The new landscape for railway operator communications

Transforming mission-critical communications for safe and efficient mainline, urban and freight operations

White Paper
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1. Why the transformation of rail communications is a high agenda item

The resurgence of rail in recent years continues to accelerate as authorities target railways as the backbone of national, regional and local transport. The European Union, for example, aims for inter-city journeys of 1,000 km or less to be made by train by the mid-2020s. Substantial growth in rail is the focus in many other regions from the Americas to Asia.

Meanwhile, growing urbanization demands more efficient, more available metro railways. The Global Health Observatory estimates that by 2017, even in less developed countries, a majority of people will be living in urban areas, with city populations growing by 1.84 percent per year between 2015 and 2020. Not only are metro rail operators building more capacity, but timetables are being extended to 24/7 operation.

Against this backdrop, many railway operators continue to manage multiple networks to support different applications. Their legacy networks, built with circuit-switched Time Division Multiplexing (TDM) and Asynchronous Transfer Mode (ATM) technologies, are becoming obsolete as new applications based on IP/Ethernet technology come to the fore. While many of these IP/Ethernet applications require equally high availability and responsiveness, they are also demanding in terms of bandwidth. Such demands cannot be met by legacy networks, leaving railway operators needing to evolve their communications to be able to succeed in the face of fierce competitive pressures, increased legislation and new passenger demands.

Railway operators have always had safety, efficiency and punctuality as top priorities. Yet the new growth trends bring added pressure on these priorities as well as creating fresh demands, such as a richer customer experience by providing on-board broadband services.

Communications technology has advanced extremely rapidly in the last decade. A variety of solutions are available to address all the challenges that railway operators face as they consider how to upgrade their existing communications networks.

The decisions that railway operators make now with regard to their communications networks will affect their operations and business success for decades to come.
This paper looks at how railway operators can address the three major challenges they face:

- **Maintain safety as the highest priority by:**
  - Meeting the availability and reliability requirements of mission-critical applications such as automatic train control (European Train Control System Level 2 (ETCS L2) and CBTC)
  - Deploying new and advanced safety-related applications
  - Supporting non-stop operations through an always-on, secure and reliable communications network

- **Run on-time and efficient operations by:**
  - Smoothly migrating to a next generation IP-based communications network to support mission-critical operations with no performance compromise
  - Supporting anywhere machine-to-machine and Internet of Things (IoT) communications to enable, for example, more effective preventive maintenance
  - Deploying standards-based network technology to ensure long-term viability and interoperability
  - Automating trains and operations to achieve higher efficiency and greater capacity

- **Improve the passenger experience and generate non-fare revenues by:**
  - Deploying broadband for passengers to improve the journey experience and achieve a competitive advantage
  - Deploying broadband multi-services networks to support more reliable operations

Figure 1. By upgrading their existing communications networks, railway operators will be able to better meet the three major challenges they face.
2.0 The key technology areas

Communications plays a critical role in each of the challenges that railway operators face, from efficient communications between drivers and controllers, to real-time positioning information for high-speed trains, to continuous infrastructure monitoring for more efficient maintenance, and many more. None of these challenges can be met cost-effectively through isolated initiatives and improvements. Instead, they demand an integrated, long-term approach to infrastructure and service evolution that addresses five key technology areas:

- GSM-R
- LTE for railway operators
- Broadband on trains
- Multiservice WAN/LAN transmission backbones
- Connected mobility

2.1 GSM-R for the safest, cross-border travel

As an internationally regulated standard for railway-specific voice and data operational services, GSM-Railway, or GSM-R, offers the highest level of interoperability in accordance with EIRENE, the European Integrated Railway Radio Enhanced Network specifications. GSM-R enhances voice and data communication with trains and allows drivers to communicate freely throughout transcontinental journeys, even when passing through tunnels, helping to greatly improve the security, reliability and safety of rail services.
As well as providing standardized operational and safety features for national and cross-border rail networks, GSM-R also enables the seamless integration of regional services and applications such as the European Train Control System (ETCS) signaling system standard. Requiring fewer fixed installations, ETCS is more cost-effective than conventional trackside signaling.

As the chosen data technology for ETCS, GSM-R is an integral component of the ERTMS (European Rail Traffic Management System, comprising both GSM-R and ETCS). The benefits are considerable, for example, a continuous flow of information can now be provided to on-board computers for calculating speed and braking profiles.

### The power of open standards

Experience shows that open standards drive down the costs of developing and deploying technology. Nokia has for many years been a strong advocate of open standards and promotes interoperability to help eliminate the boundaries of technology, vendors and national frontiers.

Nokia efforts have paid off. Now that all GSM-R interfaces have been specified and standardized, operators have access to an open, interoperable and international system that drives competition and affords them considerable savings.

### 2.1.1 What Nokia offers in GSM-R

Deployed in 20 countries, the Nokia GSM-R solution serves more than 73,000 km of railways, making Nokia the global market leader in GSM-R in terms of the number of commercial networks and length of operated GSM-R lines. Nokia has also long been a key driver in the development of the GSM-R standard.

As a turnkey solution provider, Nokia offers a complete GSM-R portfolio from the radio access and core networks, through fixed and microwave transmission and network management systems, to dispatcher systems, cab radios and handheld shunting terminals. The solution is based on state-of-the-art elements used in Nokia communications solutions installed around the world for proven reliability and cost effectiveness.

The radio and core parts of the Nokia GSM-R solution are developed and deployed for the mobile operator market and have proven their reliability and robustness under tough market conditions. Railway operators benefit directly from Nokia’s leading position in the public carrier segment with field-proven product quality in GSM-R, as well LTE for railways.
2.2 LTE for railway operators

Long Term Evolution (LTE) radio access technology and its further evolution like LTE-Advanced and LTE Advanced Pro offers railway operators a golden opportunity to converge several separate communications systems into one fully IP-based, highly efficient and high performance technology for operational and passenger communication. Furthermore, being IP based, LTE enables operators to rationalize all communication networks into a single mobile LTE and fixed IP/Multiprotocol Label Switching (IP/MPLS) network. This leads to substantial savings on network design, management and maintenance.

For railway operators, LTE offers carrier grade products, with low latency and high security while being truly broadband, making it well suited to support passenger connectivity needs, along with mission-critical operational applications such as train signaling, closed-circuit television (CCTV), on-board and emergency communications — all on a single converged IP network.

While railway agencies operating in countries with appropriate market conditions and regulations, as in an increasing number of Asia Pacific areas, can already opt for LTE as their train control technology, European mainline railway operators continue to watch standardization developments around the definition of a next-generation railway telecommunication system. Urban metro line operators globally can already opt for LTE as their train control technology.

As well as train control operations, LTE can provide mobile broadband coverage for non-mission-critical railway operator communications in trains and in stations, as well as provide services for passengers.

Figure 3. LTE enables the convergence of separate communications systems into one IP-based network.
2.2.1 Evolving to LTE in Europe and globally

There is joint activity within UIC, the European Union – Agency for Railway, ETSI and 3GPP to define a telecommunication system capable of replacing GSM-R from 2022 onwards. The migration phase is expected to last until 2030 depending on different projects. Current standardization activities strongly focus on following 3GPP evolution, where LTE is seen as the most suitable radio access technology candidate. The change to LTE will require extensive technical and regulatory standardization to achieve the necessary functionality, interoperability and a seamless migration from GSM-R.

Although NG2R (Next Generation to Rail) activities primarily address the migration challenges of the highly integrated and cross-border interoperable European railway networks, they are of interest to Mass Transit operators. These operators have been largely using TETRA or other narrowband PMR systems in parallel with one or multiple Wi-Fi networks and are now looking at the benefits of using only 4G technologies.

By deploying an LTE overlay network, existing GSM-R or other network sites can be re-used for a cost-effective roll out. In this way, the LTE overlay network supports broadband services, while the existing network is retained for voice and narrowband services.

Where they can, Nokia advises railway operators to invest in LTE today to gain the benefits of valuable applications that require higher bandwidth than GSM-R can offer, whether on board trains, track-side or in stations.

2.2.2 What Nokia offers in LTE for railways

At the heart of the Nokia LTE family is the Flexi Base Station portfolio that offers more network capacity, more efficiency and more flexibility, with lower costs. Nokia Flexi Multiradio 10 Base Station and the latest Nokia AirScale Base Station, are the world’s smallest high-capacity, software-defined, multi-technology base stations.

Nokia small cells provide easily scalable, cost-effective capacity. Nokia Flexi Zone suite is a 3G/LTE/Wi-Fi-capable small cell solution for offloading traffic from a macro network. Flexi Zone Base Stations can be deployed stand-alone or to create a zone covered by a cluster of low-power access points connected to a local controller.
What will be the role of 5G in railway communication?

There are many voices in the market talking about the huge benefits of 5G technology for rail operators especially in the area of efficient connected rail (IOT) service management. Other promises of 5G - which can be expected to be deployed from 2020 onwards after finalization of the definition and standardization phase - cover the huge capacity gain and the extremely low latency.

Nokia’s view on this is clear:

LTE can deliver already today for the efficient train operation and enhanced travel experience, and therefore is the right choice and future-proof technology platform for railway operators for the next decades.

LTE can fully cover the typical narrowband services like IOT which are primarily applicable for rail operators while the definition of 5G is targeted for wider spectrum. 5G may play a complementary role in the future for boosting capacity for specific situations on top of LTE with extremely high bandwidth.

Another important factor for the technology selection is the available dedicated frequency spectrum for rail operators which will certainly be defined rather in the narrow band area of below 10 MHz than in higher bands.

Nokia is simultaneously at the forefront of the LTE market and leading the definition of 5G technology. Our customers can fully trust us that we will embrace both technologies for safer and more efficient train operations.
2.3 Providing high-speed broadband access on trains

Railway operators are in a strong position to provide a more comfortable and convenient passenger experience than other forms of transport. An important service is to provide on-board high-speed broadband access. While private passengers will enjoy fast Internet access, video streaming and online gaming, business travellers will appreciate the chance to work while on the move.

In parallel, broadband availability on trains helps rail operators to use applications such as video monitoring for increased security, enhanced ticketing and seat reservation services, and other tools that can access data online to help improve processes and reduce operational costs.

**Figure 4.** Onboard broadband connectivity improves the passenger experience and helps to improve railway operational efficiency.

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### Connected passenger
- Information and entertainment
- Internet access

### Connected staff
- Handheld PC for ticketing
- Passenger counting system
- Train monitoring

### Connected fleet
- Train monitoring
- Surveillance cameras
- Driver decision support

### Advertising
- On-screens/laptop portal
- Bistro
- > 100,000 possible customers per month

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2.4 Multiservice WAN/LAN transmission backbones

The mission-critical wide area network (WAN) is the bedrock of the railway communications infrastructure as it interconnects all equipment installed in train stations, along the tracks, in data centers and in control centers. It also plays the pivotal role of a backhaul network for GSM-R, Wi-Fi, PMR and LTE systems.

**Figure 5.** The wide area network typically comprises a transport layer and network layer.
2.4.1 WAN transport layer

Microwave and optical technologies are the two principal transport technologies.

Microwave is a cost effective transport solution especially in hilly or mountainous areas where deployment of copper or fiber is not possible. Microwave can also be used as a back-up path for a fiber link. The advent of new microwave techniques such as adaptive modulation, packet compression, and native integration in IP/MPLS routers, makes microwave transport even more attractive.

Optical networks using WDM and layer 2 packet-switching provide a versatile, high capacity backbone to connect any application or service. Optical networks serve as a foundation for the packet network that supports IP/MPLS and Ethernet services. Fiber replaces copper and therefore optical networks are typically used in the core of the communication network where all the data flows converge. Many railway operators also deploy fiber along tracks, either to avoid theft of copper cables or to resell network capacity to third party customers.

2.4.2 Evolving network layer with IP/MPLS

A more flexible, high-speed IP/MPLS network will support new and more advanced IP/Ethernet-based applications, such as Wi-Fi, CCTV and LTE, as well as smoothly migrate existing mission critical legacy services, like emergency call points, call dispatchers and train control.

Figure 6. IP/MPLS is a flexible technology that can transport any data traffic for broadband and mission-critical applications.
The versatility of IP/MPLS enables a converged network that can flexibly transport any data traffic including TDM, serial, IP and Ethernet, to support broadband and mission-critical applications. Such a unified network integrates all applications and terminals and achieves substantial savings in network design, management and maintenance.

IP/MPLS can be used over any network topology and offers high network availability, resilience and performance for all applications. Furthermore, as a native IP technology, IP/MPLS is LTE-ready.

2.4.3 The Nokia IP/MPLS and transport networking portfolio

Nokia offers a comprehensive suite of IP/MPLS, optical and microwave transport products for mission-critical networks with high resiliency, robust security and flexible quality of service (QoS). Whether it is train control, operations and emergency communications, surveillance video or simply passenger broadband connectivity, the solution is field-proven to deliver voice and data reliably and securely.

Cost is another advantage. A unified and converged infrastructure using a common management platform will support both mission-critical and less vital services, incurring lower costs than managing disparate dedicated legacy networks.

With a WAN offering multi-tenancy capabilities, railway operators have the option to resell network capacity to third parties, potentially boosting non-fare revenues. Furthermore, the network can further evolve to embrace software defined networking (SDN) and network function virtualization (NFV) to enhance network agility, automation and responsiveness in the future when necessary.

2.5 Connected mobility: IoT for railway operators

It is expected that, by 2025, there will be more than 50 billion connected things. The Internet of Things (IoT) is a fast-growing technology area that promises to bring about a transformation in railway operations and the passenger experience.

As IoT continues to evolve, it will bring greater standardization, openness and scalability to the information provided to operators. Railway operators will be able to more easily convert the data flowing from their railway networks into valuable business benefits. They’ll gain increasing insight into how their assets are performing, which opens up many new possibilities to use big data in more creative and effective ways.

Improved fleet management will be enabled by constantly monitoring vehicles and automated workflow processes, promising to reduce substantially the 35 percent of initial train delays caused by failure of train or infrastructure components.
In addition, data from sensors can improve driving performance. For instance, adjusting the speed of the train according to its weight and length can prolong the use of brakes, while an enhanced understanding of the temperature of the engine and the brakes, the gradient of the railway and traffic conditions, can help to cut energy consumption significantly.

Real-time video surveillance linked with advanced video analytics will automatically identify issues to help improve crowd management. Analysis of heating and electricity consumption in buildings will help to improve station energy management.

These and many other applications from third-party developers can be integrated into the Nokia IMPACT Platform for Connected Railways. This horizontal IoT platform is an adaptable, scalable and highly secure solution that handles data collection, event processing, device management, data contextualization, data analytics, end-to-end security and applications enablement for any device, any protocol, and across any application.

This extensive lifecycle management capability is supported by comprehensive network, cloud and end-point security. The platform implements the latest Lightweight M2M (LWM2M) security model for IoT device management and is backed by Nokia’s extensive security portfolio.

Figure 7. The Nokia IMPACT Platform for Connected Railways helps railway operators gain substantial business benefits from the data generated by their networks.
3.0 Secure railway networks

Security is a vital consideration for railway operators, both to protect the data and privacy of passengers using broadband services while at a station or on a train, and to prevent compromises of railway operations that could affect safety and reliability. The growth of the IoT and the many new connected devices that will appear, open up new security issues.

Nokia believes that full protection for railway operations and railway-related IoT can only be achieved through an end-to-end security approach from the core network through to the end device:

- **Core network security:** The core network is secured against attacks through the Internet, Wi-Fi and roaming interface to maintain the confidentiality and privacy of customer data as well as to help ensure high service availability and network reliability.

- **WAN security:** The optical transport provides traffic through FIPS 140-2 and Common Criteria certified layer 1 encryption. For the IP/MPLS network layer, label switched path (LSP) tunnel and MPLS-based VPN provide traffic segregation to provide protection. When coupled with the use of technology like Network Group Encryption (NGE) and firewall, services and network protection is ensured.

- **Radio access security:** Radio assets are protected by securing data between the base station and core network through automated lifecycle management of security certificates along with IPSec and Security Gateways to ensure only authorized base stations can access the network.

- **Endpoint security:** Nokia NetGuard Endpoint Security is a customer protection system running on networks. Its analytics engine monitors and analyzes traffic to search for patterns that are consistent with malware behavior. The information on known malware behavior comes from a Nokia intelligence database. The solution reports anomalies on IoT device communications and provides effective protection for IoT devices and smartphones.

Figure 8. Full protection of railway operations and railway-related IoT can only be achieved through an end-to-end security approach.
4.0 Expert support in communications is vital

With the introduction of new technology layers such as LTE, railway operators will look to the communications industry to help them ensure they make the right technology choices, implement the infrastructure effectively and operate and maintain their communications services as efficiently as possible.

Nokia services are tailored to the unique needs of metro and railway operators, such as operating train timetables and stringent trackside security procedures. Nokia project managers are PMP® Certified and highly experienced in implementing large-scale projects in challenging health, safety and environment conditions.

The range of Nokia services can be split broadly into three categories:

- **Consulting and design**: Nokia helps railway operators to make informed choices about modernizing their communications networks while maintaining services, improving customer and staff safety, and keeping costs under control.

- **Integration and deployment**: Network implementation services encompass radio, core and transport networks, Turnkey projects include project management, systems integration, installation, commissioning, testing, validation and implementation of end-to-end applications.

- **Operations and maintenance**: Nokia Care Services help railway operators to achieve the highest performance and reliability form their communications through a proactive and predictive approach to network maintenance. Our Managed Services include service and network management, customer experience management and telco cloud operations.

Nokia also offers a Build-Operate-Transfer solution in which Nokia designs, builds and operates a new network or network extension, and then runs the network for an agreed period while providing a smooth transfer of know-how for successful handover of the network. Alternatively, network operations can be continued by Nokia under a Managed Services agreement.

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**Global expertise for high-availability networks**

Nokia Global Service Delivery provides services through a virtualized delivery model that encompasses network planning, implementation, system integration, managed services, care and optimization. By managing work from its Global Delivery Centers (GDC), Nokia is able to provide the technical expertise required and crucially to ensure that maintenance and modernization work do not cause passenger travel delays.

GDCs offer integrated services for multiple technologies with proven capabilities in multi-vendor environments. Each GDC brings together highly competent people, state-of-art tools and standardized processes to ensure that services across the complete network lifecycle are delivered with the highest quality, efficiency and speed.
5.0 What’s next in railway communications?

As the demand for capacity increases, especially in the urban rail environment which needs to support the growing number of megacities, train operators are facing huge challenges in keeping their rail networks ready for the future.

Alongside these challenges we see four major rail communication trends that will determine technical developments over the next decade:

1. Safe train operations
2. Connected trains
3. Big data, train applications from the cloud
4. Broadband everywhere

5.1 Safe train operations
The introduction of LTE in the rail sector will significantly help to increase the safety of train operations when used for train control, as well for less critical services like CCTV and driver look-ahead. The wider deployment of fully automated rail lines, especially in high population areas, will reduce accidents caused by human error. Broadband communications can help to maintain safety even under extreme capacity load, such as in metros during rush hours.

5.2 Connected trains
With the introduction of LTE connectivity, connected rail / IoT use cases will increase rapidly to bring significant benefits for rail operators and passengers. IoT services will improve railway operational efficiency substantially, saving time and costs through the use of predictive lifecycle maintenance.

New intelligent railway applications for passengers will calculate the most efficient ways to reach a destination. All public transport options, including buses, taxis and trains, will be fully connected in real time to provide intelligent, comprehensive and connected schedules and intelligent ticketing.

5.3 Big data, train applications from the cloud
Big data services will play a major role for railway operators. Huge data streams generated by thousands of sensors will further increase operational efficiency. The integration of intelligent mining platforms to filter data streams and identify the most relevant information will enable the automatic triggering of action by operational personnel.

Rail applications from the cloud will help to flexibly introduce new operational services with easy installation processes and zero downtime of critical train control systems.
5.4 Broadband everywhere

Full broadband network coverage along tracks, in stations and depots and on board trains will help train personnel to communicate and interact much more efficiently. Broadband everywhere will also give train passengers access to unlimited information and entertainment. A multitude of access technologies, including like 5G, LTE and Wi-Fi, will work seamlessly together to provide the best and most efficient coverage where needed.

These solutions will not only help railway operators to further improve efficiency, security and the passenger experience, but also to generate new business and deliver excellent return on investment. Railway operation requires coordinated management of assets, infrastructures and resources. Nokia helps railway operators to build a converged and reliable railway network to achieve 100 percent safety, improve agility, maximize resource utilization and simplify routine work.

6.0 Conclusion: different technology evolution routes for different operators

Most communications networks used by railway operators around the world are either obsolete or approaching end of life. No longer can these legacy systems meet the needs of railway operators who face new demands for extreme efficiency, ultimate safety and a superior customer experience.

Renewing their communications systems is a high priority for most railway operators. However, operators around the world need to approach the evolution of their communications in different ways.

In Europe, for example, mainline and freight rail operators running GSM-R currently can benefit from continuing to invest in these systems for their voice and ETCS needs as they wait for standardization of next generation technologies, which are not likely to be finalized until after 2020. It is highly likely that this standardization will select LTE as the technology for mission-critical operations in the future. At the same time these operators can deploy an LTE overlay network to support their non-critical broadband data needs. Mainline railway companies outside Europe and with no plans to implement GSM-R have the option of investing today in LTE for their broadband and mission-critical needs.

Urban mass transportation operators face no restrictions on the technology choices and many are already adopting LTE based on current 3GPP releases.

For all operators, the future holds the promise of being able to consolidate several communications technologies currently used onto one IP-based platform in the shape of LTE for simplified operations and improved efficiency.
Nokia is well placed to support operators, whichever evolution path they travel down. With more than 30 years of experience in the sector and the most complete portfolio of products and services, Nokia is the market leader with 20 GSM-R networks and more than 80 mission-critical railway networks deployed. As a principal driver of the industry’s standardization work in GSM-R and the evolution to LTE, Nokia knows the complexities and requirements of migrating from legacy to IP-based networks. In addition, Nokia has been at the forefront of helping operators migrate from TDM, SDH, or SONET networks to modern IP/MPLS and optical networks.

With a full portfolio of both mobile and fixed network solutions, Nokia has the unique capability to offer railway operators the most integrated approach to modernizing their communications systems and meeting the needs of the future.