

Mobile communications

Migrating from GSM-R to FRMCS in Great Britain



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The Future Railway Mobile Communications System, FRMCS, is the next generation worldwide telecoms system designed in close collaboration with stakeholders as the successor to GSM-R. This article looks at the migration to FRMCS, as GSM-R is based on 2G GSM technology which is quickly becoming obsolete.

FRMCS is based on 5G, which will support ultra-reliable, low-latency mission-critical communications. It offers high capacity, performance, and reliability, along with support for applications such as massive and critical machine type communications and the Internet of Things (IoT). GSM-R was an 'add on' to GSM, but with FRMCS many of the railways' requirements are already built into the 5G architecture.

Today's main line railway in Britain operates on a wide variety of signalling and telecoms solutions, and while many parts of the railway have undergone modernisation over recent years, some parts continue to operate using solutions deployed many years ago. A significant number of telecoms assets continue to be operated on technologies that are beyond their design life and there are issues associated with ageing railway specific telecoms systems, which include GSM-R, with its fast-approaching end of technical life, commercial service life, and imminent end of support.

GSM-R was deployed to provide track-to-train radio communications coverage, with the exception in Great Britain (GB) of certain freight only branch and Radio Electronic Token Block (RETB) lines. Further adaptations were also required to support GB specific use cases, for example the alphanumeric format train head codes used as part of the journey registration process.

At the time GSM-R was being developed the extent to which the European Train Control System (ETCS) would be deployed, and its data communications, were not clear. So GSM-R was initially 'voice only'. ETCS data over GSM-R was eventually provided using circuit switching. Circuit switching for data communications is inefficient by today's standards. It requires continuous connections between base stations and mobiles, and dedicated channels per user, for what is a relatively a low volume of data. This limited GSM-R's usefulness as a data communication system.

While circuit-switched GSM-R may be sufficient for ETCS operation, even on high-speed lines, problems start to occur with a high density of GSM-R users in a limited area. For example at busy railway stations, which require careful advanced cell planning and tuning. The use of packet switching for data communications is more efficient although it requires the deployment of General Packet Radio Service (GPRS) extensions to GSM-R for ETCS.

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Whilst GSM-R has been a game-changer for many railways, changing expectations and changing technology have brought a need for the adoption of a new mobile communications system for railways.

Even if GSM-R was not nearing the end of its life, its limitations compared to modern communications do not support a truly digital mobile solution for applications such as national ETCS. Along with the availability and cost challenges of obsolete equipment and services, the industry is also starting to suffer from skills gaps, whereby the older the technology the fewer engineers are available with the competent skills, and less engineers with an interest in developing old technical skills. Without a robust plan to migrate to FRMCS, investment will be required to extend the life of existing systems and in the face of life expiry, diminishing support and diminishing skills.

FRMCS will require a robust, consistent fixed (possibly MPLS based) transmission network and this will also allow full convergence of fixed and mobile data traffic, optimised for railway operation. At the time of writing this article, Network Rail has entered into discussions with a preferred bidder for Project Reach (see panel). As part of Project Reach a new fibre optic communications network is likely to be provided trackside, which will deliver high-capacity connectivity throughout the network.

There are a number of 'gains' associated with the migration to FRMCS sooner rather than later. FRMCS will not only support continued operation of the railway in the same way that it is operated today, but it will enable significant step-changes in improvements, primarily through a greater ability to exploit railway system data to create more intelligent and improved 'data-driven' railway systems.

Project Reach

UK infrastructure manager Network Rail is seeking private sector investment for its trackside fibre optic cable network to deliver performance, safety, and connectivity benefits for passengers. It aims to save taxpayers up to £1bn (€1.16bn, \$1.26bn) and support the Government's objectives to improve connectivity across Britain, including in rural areas. Over 16,000km of data cables laid next to Britain's railway – carrying information essential to running the railway such as signalling for trains, trackside sensors, CCTV, and internet for trains, railway depots and offices – are due to be upgraded. Telecoms services run by the investor would also help to support the Government's aim to provide gigabit-capable connections to hard-to-reach rural areas and help deliver improved internet connectivity for passengers.

FRMCS will help to enable full digitalisation of the railway, increasing operational safety, performance, and efficiency. There are some improvements we already know about, but the full digitalisation of the railway will inevitably lend itself to improvements we haven't even thought of, as rail moves to an ever more connected wireless world, leveraging cloud, IoT and Artificial Intelligence (AI) technologies.

More commercially available technologies will also be available for FRMCS. Technologies that are used on a much larger scale than railways alone, allowing the railways to benefit from greater economies of scale over the life of the system, means that we need to make sure we don't make FRMCS too railway or GB specific.

Depending upon the degree to which railways want to retain ownership of the hardware and software that make up these modern information and telecoms systems, railways also may have the opportunity to significantly decrease the capital expenditure and overall cost of ownership and obsolescence

Decarbonisation should also be addressed, with design solutions that are smaller, lighter and requiring less energy. They need to be more readily reusable and recyclable.

As GSM-R reaches the final stages of its supported life, and with the 'pains and gains' already discussed, a plan for migration to FRMCS is required now, with some urgency.

The challenges

While 5G is a commercial reality, the specifications for FRMCS are still taking shape under the governance of global standards bodies, notably the European Telecommunications Standards Institute (ETSI) the 3G Partnership Programme (3GPP) and the International Telecommunication Union (ITU).

Working closely together with the standards bodies, the International Union of Railways (UIC) is also in collaboration with a number of other key railway stakeholders, including the European Union Rail Agency, (ERA) and UNIFE, the Association of the European Rail Supply Industry, to prepare the specifications, covering user, functional and system

Whilst 5G is a commercial reality, the specifications for FRMCS are still taking shape.
Photo Shutterstock/Lisic.



requirements. As a sub-group of UNIFE, the UNITEL Committee has been established to support and actively contribute to the UIC and ERA working groups dealing with the technical standardisation of next generation railway telecoms systems.

With the User Requirements Specifications already iterated, V1 of the Functional Requirements Specifications (FRS) and System Requirements Specifications (SRS) were published in June 2023. The Technical Specifications for Interoperability for Control, Command and Signalling (CCS TSI) will be updated to contain V1 of the FRMCS technical specifications and published (most likely as CCS TSI 2023) as a means of providing FRMCS readiness by preparing the European Train Control Systems (ETCS) specifications to interface with the new radio system once available.

However, it is not expected that the content of the updated CCS TSI and the V1 FRMCS technical specifications will be mature enough for the implementation of FRMCS at this stage, but it is rather intended to position legislation to enable further prototype development, trials, preparation of tenders and early deployments to start building readiness for V2 of the FRMCS technical specifications. Knowledge and experience gained from prototyping activities and feedback on the V1 FRMCS technical specifications will be used to inform the development of V2 specifications, the publishing of which is anticipated in the first half of 2024, upon which a further update to the CCS TSI (most likely CCS TSI 2025) will make FRMCS mandatory, and upon which European Member States are to develop their migration plans. Alongside the specification activities, a number of key projects are being undertaken to validate the specifications, including 5GRail:

With funding from the European Union's Horizon 2020 innovation and research programme, 5GRail is targeting the first FRMCS demonstrator, especially for the Train On-Board Architecture (TOBA) to aggregate all of the telecoms streams for operational services within the train, for delivery in October 2023. A high-level milestone for 5GRail will be the validation of the FRMCS V1 specifications and associated standards through the completion of FRMCS pilots, verifying and validating the FRMCS V1 technical, functional and system elements, together with the key players of railway telecoms manufacturing industry.

The European rail telecoms supply industry remains cautious, with a view that a programme for market trials and pilots of FRMCS in real operational railway environments is required. In the late 1990s the Morane (MOBILE Radio for RAILway Networks in Europe) Project was used to assist the adoption of GSM-R. Europe's Rail Joint Undertaking, EU-Rail, the successor to the Shift2Rail Joint Undertaking, is central to defining the FRMCS migration plan and its introduction across Europe's Networks. Its system pillar aims to support FRMCS development and adoption through component demonstration and validation, contributing to deployable commercial solutions. Some elements of market trials and pilots of FRMCS will be achieved under EU-Rail current projects, but a more comprehensive/integrated approach is needed, a successor to the Morane Project, Morane 2.

While commercially available 5G technologies already exist, including New Radio (NR) equipment types, the technical specifications are already being progressed for 6G under the 3G Partnership Project, 3GPP, which defines the technical specifications for evolving cellular telecoms technologies, including the radio access, core network and services capabilities that provide a complete system description for mobile telecoms. Alignment of the technical specifications for FRMCS with those of 3GPP allows for synergies in products and solutions evolving on a larger scale, and avoids locking railways into a specific solution, in the same way as 2G GSM-R has.

Until the FRMCS technical specifications have been completed, full technology readiness remains to be achieved, but it is the goal of the UIC to enable commercially available FRMCS solutions from the end of 2026.

When it comes to solution architecture choice, there will be the opportunity to define a Radio Access Network (RAN) based solution from the large established 5G mobile telecoms manufacturers or to define an Open Radio Access Network (ORAN) through open hardware, software and interfaces. ORAN offers the potential to deliver enhanced resiliency, scalability through disaggregation, faster innovation, and improved cyber security at potentially lower costs.

The role of the European Conference of Postal and Telecommunications Administrations, CEPT, is to define the radio frequency spectrum allocation in Europe. Ofcom has this role in the UK.

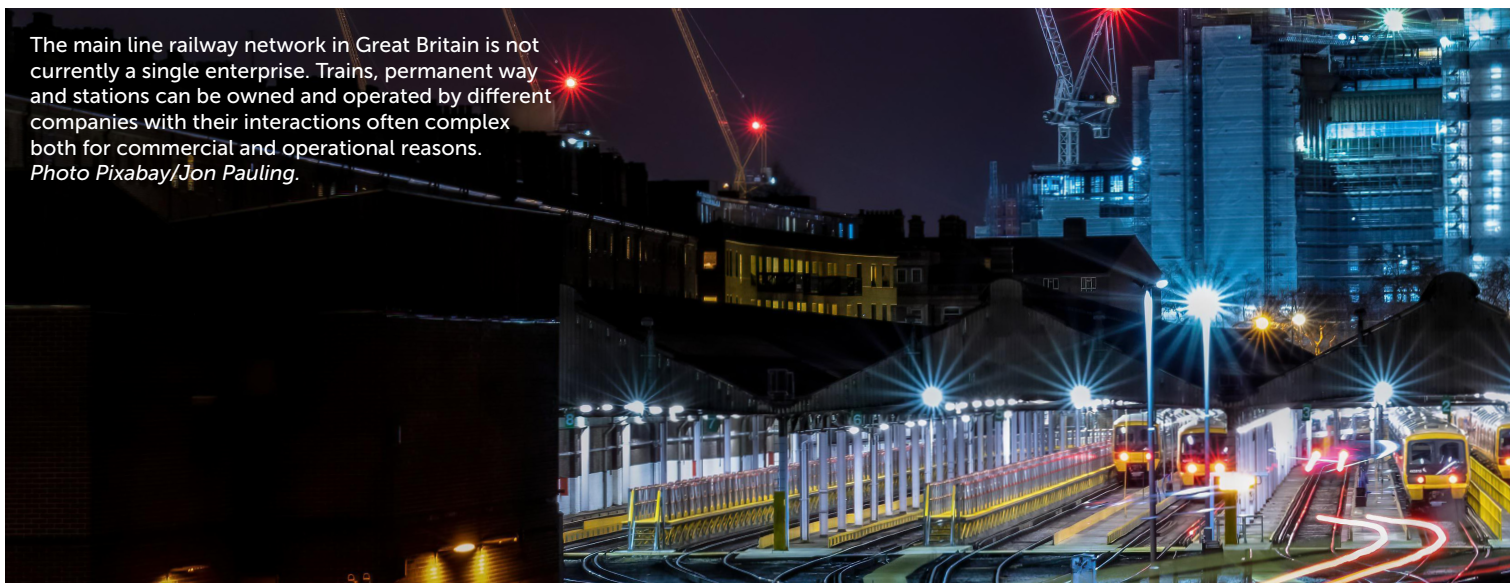
CEPT has determined that the best option for the long-term development of FRMCS (and for the development of EU-harmonised technical conditions, possible for shared spectrum use, covering the period of migration from GSM-R as well as beyond GSM-R switch-off) is to make use of the paired frequency bands. These are 874.4-880.0MHz and 919.4-925.0MHz and the unpaired frequency band 1900-1910MHz. Currently, the paired frequency bands 874.4-880MHz and 919.4-925.0MHz are allocated to rail use in the UK by Ofcom.

In May 2023 Ofcom opened consultation on the optimal use of the unpaired frequency band 1900-1920MHz, noting that EE's current 4G licence to provide the Home Office's ESN Gateway using the frequency band 1900-1910MHz may not be optimal, and that the frequency band 1915-1920MHz could be suitable for the ESN Gateway. Ofcom's consultation drew 14 responses, including from Network Rail and the Home Office; whilst the Home Office has indicated that alternative spectrum allocation is a possible option for its ESN Gateway, it has expressed a concern that it will increase the costs and timescales for ESN.

Meanwhile Network Rail has re-emphasised the case for the primary allocation of the band 1900-1910MHz for FRMCS in the UK. Subject to the outcome of Ofcom's review, the frequency band 1900-1910MHz could be re-allocated to FRMCS, fully aligning the spectrum allocation for GSM-R and FRMCS with that of CEPT.

As Project REACH delivers its high-capacity network, the opportunity may exist to deliver improvements to conventional public 5G connectivity along railway corridors, benefitting both passengers and rail users. The deployment of FRMCS alongside public 5G offers a number of potential synergies, subject to final spectrum allocations. For example the capacity provided by FRMCS may be enhanced using public 5G spectrum, but remaining under the control of FRMCS. Conversely, with extra spectrum FRMCS could also be used to supply non-mission critical services, for example where there are black spots in public 5G coverage across the railway environment, but with FRMCS providing coverage as a 'neutral host'. Careful spectrum planning and architecture design for FRMCS could allow these mutual synergies to be exploited.

The main line railway network in Great Britain is not currently a single enterprise. Trains, permanent way and stations can be owned and operated by different companies with their interactions often complex both for commercial and operational reasons.
Photo Pixabay/Jon Pauling.



Official information provided by the suppliers of GSM-R confirms that support will be provided to GSM-R until at least 2030. But as with any ageing technology it is not clear exactly when GSM-R obsolescence will start to become a problem.

The support costs will also begin to increase as the hardware and software components age and dedicated specialist support is required, which could be difficult to provide.

Industry readiness

The main line railway in GB is currently not a single enterprise or business. Network Rail manages and operates the national main line railway infrastructure through its regions and routes, along with 20 of Britain's biggest and busiest railway stations.

Twenty-eight Train Operating Companies (TOCs) manage and operate some 9,000 passenger trains on the main line railway network along with over 2,500 main line railway stations, and four main freight operating companies manage and operate some 1,100 freight locomotives on the main line railway network, all of which currently make use of GSM-R.

Given the structure of the main line railways in GB there are many Railway Undertakings (RUs), stakeholders and systems to align in terms of a migration to FRMCS.

As a result it will take considerable efforts and time to facilitate and reach an agreed vision, strategy, and to develop realistic cross-industry plans for the migration to FRMCS across the numerous RUs and stakeholders that make up the industry.

While the specifications for FRMCS (and indeed its use for ETCS as

defined by the CCS TSI) may not be currently finalised, the underpinning technologies largely exist at technology readiness levels that are close to allowing full commercialisation, in LTE/5G RAN and ORAN.

Even though the technology readiness level may be sufficient to start planning the migration to FRMCS, the key ingredient for successful commercial adoption of the technology is not the that, but the business readiness level. That is the degree to which an enterprise or business is ready to adopt the new technology within its core operations.

Competency

The single most challenging aspect of migrating to FRMCS is likely to be the effort and time required to build business readiness in the many undertakings that make up the GB main line railway.

Whilst Network Rail's IT and Telecoms Services and a small number of industry OEMs and integrators possess pockets of technical expertise in FRMCS, the industry currently lacks the depth and breadth of technical expertise needed to plan and implement an efficient migration to FRMCS.

The development of real competence takes time, and successful migration from GSM-R to FRMCS will require competence in GSM-R, FRMCS and the interworking between them. For this reason, UIC is establishing a new service, the UIC Rail Academy, which intends to deliver railway telecoms training, covering railway telecoms foundation training, legacy railway radio engineering, particularly GSM-R, and FRMCS. Its first FRMCS training modules, FRMCS Module 1 – Basics, and FRMCS Module 2 – Advanced, are already available, with online and classroom courses started in July 2023.

Even when alignment has been reached on the vision and strategy for the migration to FRMCS across the businesses and stakeholders that make up the GB railway industry, much work will be needed to create cross-industry collaboration to competently plan and deliver the migration, including planning, engineering, procurement, and delivery.

It is possible the capacity of key industry stakeholders may be fully consumed by Project Reach, with little or no spare capacity to undertake the migration from GSM-R to FRMCS. There is also a risk that FRMCS may be consigned to being a safety-critical signalling communications bearer only, supporting voice communications between drivers and signallers, and movement authorities between trackside and train-carried equipment.

Perhaps the establishment of a commercially neutral cross-industry body could secure the collective support of the industry to carry out the work on behalf of the key industry stakeholders, in drawing together the breadth and depth of considerations necessary to making informed decisions.

Supply chain readiness

All RAN OEMs are engaged in the drafting of the technical specifications for FRMCS and some are also engaged in the 5GRail project. RAN OEMs are likely to be keen to support and participate in the migration from GSM-R to FRMCS.

Meanwhile the ORAN Alliance continues to facilitate the collaboration of technology suppliers in establishing and standardising interoperable radio access network components comprising open hardware and software components. All major equipment manufacturers are supporting ORAN standardisation efforts.



The UK Government is also supporting the take-up of ORAN, via a market intervention to make UK less reliant on a small group of vendors. ORAN will diversify the supply chain and potentially reduce the whole life costs, by increasing the interoperability of equipment from different vendors, by creating standardised interfaces between different sub-systems. ORAN products are starting to appear in conventional telecoms and their use is likely to accelerate.

As with the standardisation of any new technology, suppliers to the rail industry, such as integrators, consultants and contractors will possess pockets of capability, as interested parties monitor and contribute to the development and standardisation of FRMCS. However, supply chain capability and capacity will take time to develop.

The migration planning will need to take account of supply chain development and will likely need to iterate through successive and ongoing engagement with the suppliers to the rail industry.

Technical readiness

Inevitably there will be technical challenges in the journey to FRMCS, for example:

- Co-existence of FRMCS alongside GSM-R during the migration, the potential for interference between the two, and the need to support the operation of the two systems in parallel as the migration progresses. This will include spectrum allocation, and the need to retain spectrum for GSM-R alongside spectrum for FRMCS, until GSM-R can be retired.

- Choice of deployment model for the cloud-native core 5G network for FRMCS, between railway-owned enterprise data centres, the use of commercial or wholesale data centres (and whether the use of multi-tenant/co-located data centres would be acceptable, or if they need to be single-tenant/dedicated data centres), and/or partial or full cloud deployment. As critical national infrastructure, it is essential that access and service levels remain guaranteed and so the options need to be thoroughly evaluated against a carefully devised set of criteria.
- Dependency on a modernised IP-MPLS based transmission network, allowing full convergence of fixed and mobile networks to support multi-services for optimised railway operation, which could be provided by Network Rail's Project Reach.

Financial readiness

There will also be financial challenges:

Will the replacement of GSM-R with FRMCS be progressed on the basis of a renewal, with FRMCS deployed and configured to deliver voice and data communications capabilities as a modern equivalent to GSM-R? Or will it be as enhancement, with the additional capabilities and the value they bring to the digital transformation of the railways being recognised?

Some trains have been procured via Private Finance Initiatives (PFI) where changing any aspect of the train can incur significant cost for the associated risk. Penalty charges can also arise when taking trains out of service for any change. The industry and government must find an affordable solution for modifying trains for FRMCS.

If the business case for FRMCS is based on the replacement of GSM-R capabilities alone, then perhaps it will only be possible to make a case to progress the replacement as a renewal. However, if the business case is based on the value that a multi-use digital radio communications bearer will bring to a digitally enabled future operating model, then perhaps it will be possible to make a compelling case to progress FRMCS as an enhancement.

By focusing on the top 5-10 or so digital applications, those with the most significant impact on railway operational effectiveness and efficiency (the benefits of which will be unlocked by a multi-use digital radio communications bearer) it may be possible to make a case to deploy and configure FRMCS as an enhancement.

Modern trains are highly sophisticated ground-mobile systems, and tend to be fitted with multiple radio antennas to support multiple data communications streams, with ever increasing data demands. Consideration needs to be given to future applications and data demands across safety-critical, mission-critical, and non-critical communications.

Where will the funding come from, especially for commercial operators who do not stand to make financial returns from FRMCS alone, with their returns ultimately coming from increased levels of intelligence and automation?

FRMCS capabilities will bring benefits to all parties involved in operating and maintaining the railway, but to secure the commitments needed, the business case will need to draw out and demonstrate the benefits for each and every discrete stakeholder, many of

whom will need to endure the disruption that migration is likely to bring. For example, the impact of taking trains out of service for train fitment and training train drivers in rotation needs to be done at a reasonable cost.

How can the benefits be aligned with the investment and maintain a positive net present value throughout migration for what is essentially an enabler?

How to migrate

Given the challenges, it is crucial to establish a cross-industry collaboration involving all of the RUs, as well as the OEMs and integrators along with academia, who together possess the capabilities required to support the planning of an effective and efficient migration strategy.

The migration to FRMCS could be likened to the migration of conventional signalling to ETCS from a migration planning perspective, although the migration to ETCS on GB's main line railway has not yet faced the same end of life imperative. The following will need to be addressed:

Technical solution development, including the way in which the solution could be optimised to realise maximum business benefit and an incremental approach to the clarification and resolution of technical challenges through a sequence of incremental deployments.

It will be very difficult to provide and operate dual fitment of GSM-R and FRMCS radios on trains. Could a single user interface be provided, with the selection of GSM-R/FRMCS made automatically 'behind the scenes'? Could the existing GSM-R radios be modified to operate FRMCS as well, or would it need a new train radio? Could the fixed operator terminals be similarly provided? If dual fitment is required, what are the implications of a route-based migration strategy for trains that have to switch between networks mid-journey? Where ETCS is already provided, the ETCS onboard and ETCS trackside (not just the radios) may have to be upgraded in parallel with FRMCS migration, with similar issues of dual fitment.

Operational concept development, looking at how the operational concept for the overall railway could be optimised including leveraging ETCS, and the way in which current operations would migrate to ETCS operations.

Migration planning, to establish the sequence of train fitment aligned with route deployment, in a way that seeks to align business benefit with investment and to maximise the business case for all parties as far as possible.

Overall business case development for the change to FRMCS, taking account of the migration plan. Consideration should be given to alternative business models, potentially including Public-Private Partnerships and Private Finance Initiatives

In the case of the national ETCS programme, despite the context of the Uff/Cullen Report and its recommendations that the industry adopt ETCS as a means of securing the safety benefits of continuous ATP, the national adoption of TPWS resulted in the case for migration to ETCS not being justified on the basis of safety improvements alone, but was driven by the need to improve railway capacity. This is by leveraging the benefits of ETCS Level 2 without signals and allowing the signalling layout to be optimised on the basis of cab-signalling and continuous ATP, whilst aligning with European Regulations for Interoperability.

However, there is a stronger imperative for the migration to FRMCS, and given its cross-cutting nature and the volume of work to be done the need to form a cross-industry team is even greater. This would collaboratively and iteratively grow the industry knowledge and understanding of the challenges, and create a compelling cross-industry vision, strategy, and plan. Items to include are technical solution development, operational concept development, industry business case development and ultimately a credible, realistic, achievable migration plan. It could even be called the National FRMCS Programme.

What can be learned from other sectors?

The migration from early generations of public GSM has been challenging. 2G–3G required swapping out of considerable infrastructure due to frequency changes, and a significant upgrade cost. 3G–4G again required significant upgrade costs, swapping out infrastructure due to frequency changes. The migration to 4G resulted in Long Term Evolution (LTE), which promised a smoother upgrade path and some 4G infrastructure, e.g. the base station Evolved Node B (eNB), were designed to support legacy standards and to assist in swap out.

The migration of later generations of public mobile radio have gone more smoothly. 4G–5G has been easier due to the LTE philosophy. The 5G base station gNodeB or gNB is still mostly hardware, and software solutions to key components are emerging. The

migration to an all IP-based network will further improve future interoperability. A cost neutral approach (cost per user) was an early philosophy, given that public radio customers are unwilling to pay more.

Improvements with 5G had to come through technological innovation, including methods of supporting infrastructure densification. ORAN will come fully on stream during 5G deployment, which will allow for greater flexibility and reuse of hardware and software from more mainstream 5G applications. The migration from 5G to 6G will likely be an even smoother upgrade path, with more of a software upgrade for below 6GHz operation, although higher frequency bands will need new infrastructure.

The Home Office new Emergency Services Network (ESN) for critical communications is likely to represent another source of learning for railway migration from GSM-R to FRMCS. The current Airwave service used by the emergency services across GB is to be replaced with a commercial 4G network. Interestingly, the move from Airwave to 4G is not driven by technology or service obsolescence, but by functionality. Airwave technology is deemed relatively reliable and fit for purpose, but its limited capability means it cannot match the functionality offered by newer communications mobile technology.

The network infrastructure is being built by mobile network operator EE, which is upgrading its existing network of around 19,000 masts and deploying 700 additional 4G masts in rural areas. The Home Office is supplementing this coverage by building 292 masts to provide the emergency services coverage in some of the most remote and rural areas of GB, where it was not previously possible. A modern voice and data platform which will enable the emergency services to improve front-line operations, and a common platform will enable emergency services to work more closely together for data sharing in emergencies.

In the rail sector there are lessons to be learned closer to home. We need to learn the lessons from the deployment of GSM-R, as well as the lessons of using a GB-specific version. Based on the industry experience so far in delivering the East Coast Digital Programme, as challenging as technical change may sometimes be, the real challenge will be managing the business change of numerous separate RUs, each with their own commercial constraints and business imperatives.



FRMCS under test in the lab, Toronto. ORAN AIO (All In One) small cells. The lab operates in 5G SA mode in band n77 and n79. Photos Thales.

Five key principles appear to be emerging for successful delivery:

1. Migration planning needs an integrated and strategic approach towards what is a whole-industry change.
2. Establish a partnership across the operators (train, freight, and infrastructure).
3. Deliver operational change, aimed at fully realising the benefits the technology enables.
4. Adopt a user-centric approach, bringing together the engineers and the operators.
5. Leverage commercial models centred on outcomes, not on the delivery of equipment.

The transition from GSM-R to FRMCS will require new infrastructure, but this can be based on standard telecom company (telco) equipment with modifications, e.g. hardware to deal with different frequencies, with software for specific functionality. Mission critical applications are well supported within 5G. Private 5G networks are well understood by the telcos and FRMCS can be considered as another type of private network.

The transition to FRMCS could be via a compatible private network route, allowing for its functionality to be built via evolutionary steps. Consideration may also be given to joining the ORAN Alliance, whose mission is to re-shape the RAN industry towards more intelligent, open, virtualised, and fully interoperable mobile networks. Their activities include the specification and standardisation of ORAN, the development of open software for RAN and support to ORAN member companies in testing and integration of their ORAN implementations.

Maturing technology readiness

A pragmatic approach is required to maturing the technology readiness level ready for deployment to the national railway network, in parallel with a staged approach to maturing the business readiness level for the Railway Undertakings involved/impacted, and testing done at the UIC and international level.

The testing could involve modelling, lab-based testing (as pictured above), followed by trials to de-risk and build confidence in the performance of proposed system and migration from GSM-R to FRMCS. A model could be created for the whole network,

bringing many benefits to both solution optimisation and migration planning. This could look like:

Stage 1 – Modelling of a 5G FRMCS compatible system and architectures, e.g. location of different modules, frequency of operation, likely throughput, latencies, reliability, and interoperability with existing approaches. Critical to this is the detailed migration path and sequence of events needed to move from legacy GSM-R infrastructure to the FRMCS. This enables the cost-benefits of different migration approaches to be considered, to provide a clear foundation for the future migration strategy.

Stage 2 – Lab based test of chosen architecture at a small scale, with the aim of testing different rail-based applications to validate the Stage 1 approach. This enables the most significant parts of the architecture to be evaluated, e.g. migration from GSM-R to IP-based FRMCS enabled infrastructure.

Stage 3 – Medium scale trials on a test track to show the architecture will work in the field, importing lessons learned from 5G Rail and ironing out any problems. The focus here is to validate the operational aspects of migration.

Stage 4 – Large scale trial on an operational route, e.g. West Coast Main Line, given its mast spacing, to test telecoms performance and various test apps. The trial would validate the approach on an operational route to de-risk future more extensive testing.

Stage 5 – Large scale trial on an operational route including key rail apps. This enables more complex operational tests, prior to more commercial deployments.

General migration approach

Migration is likely to require the two systems to inter-operate in parallel during implementation, with services incrementally or fully migrated over from one to the other where both the infrastructure and the trains operated over the infrastructure permits. Most importantly, a Railway Emergency Group Call (REC) made using one system will need to alert trains operating on the other.

Table 1 shows the options for the general migration from GSM-R to FRMCS. Unlike ETCS, for which it was not possible to dual-fit the infrastructure, it would either be fitted with conventional signalling or with ETCS Level 2 (without signals where all trains using the route are fitted with ETCS onboard, or with signals where any trains using the route are not fitted with ETCS onboard), although unlikely to be necessary (subject to the train fitment programme) FRMCS does offer the option to dual-fit the infrastructure and/or the trains.

In Option 1 the infrastructure is fitted with FRMCS to operate alongside GSM-R first, and then the trains are migrated incrementally, switching over to FRMCS as the rolling stock is fitted.

In Option 2 the trains are fitted with FRMCS to operate alongside GSM-R first, and then the infrastructure is migrated incrementally, switching over the FRMCS as the infrastructure is fitted.

In Option 3 a more route-based approach is taken, with routes being fitted with FRMCS to operate alongside GSM-R in sequence, and with the trains that make use of the route fitted with GSM-R also being fitted with FRMCS, enabling routes to be migrated to FRMCS in sequence.

In terms of the co-existence of both GSM-R and FRMCS, careful consideration needs to be given in light of Ofcom's intended radio frequency allocation in the UK. Conventional 4G and 5G are able to host 2G services, so there's a possibility that some GSM-R services could be supported beyond the life of GSM-R. However, given the criticality of GSM-R voice communications to the safe operation of the railway, continuous coverage is required throughout migration, at least until these services are provided by FRMCS to the same or greater levels of dependability. As discussed, FRMCS is capable of incorporating other bands alongside the core railway spectrum allocations and these could be used to provide supplementary capacity that could handle some of the services, at least during migration. However, over the near term it may be prudent to

remain focused on the harmonised spectrum, but to recognise the bearer-independent capabilities FRMCS offers, with more work needing to be done on the specifications to cover the public mobile network operator bands that can be standardised.

The detailed approach to migration should be modelled to better understand the way in which routes and trains would be migrated in incremental stages within signalling controlled areas, with an economic model covering costs and benefits, with the aim of deriving greater benefit than cost as the migration progresses.

Detailed migration planning

Figure 1 proposes a roadmap for the development and definition of the detailed industry plan for the migration to FRMCS. The most challenging aspects of the migration are likely to be the way in which the fitment of every train cab is scheduled, involving the train operators, train care OEMs, and the Rolling Stock Companies (ROSCOs), the way in which driver and signaller training is scheduled, and the way in which these are aligned with trackside fitment.

It is recommended that the cross-industry collaboration group covers:

Technical solution development, including the way in which the solution could be optimised to realise maximum business benefit, with an incremental approach to the clarification and resolution of technical challenges through a sequence of incremental deployments.

Figure 1 – Proposed roadmap for the development and definition of detailed industry plan.

FRMCS technology maturation

Cross-industry FRMCS programme team

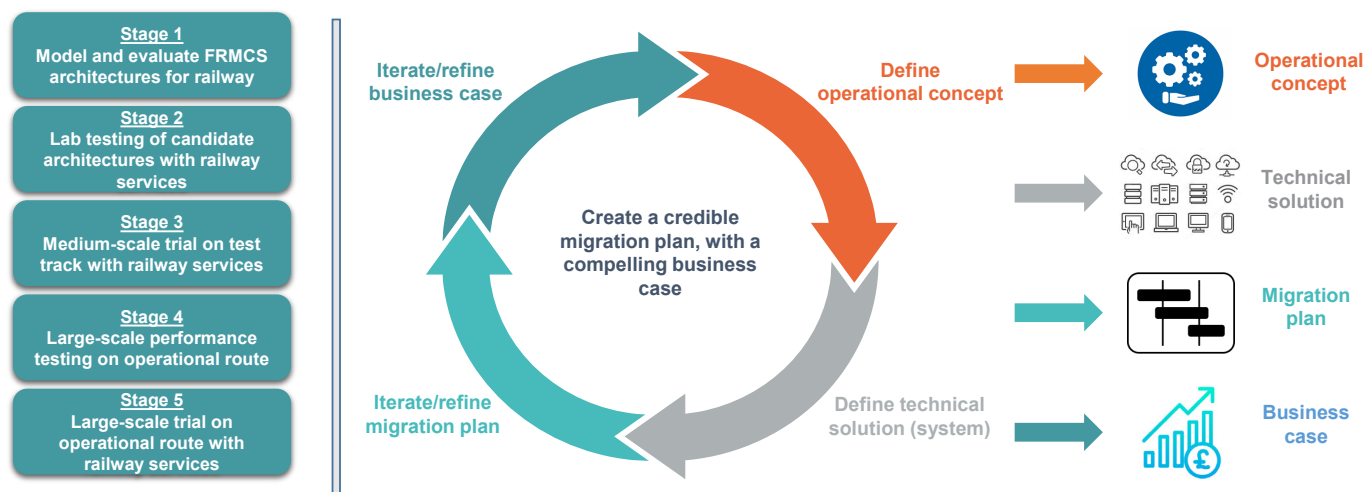


Table 1 – Options for migration from GSM-R to FRMCS.

Option	Migration step	Infrastructure status	Train status	Comments
	Step 0	GSM-R	GSM-R	Current state
Option 1	Step 1	Dual fit with FRMCS	Retain GSM-R	Infrastructure requires backbone
	Step 2	Dual fitted	Migrate to FRMCS	Incremental onboard fitment
	Step 3	FRMCS Operational (network)	FRMCS operational over entire network	
	Step 4	Migrate services from GSM-R to FRMCS (network)	Migrate voice and data services (where deployed)	
	Step 5	Decommission GSM-R	Decommission GSM-R	May include adjustments to FRMCS to make use of GSM-R frequencies
Option 2	Step 1	Retain GSM-R	Dual fit with FRMCS	
	Step 2	Migrate to FRMCS	Dual fitted	Incremental infrastructure fitment
	Step 3	FRMCS Operational (network)	FRMCS operational over entire network	
	Step 4	Migrate services from GSM-R to FRMCS (network)	Migrate voice and data services (where deployed)	
	Step 5	Decommission GSM-R	Decommission GSM-R	May include adjustments to FRMCS to make use of GSM-R frequencies
Option 3	Step 1	Dual fit defined route with FRMCS	Dual fit all trains that make use of the route with FRMCS	Fitment of route and trains, aligned
	Step 2	FRMCS Operational (route)	FRMCS operational over route	
	Step 3	Migrate services from GSM-R to FRMCS (route)	Migrate voice and data services (where deployed)	
	Step 4	Decommission GSM-R (route)	Retain GSM-R for other routes	
	Step a	Dual fit another defined route with FRMCS	Dual fit all trains that make use of the route with FRMCS	Fitment of route and trains, aligned
	Step b	FRMCS operational	Incremental infrastructure and onboard fitment, aligned	
	Step c	Migrate services from GSM-R to FRMCS (route)	Migrate voice and data services (where deployed)	
	Step d	Decommission GSM-R	Retain GSM-R for other routes	
	Step 5	GSM-R Services superseded by FRMCS service	GSM-R service redundant	
	Step 6	Decommission any remaining GSM-R	Decommission any remaining GSM-R	May include adjustments to FRMCS to make use of GSM-R frequencies

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Operational concept development, looking at how the operational concept for the overall railway could be optimised by leveraging FRMCS, including the way in which current operations would migrate to FRMCS operations and the training and development needed.

Migration planning, looking at the sequence of train fitment aligned with route deployment, in a way that aligns business benefit with investment and maximises the business case for all parties as far as possible.

Overall business case development for migration, taking account of the migration plan. It is recommended that technology maturing is carried out in parallel with the formation of a cross-industry FRMCS programme team and its development of the operational concept, target technical solution, detailed migration plan and underpinning business case. The technology de-risking aims to mature the technology readiness, crucially for its application to the operational railway, whilst growing knowledge and expertise in FRMCS technologies

Conclusions and recommendations

A significant opportunity exists to enable the full digitalisation of railway operations through the improvements in railway communications offered by migrating to FRMCS. There are various unresolved elements at present, with the specifications for FRMCS, the technology itself and the spectrum allocation all evolving. It's only a matter of time now until the constellations align and FRMCS is a commercial reality.

The specifications and the technologies for FRMCS are growing in maturity, and preparations are well underway to allocate spectrum for FRMCS in GB.

Given the GB railway's reliance on its GSM-R installed base for its continued safe operation, the migration from GSM-R to FRMCS across the GB rail network and train fleet needs to be carefully considered and planned.

It is recommended that a cross-industry team be formed to start work on the collaborative development of a compelling cross-industry vision for a FRMCS enabled railway, with an effective migration strategy and a credible migration plan.

It is further recommended that the industry knowledge of the technology and the technological challenges faced be matured in parallel with the development of the migration plan, as a means of growing industry readiness.

As a reader of this IRSE article, you may also want to prepare yourself with the skills to be ready to participate in, or to contribute to, the migration to FRMCS by carrying out self-study into FRMCS, ORAN and 3GPP.

FRMCS is likely to be a long-standing component part of our future of digital railway systems, and as such, the knowledge and experience gained by early adopters will be invaluable, which is likely to be good for everyone involved, particularly if we can show demonstrable benefit in doing so.

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What do you think?

Do you think the conclusions for the migration of GSM-R to FRMCS in Britain are correct? For members around the world what are your plans for the migration? Could the IRSE help with the migration. We would love to know what you think, email us at editor@irsenews.org



To learn more about FRMCS visit 5grail.eu/frmcs

About the authors

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