certifying satellite technologies for use with ETCS. The use of satellite networks rather than cellular telecoms to support communications between the train and the Radio Block Centre for ETCS operation is covered within the emerging FRMCS specification, and formed part of the ERSAT trials that have taken place over recent years in southern Italy, rural Spain and elsewhere.

Meanwhile, other R&D initiatives are underway in this field, including in the UK, where the Satellites for Digitalisation of Railways project has been

Barrier 4

The technology choice

While 5G telecoms will clearly have a key role underpinning the digitalisation of rail, other data transfer and geolocalisation technology is emerging, including satellite and train-to-train communications. Maintaining interoperability in an FRMCS world without stymying technological innovation remains a major hurdle.

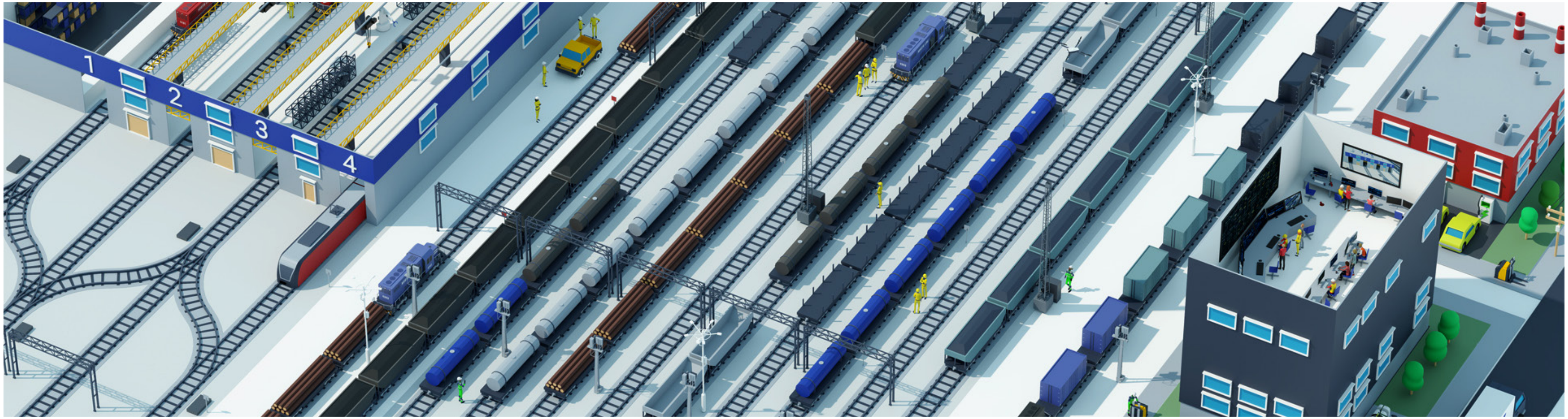


Image: Nokia

launched under an agreement with the Department for Digital, Culture, Media & Sport, the UK Space Agency and the European Space Agency. SODOR is intended to demonstrate how constellations of communication satellites could be combined with terrestrial telecoms networks to provide passengers and train operators with better onboard connectivity, including in stations and tunnels. It forms part of a wider British initiative to demonstrate the use of 5G for transport and logistics applications.

In a separate trial, potential uses of very precise train location data are being assessed from a trial installation of Thales' Robust Train Positioning System on a Great Western Railway diesel multiple-unit. RTPS combines data from satellite positioning systems, inertial and radar velocity sensors and a digital track map to locate the DMU with a high degree of precession without the need for lineside equipment.

Outside Europe, similar initiatives are underway. A very recent example comes from South Korea, where the Korea Railroad Research Institute has successfully tested train-to-train data communications over distances of 2 km in the open air and 4 km in tunnels. The communications use a directional antenna developed by KRRI, which said it was the first successful test over such distances. A nine-year autonomous train development programme running to 2024 is being undertaken at the New Transport Science Technopolis in Osong, with backing from the National Science & Technology Research Council of the Ministry of Science & ICT. The aim is to develop a distributed control method through which trains would share information such as routing, stopping patterns and speed. Each train would then determine its own performance profile.

Taken together, these initiatives do not in any sense undermine the case for developing a 5G-led FRMCS programme, but rather serve to show that the likely future of railway communications is going to be made up of an array of largely complementary technologies. However, the rail industry and its partners will need to work hard to keep interoperability, open data principles and future-proofing at the heart of all these efforts; this philosophy will also need to sit at the heart of the FRMCS roll-out.

> **Most benefits arise when synergies in products, markets and standardisation with other industries can be utilised**
>
> **UNIFE position paper published September 2021**

Photo: Deutsche Bahn

In a sense, the recent history of ERTMS should serve as a salutary lesson: how far do promoters 'freeze' specifications to ensure cost-effective and rapid adoption, and how far do they allow for technical change to account for the very short life-cycles of modern digital technology? It is to be hoped that the flexible, software and cloud-based architecture of FRMCS means that some of these pitfalls can be avoided.

Show the benefits now

As railways across the globe emerge from the worst ravages of the Covid-19 pandemic, it is already clear that policymakers are expecting the industry to make faster progress towards realising its full potential to deliver an excellent customer experience and deliver on its wider societal benefits, in particular by reducing emissions from transport through modal shift. Yet it is equally apparent that, in a world roiled by geopolitical instability and looming economic slowdown, the rail mode must achieve those goals while reducing the amount of upfront funding it needs from the public sector.

A clear consensus is emerging that the sector does not have decades in hand to deliver transformational change, especially through digitalisation. For one thing, emissions cuts must happen in line with the global goals of the Paris Accord and COP26 this decade. As one senior European rail industry figure told *Railway Gazette* in June, 'climate campaigners would be screaming if they heard us talking about 2050 in terms of modal shift to rail'. Tangible gains will need to be shown by 2030 in a diverse set of disciplines right across the industry, from automation to track maintenance to operating rules and staff recruitment and retention.

FRMCS is just one brick in this highly complex wall. Given the panoply of differing priorities for investment facing railways today, it is perhaps not a surprise that there has been no all-out rush to embrace it so far. But for these clear barriers to adoption to be overcome, one thing is clear: the benefits of FRMCS and a commercially viable roadmap for its deployment need to be seen by the middle of this decade at the latest.

The good news is that there is enough evidence of progress being made in both the finalising of the FRMCS specification and in field testing to suggest that this should be possible. In the immediate future, all eyes will be on Germany: a fully fledged test zone demonstrating highly automated, digitally connected train operations in the Erzgebirge mountains could be just the fillip the industry needs to accelerate progress in making the transition to FRMCS a reality.

Nick Kingsley, Executive Editor, Railway Gazette International
September 2022

Barrier 5

A two speed migration

Will railways in regions where interoperability, such as parts of Asia or Russia, move to adopt 5G technology quicker than those in Europe, for example, where harmonisation with major programmes such as ERTMS is a key priority?

Published by Railway Gazette International in association with Nokia

Railway Gazette International
1st Floor, Chancery House
St Nicholas Way
Sutton, SM1 1JB
UK

www.railwaygazette.com

A publication of DVV International

Railway Gazette Group
Part of
DVV Media International