# GSM-R – railway communication solutions from the market leader

NOKIA

# Nokia GSM-R: Global Leadership in Railway Communications

Reliable communication and control are essential to railway safety and efficiency. Nokia's GSM-R has set the standard for mission-critical voice and data for decades. Now Nokia is pioneering the next generation: FRMCS.

**Unflagging commitment to GSM-R**

Nokia designs, deploys, and supports end-to-end GSM-R solutions tailored for railway operations, leveraging deep expertise in both railway engineering and mission-critical mobile communications. As the global market leader, Nokia continues to fully support GSM-R networks through lifecycle services, including consultancy, design, implementation, operation, and maintenance - while also providing a clear evolution path toward FRMCS.

Whether your current GSM-R network remains fully appliance-based, is preparing for cloud-based enhancements, or is beginning the transition to FRMCS, Nokia delivers every network component and service required to ensure continuity at every stage.

**Shaping the future with standards**

Nokia remains at the forefront of railway communications standardization, actively contributing to GSM-R and now FRMCS through leadership roles in key bodies including UIC, ETSI, and 3GPP. As a core participant in MORANE 2 and related trials, Nokia helps define interoperability principles and ensures practical alignment with emerging industry requirements.

Working closely with leading railway associations and the European Union Agency for Railways, Nokia continues to drive the evolution and implementation of next-generation railway communication standards worldwide.

## Evolution to FRMCS

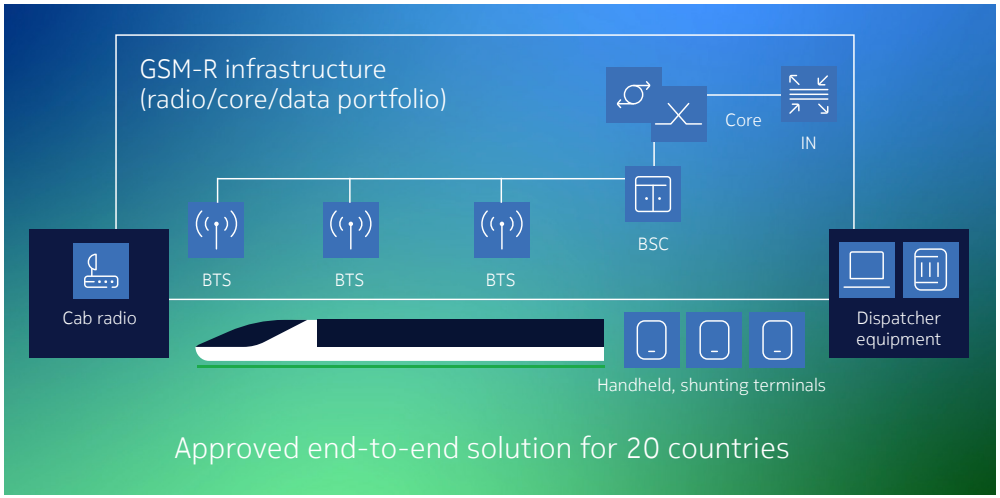
As GSM-R nears the end of its maintenance lifecycle, railway operators worldwide are preparing to evolve their networks to FRMCS (Future Railway Mobile Communication System). Based on advanced 5G technology, FRMCS will enable broadband connectivity, enhanced mission-critical services, and more efficient railway operations.

Nokia's new FRMCS Solution provides a clear and reliable evolution path, leveraging state-of-the-art 5G core and radio infrastructure, industry-leading transport technologies, and proven mission-critical communication (MCX) capabilities. This ensures seamless continuity from GSM-R while unlocking new levels of performance, safety, and efficiency.

## Trendsetter in standardization

Nokia actively shapes global railway communications standards through leadership and participation in key industry groups. As a delegate to the European Union Agency for Railways (EUAR) and Railway Operational Communications Industry Group (ROC-IG), we drive specifications and recommendations for ERTMS and FRMCS implementation. We play leading roles in critical standardization bodies, including UIC working groups, ETSI (TC RT), and 3GPP, and have contributed significantly to MORANE 2 and related FRMCS initiatives.

Our commitment to standardized interfaces enables railway operators to seamlessly integrate solutions across national borders and vendor ecosystems. By promoting openness, interoperability, and vendor flexibility, Nokia continues to help operators reduce complexity, lower costs, and smoothly transition to next-generation railway communication systems.




## Top reliability for mission-critical communications

Nokia's core network sets the standard for railway reliability, with proven geo-redundancy and disaster tolerance for GSM-R and FRMCS.

Through a strategic partnership with Leonardo, Nokia delivers fully integrated MCX services tailored for railway operators. Leonardo's mission-critical applications are integrated with Nokia's carrier-grade core to deliver seamless MCX functions – ensuring resilient, high-availability communications for safe and efficient rail operations.

# GSM-R infrastructure contracts

Nokia has been at the forefront of GSM-R since its inception and today supports more than half of the world's installed base. We are the trusted partner for safe and reliable rail communications, having delivered over 150 mission-critical railway networks, covering roughly 110,000 track miles worldwide. Our newest contracts focus on modernizing these networks and preparing them for the transition to FRMCS.

**Netherlands, Pro Rail**
Dutch infrastructure manager ProRail awarded Nokia a 10-year managed services contract in 2021 to operate, maintain, and gradually enhance the nationwide GSM-R network. In 2025, this collaboration expanded with a four-year modernization project deploying the rail industry's first cloud-native GSM-R core network. This upgrade extends GSM-R operational life, improves reliability and safety, reduces downtime and total costs, and explicitly lays the foundation for ProRail's future migration to FRMCS.

**Poland, PKP Polskie Linie Kolojewe**
In 2021, Polish national railway infrastructure manager PKP Polskie Linie Kolejowe awarded Nokia its largest-ever GSM-R contract - a five-year nationwide modernization covering 13,800 km of railway lines, including 11,000 km of fiber-optic IP/MPLS backhaul infrastructure. This project builds upon earlier upgrades like the E65 Warsaw–Gdynia high-speed line (completed in 2021 with ETCS Level 2 signaling and GSM-R communications), significantly enhancing reliability, safety, and compliance with European interoperability standards (ERTMS). These extensive upgrades ensure the Polish railway network remains robust, reliable, and fully prepared for future migration to FRMCS.

**Germany, Deutsche Bahn**
Nokia has provided GSM-R infrastructure for Deutsche Bahn's nationwide rail network for many years, ensuring robust and reliable voice and data communication. Building on this trusted partnership, Deutsche Bahn selected Nokia in 2019 for a pioneering "Digital Rail" project in Hamburg, combining proven GSM-R with early testing of next-generation FRMCS technology. Closely aligned with MORANE 2 standardization activities, this forward-looking project demonstrates how Nokia helps railway operators extend the value and lifespan of GSM-R investments, while smoothly paving the way toward FRMCS. Nokia is today a key player in the ongoing MORANE 2 trial.

### India, NCRTC (Dehli-Meerut RRTS)

Nokia and Alstom are supplying an 82 km high-speed Delhi–Meerut Regional Rapid Transit System with the rail industry's first 4.9 G/LTE private wireless network - chosen in place of GSM-R, which is expected to be obsolete by decade-end. Nokia's Modular Private Wireless (LTE/5G-ready) solution delivers high-capacity, low-latency links for ETCS Level 2 signalling, Automated Train Operation, virtual blocks, and platform screen doors. This mission-critical LTE network preserves GSM-R-grade reliability while creating a direct, future-proof path to FRMCS, exemplifying how greenfield lines are modernizing communications and leveraging Nokia's global GSM-R expertise.

### China, China Railway

In 2023 Nokia completed a life-extension program for China Railway's GSM-R network, upgrading the core that supports 19,000 km of high-speed lines - the world's largest such network. The project introduced a geo-redundant core architecture, duplicating critical servers and databases at separate sites to ensure uninterrupted CTCS-3 (ETCS Level 2) operation and improve safety on densely trafficked routes. Nokia also streamlined network-management processes, boosting availability and lowering long-term costs. By reinforcing GSM-R now, CR secures reliable communications for today's high-speed services while laying a solid foundation for eventual migration to FRMCS.

### Switzerland, SBB

SBB opted for a nationwide GSM-R project covering main lines in 2002, implemented in five phases over the ensuing years. The first lines are up and running with full ETC operation. In 2016, the Gotthard Base Tunnel opened, with Nokia playing a pivotal role by deploying the entire communications network for mission-critical operational and passenger services.

### Denmark, Banedanmark

In June 2010 Banedanmark, selected Nokia to implement a country wide GSM-R network under a turnkey agreement. The GSM-R network went live in January 2013, meeting the original time schedule.

# The leading GSM-R solution

Nokia's GSM-R portfolio is built from 3GPP-compliant, field proven core, radio and transport components that are widely deployed in other Nokia mission-critical networks. These modular elements interconnect seamlessly, delivering high reliability, availability and deployment flexibility. Multi-vendor interoperability is assured, validated through extensive ETSI/EIRENE test campaigns and live-network integrations.

**Geographic redundant virtualized core**

Nokia's GSM-R core uses a fully virtualized, geo redundant architecture. Call-control functions (MSS) and bearer traffic (MGW) run on common COTS or cloud-native platforms, with redundant hardware, storage, and software at separate sites to ensure uninterrupted service. Packet data nodes (SGSN, GGSN) and network management applications share the same infrastructure, allowing multiple core elements to be deployed flexibly on multi-purpose hardware or in private-cloud environments - ready for future migration to FRMCS.

**Carrier-grade connections with zero outage resilience**

Nokia's GSM-R core uses a virtualized, 3GPP-compliant MSC-Server (MSS) and Media Gateway (MGW) architecture running on IP-based, cloud-ready platforms. Advanced resilience features like MSS pooling, MGW clustering with virtual MGW instances, and multihoming for BSC and SIGTRAN interfaces eliminate single points of failure, ensuring uninterrupted operation even during site outages or maintenance activities.

**GPRS packet core for ETCS data**

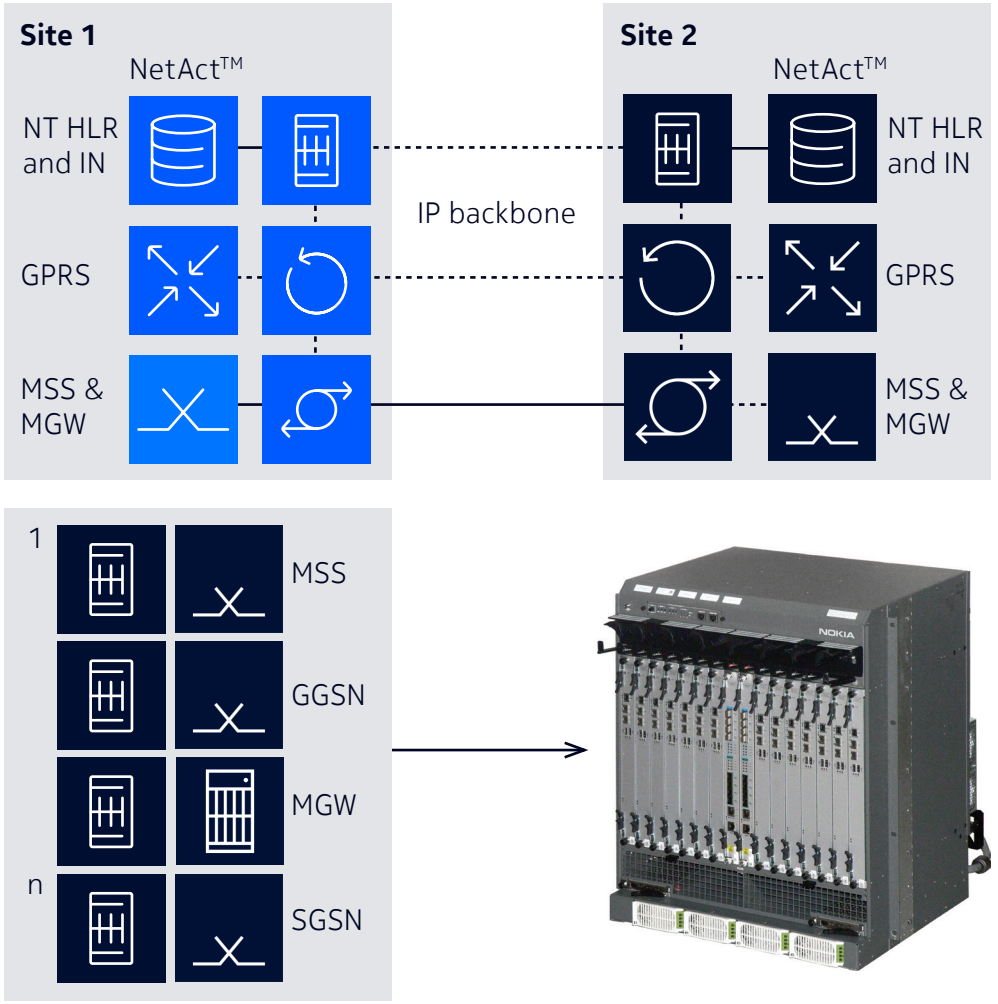
Nokia's GSM-R architecture includes a virtualized Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN), delivering secure IP connectivity for ETCS Level 2, diagnostics, and other railway data services. Running on the same COTS / cloud platform as the voice core, the SGSN–GGSN pair provides end-to-end QoS, private APNs, and flexible scaling. This packet-data layer ensures reliable ETCS performance today while offering a straightforward upgrade path to LTE/5G user-plane services in future FRMCS deployments.

## Cloud ready IN and Subscriber Database

Nokia's virtualized Intelligent Network (IN) delivers the full EIRENE feature set for GSM-R, now deployable on cloud-native infrastructure:

- Follow-Me Functional Numbering Numbering (FFN) via USSD
- Basic and enhanced Location-Dependent Addressing (LDA/eLDA) with direct links to train-positioning systems
- Access Matrix and other administration / authorization functions
- Integrated Acknowledgement Centre (ACKC), on board functional calling, and optional SIM-profile management

Subscriber data can reside on Nokia's geo-redundant OneNDS platform or the modern cloud-native Shared Data Layer (SDL) - providing a smooth upgrade path for FRMCS deployments. The database is distributed across multiple sites, eliminating single points of failure.



## Radio

Nokia's GSM-R radio access network pairs a virtualized BSC/TRAU with modular Flexi / AirScale base stations. The control and transcoding functions run on common COTS hardware and connect over all-IP transport (fiber, IP/MPLS or microwave), eliminating legacy PDH/SDH constraints and reducing cost.

The latest Flexi Multiradio / AirScale platform operates GSM-R today and LTE/5G FRMCS tomorrow on the same RF and baseband hardware, including the 900 MHz and 1900 MHz bands earmarked for early FRMCS rollout. Remote Radio Heads can be distributed along the track or inside tunnels; Nokia's integrated tunnel solution covers about 80 % of rail tunnels without extra active gear, cutting OPEX while boosting coverage quality.

This modular, cloud-ready architecture accelerates site rollout, re-uses existing infrastructure, and supports RF resource sharing between GSM-R and broadband services - giving rail operators a cost-effective, future-proof path to FRMCS.

## Network Management

The Nokia Manta Ray management suite provides end-to-end visibility and control across radio, core, transport, and applications. It unifies element managers under a single "umbrella" interface, adds advanced performance analytics, and supports automated disaster-recovery workflows.

## Converged IP/MPLS & Optical Backhaul

Nokia's carrier-grade IP/MPLS and optical platforms deliver deterministic QoS, multi-fault resiliency, and embedded security - including encryption and integrated firewalls - for GSM-R and other railway applications. The converged transport layer supports flexible topologies and VPN services today, while seamlessly scaling to meet FRMCS and future broadband

## Microwave transmission

Nokia's Wavence portfolio provides high-capacity, all-IP backhaul where fiber is impractical. Full-outdoor and split-mount options enable fast, low-cost deployment, while native IP/MPLS, carrier-grade QoS, and built-in encryption integrate seamlessly with the converged transport network and scale for future FRMCS bandwidth demands.

# Nokia GSM-R

## Value added services on top of a fully standard compliant solution

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|---|---|
| Value-added services | • Broadcast point in BSS/Transcoder in MGW<br>• Up to 20 dispatcher/group call<br>• 1 CHM and 1.5 CHM even in the same network<br>• Application data (for shunting)<br>• Enhanced railway emergency call |
| EIRENE functionality | • Functional and location-dependent addressing<br>• High-priority call confirmations<br>• High-speed: 500 km/h |
| GSM enhancements for railways (by ETSI) | • Voice group call service<br>• Voice broadcast service<br>• Enhanced multi-level precedence and pre-emption |
| ETSI GSM functionality | • All functionalities can be used with GSM-R |

## Unified Signaling with ERTMS

GSM-R is the mandated radio bearer for ETCS (Level 1/2/early 3) and therefore an integral part of ERTMS. The digital link delivers continuous speed and braking data to on-board computers, supports secure driver–dispatcher voice, and enables emergency group calls with automatic recording in an Acknowledgement Centre for post-incident analysis.

Modern EIRENE-compliant cab radios from multiple vendors interoperate seamlessly with Nokia infrastructure, ensuring safe operations across any GSM-R-equipped network. With ETCS-over-IP (GPRS/EDGE) now widely adopted, GSM-R supplies efficient packet capacity for mission-critical train-control data while remaining fully interoperable with forthcoming FRMCS upgrades.

## Safety features

GSM-R provides mission-critical voice and data services that enhance railway safety every day:

- Emergency and priority calls (REC, VGCS/VBS) reach drivers, dispatchers and trackside teams instantly, with assured pre-emption and call set-up times.
- Location-dependent addressing pinpoints trains for rapid, targeted response - even in tunnels where dedicated radiating-cable solutions maintain full coverage.
- Geo-redundant core and secure IP backhaul eliminate single points of failure, keeping communications available during incidents or natural disasters.
- Cross-border interoperability under EIRENE/ETSI ensures drivers stay connected when moving between countries, supporting a seamless ERTMS corridor.

As networks evolve, these GSM-R safety functions will transition unchanged onto FRMCS broadband platforms, adding video and higher-rate data while preserving the proven reliability railways depend on.

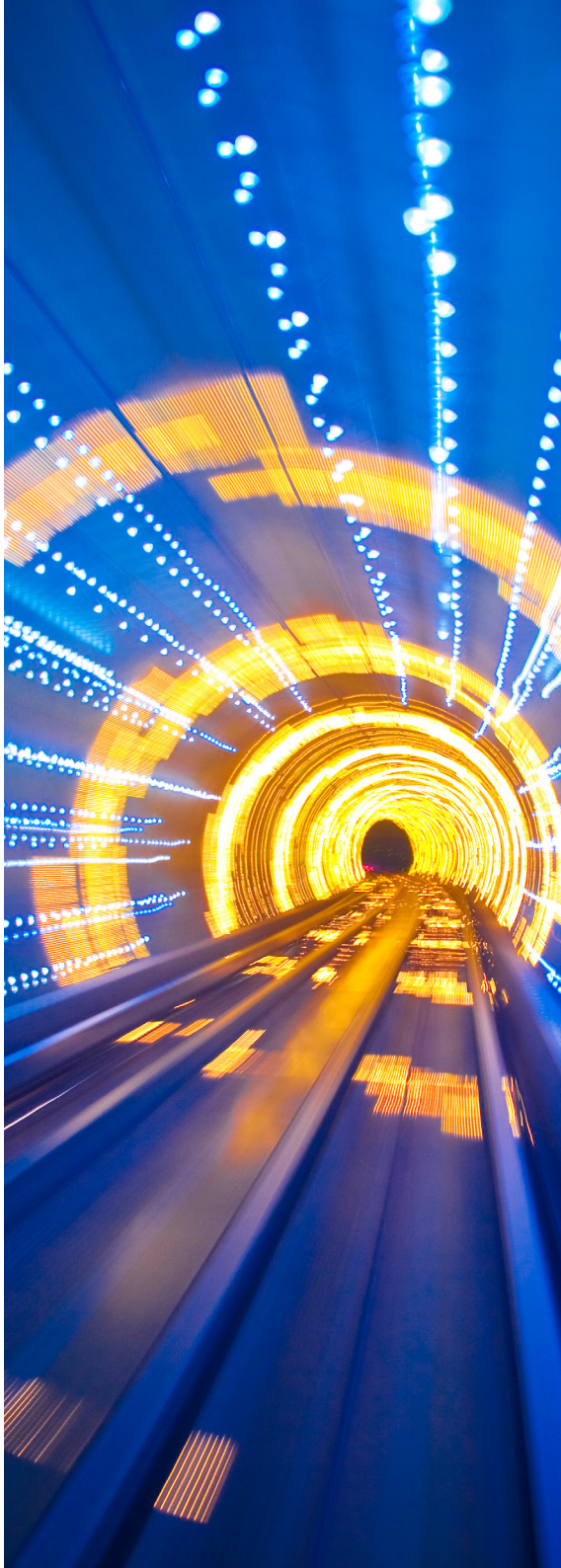
## The Nokia performance promise

Nokia GSM-R solutions enable railway operators to deliver safer, more efficient services while controlling operational costs. Backed by decades of rail experience and sustained R&D investment, we provide a complete, end-to-end portfolio—from radio and core to IP/MPLS, microwave, cloud infrastructure, and lifecycle services.

Our consulting, design, and turnkey capabilities help railways adopt open, standards-based architectures and build business cases that extend today's GSM-R and prepare seamlessly for FRMCS. Start with the functionality you need now; scale as requirements grow. Migrate seamlessly to FRMCS when you are ready. With Nokia, you gain lower total cost of ownership, enhanced safety, technology freedom, and a clear path to next-generation railway communications.

# Abbreviations

| | |
|---|---|
| ACKC | Acknowledgement Centre |
| Airscale | Nokia AirScale radio/base-station platform |
| ASCI | Advanced Speech Call Items |
| ATCA® | Advanced Telecommunications Computing Architecture (or AdvancedTCA®) |
| BSC | Base Station Controller |
| BTS | Base Transceiver Station |
| CIU | Central Integration Unit |
| COTS | Commercial Off The Shelf |
| CTCS | Chinese Train Control System (CTCS-3 ~= ETCS Level 2) |
| EDGE | Enhanced Data rates for GSM Evolution |
| EIRENE | European Integrated Railway radio Enhanced Network |
| eLDA | enhanced Location-Depending Addressing |
| eMLPP | Enhanced Multi-Level Precedence and Preemption |
| ERTMS | European Rail Traffic Management System |
| ETCS | European Train Control System |
| ETSI | European Telecommunications Standards Institute |
| EUAR | European Union Agency for Railways |
| FFN | Follow-me Functional Numbering |
| GPRS | General Packet Radio Service |
| GSM | Global System for Mobile communications |
| GSM-R | GSM for Railways |
| IN | Intelligent Networks |
| LDA | Location-Dependent Addressing |
| LTE | Long Term Evolution Coms standard |
| MORANE | Mobile Railway radio Network for Europe |
| OPEX | Operational Expenditure |
| PBX | Private Branch Exchange |
| RBC | Radio Block center |
| REC | Railway Emergency Call |
| ROC IG | Railway Operational Communication Industry Group |
| RRTS | Regional Rapid Transit System (Delhi-Meerut line) |
| SDL | Shared Data Layer (cloud-native subscriber database) |
| SMS | Short Message Service |
| UIC | International Railway Union |
| VBS | Voice Broadcast Service |
| VGCS | Voice Group Call |
| VGCS | Voice Group Call Service |
| Wavence | Nokia Wavence microwave packet-radio portfolioenter |



Nokia OYJ
Karakaari 7
02610 Espoo
Finland

Tel. +358 (0) 10 44 88 000

CID:200108

nokia.com

**About Nokia**

At Nokia, we create technology that helps the world act together.

As a B2B technology innovation leader, we are pioneering networks that sense, think and act by leveraging our work across mobile, fixed and cloud networks. In addition, we create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

With truly open architectures that seamlessly integrate into any ecosystem, our high-performance networks create new opportunities for monetization and scale. Service providers, enterprises and partners worldwide trust Nokia to deliver secure, reliable and sustainable networks today – and work with us to create the digital services and applications of the future.