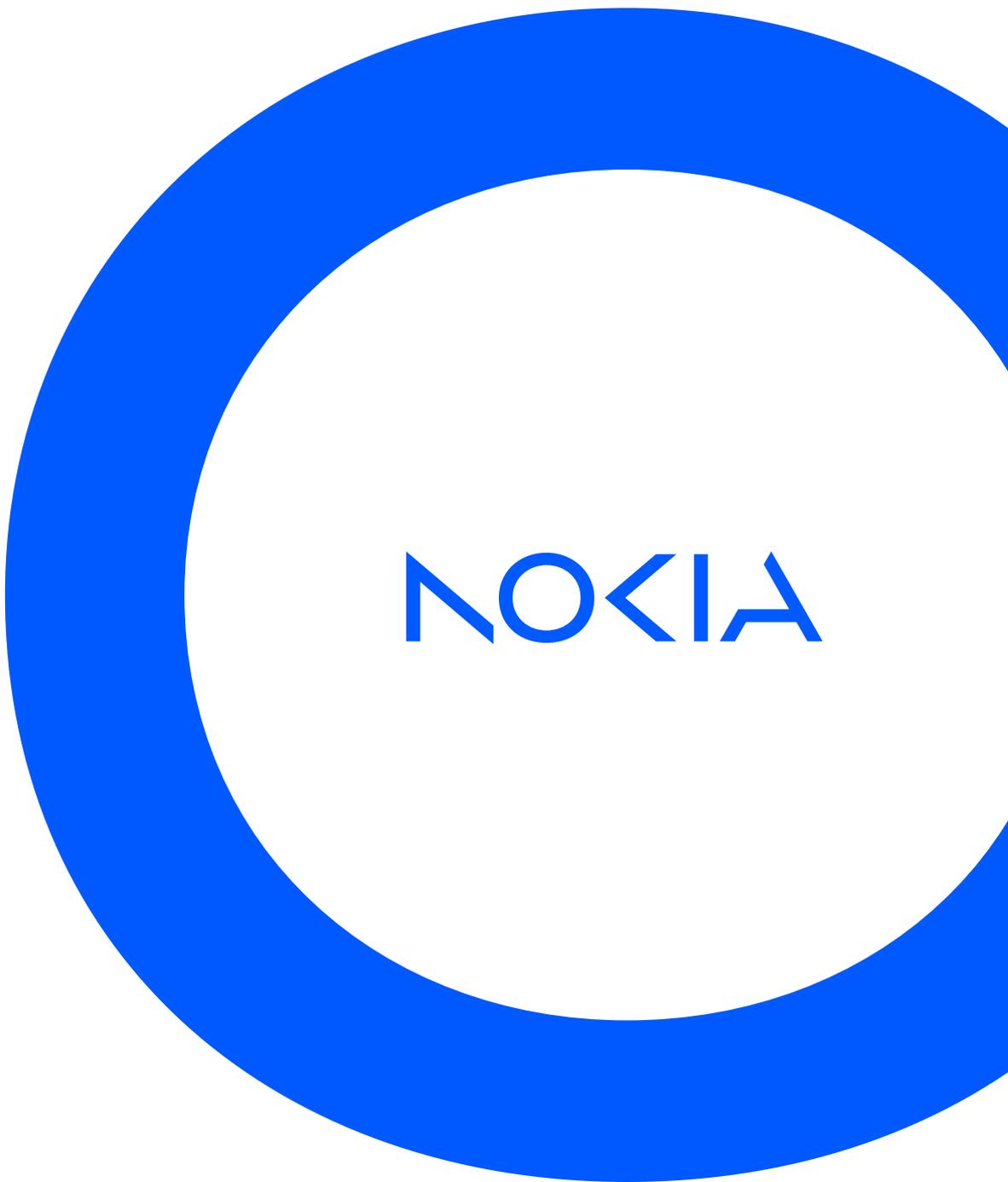


Converged IP/MPLS networks for urban railways

Highly available mission-critical communications infrastructures

Application note

The Nokia logo is centered within a large, thick blue circular ring. The word "NOKIA" is written in a blue, sans-serif font, with the letters slightly spaced out.

NOKIA

Abstract

As urban populations continue to expand rapidly, urban railways operators are challenged to provide reliable, sustainable and safe transportation that can also scale and evolve to meet future passenger traffic volume and needs. To meet the challenges, they need to embrace digital transformation and adopt new technologies. This application note explains how the Nokia Converged IP/MPLS Network for Urban Railways solution can become the communications foundation of digital transformation and enable operators to meet these needs for today and tomorrow.

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Challenges for urban railway network operators

According to United Nations data¹, 66 percent of the global population will live in urban areas by 2050, up from 54 percent in 2014, and representing a net urban population increase of 2.5 billion people. Growing urbanization brings unprecedented pressure to city infrastructure and services in general, and to public transportation in particular.

To adequately serve the growing urban population, an expanded and modern urban railway system is of prime importance. It plays a fundamental role in a city's economic and social activities, and is pivotal to a sustainable urban life style. It is also an integral part of a green environmental framework to alleviate congestion, reduce pollution and carbon footprint, and build a sustainable city.

Consequently, urban railway operators are under immense pressure as they strive to provide dependable, safe, affordable and connected public transportation across cities. They need to overcome three challenges.

Attaining efficient, on-time operation

As urban railway has become the transport backbone of today's cities, operators need to be able to move more passengers quickly while still tightly controlling costs. Whether it is rush hour on weekdays or off-peak periods during weekdays and weekends, service must be consistently on schedule, reliable and fast, with enough capacity for all riders. If there are unscheduled changes, passengers need to be informed quickly. Operators also need to continually monitor railway asset health status for preventive maintenance and to avoid unexpected breakdowns that affect passenger services.

Maintaining round-the-clock safety and security

Safety and security are always operators' paramount concerns. It is imperative to continue providing safe passenger transport while increasing the service level. Whether in a station or at a train stop, on the platform or in the train, operators also need to constantly ensure physical security for passengers and staff everywhere across the railway infrastructure.

Enhancing the journey experience

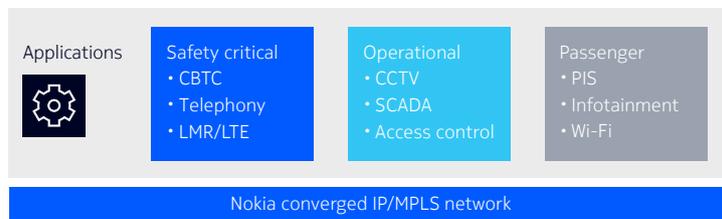
Passengers in a digital society expect to be online anywhere they go. Riding on a train is no exception. They want to stay connected while in transit. They also want to be kept informed of the trip status in real time with information such as their present location, the time-to-next-stop, and local attractions.

¹ "World Urbanization Prospects, The 2014 Revision (Highlights)," The United Nations.

Digital transformation is required

To meet these challenges, urban railway operators are embracing digital transformation by introducing new IP-based railway applications across their infrastructure. These range from safety-critical control and signaling systems such as communications-based train control (CBTC), to operational ones including CCTV and intrusion and access control (IAC) systems, to passenger applications such as passenger information display systems (PIDS) (see Figure 1). (For existing lines, operators sometimes just upgrade existing applications or deploy additional systems to improve control and extend operational capabilities.) To improve the ride experience, many operators are also starting to provide infotainment and Wi-Fi® services.

Figure 1. Sample applications used by urban railway operators



Digital transformation requires a reliable, secure network that interconnects all application subsystems and components across the railway infrastructure. The essential attributes of the network are discussed in the following sections.

Full service convergence

In the past, railway operators have deployed purpose-built networks to support specific applications. As a result, they need to operate multiple networks with different generations of technology. With extensive adoption of applications, this old paradigm of an application-specific, purpose-built communications network is no longer feasible. Operators need a converged network architecture that can support multiservice applications with IP/MPLS VPN technology.

Furthermore, because new applications such as CBTC, CCTV and LTE radio systems are typically IP-based, scalable IP VPN capabilities, combined flexibly with layer 2 VPN when necessary, in the converged network are imperative to be prepared for a multitude of applications today and tomorrow.

Deterministic QoS

There is a diverse set of applications across the infrastructure, and each has a different network QoS requirement (see Table 1). Real-time, safety-critical applications such as CBTC require strict delay. Other applications, such as CCTV and PIDS, have less demanding network performance requirements. With deterministic QoS, the network can consistently meet different application-specific requirements, ensuring that all application performance levels are met constantly.

Table 1. Sample rail applications and associated network QoS requirements

	Latency	Bandwidth	Reliability	Criticality
CBTC	Low	Low	High	High
CCTV	Medium	High	Medium	Medium
Passenger Wi-Fi	High	High	Low	Low

High network availability

When network connectivity is disrupted, affecting critical applications such as CBTC and signaling, operators lose oversight of the trains and need to halt train services to ensure passenger safety. This causes significant passenger delay and dissatisfaction as well as incurring economic loss and tarnishing the city’s reputation. For these reasons, it is imperative that railway operators strive to design the network with ultra-high network availability.

Rigorous security

Digital transformation ushers in wide use of information and communication technologies (ICT) in railway operations, increasing the attack surface and engendering new vulnerabilities. Consequently, cyber security has become a top concern. Operators need to safeguard the ICT infrastructure from malicious attacks. Accordingly, operators need a robust network defense to safeguard railway infrastructures.

Bridging the past to the future

Urban railway systems have served the public since 1863, when the London Underground first opened. They have adopted applications at different times to attain operational efficiency and safety. One example is the introduction of SCADA systems to supervise and manage train operations and railway assets.

Once in use, these applications typically have a long life and are seldom replaced. Therefore, it is crucial that the converged network can seamlessly interoperate with these systems with no performance degradation or disruption of operations.

Simplified management

Managing a reliable network carrying numerous applications with many connected devices and application subsystems is a monumental task. Operators need a network management platform that can help them to provision, operate, maintain and troubleshoot the network proficiently.

To optimize efficiency and maximize network availability, a service-centric management platform can:

- Enable unified, end-to-end management, with fast and proficient provisioning
- Support proactive service assurance and intelligent alarm correlations
- Simplify other aspects of network operation, including configuration backup and upgrade

Converged IP/MPLS Network for Urban Railways solution

The Nokia Converged IP/MPLS Network for Urban Railways solution is based on a converged, service-oriented architecture to support all applications. It provides high resiliency, assured QoS and robust agility. As a converged network, it can support all railway applications regardless of their criticality over a common network infrastructure, with no compromise in performance and security.

Solution components

The network solution extends IP/MPLS and service capabilities from the core to distribution to access, across the railway infrastructure. It includes the following main components:

- [Nokia 7750 Service Router \(SR\)](#)
- [Nokia 7250 Interconnect Router \(IXR\)](#)
- [Nokia 7210 Service Access Switch \(SAS\)](#)
- [Nokia 7705 Service Aggregation Router \(SAR\)](#)
- [Nokia Network Services Platform \(NSP\)](#)

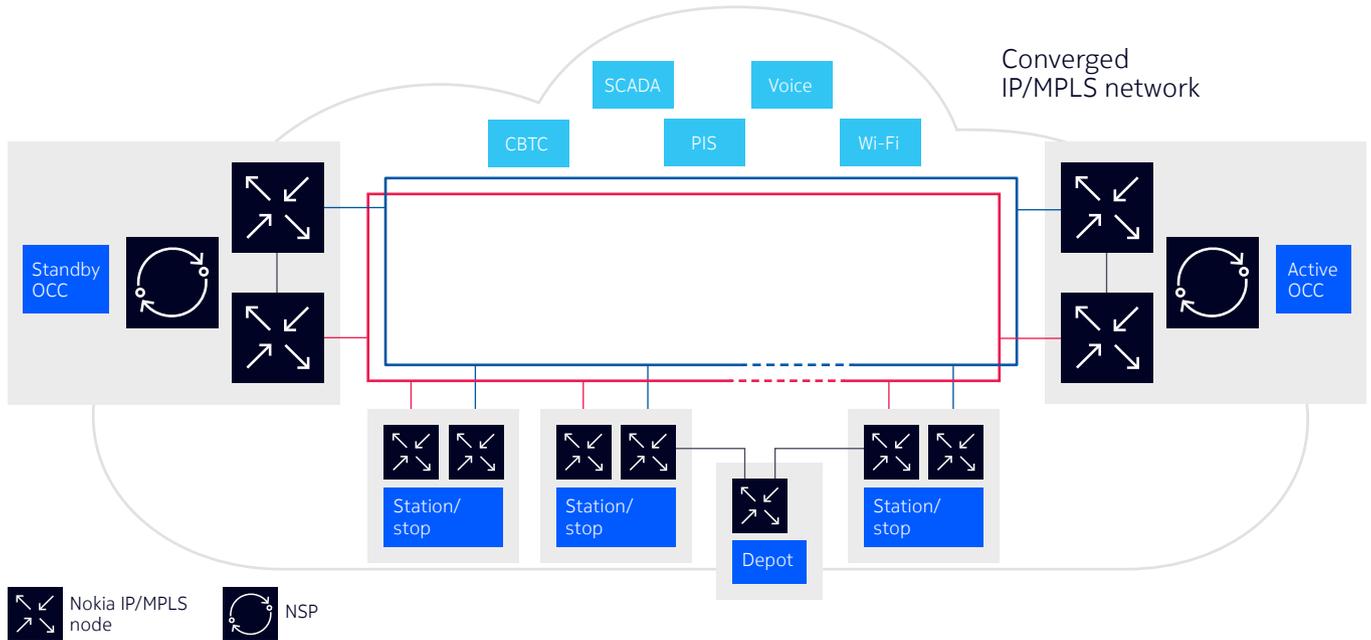
The Nokia IP/MPLS products provide routing, switching and multiservice capabilities, enabling urban railway operators to carry both critical applications such as CBTC and best-effort applications such as passenger Wi-Fi service in the same network, without compromise.

Solution blueprint

The railway infrastructure typically encompasses train stations and stops, depots and a pair of geo-redundant operations control centers (OCCs). There are many types of application subsystems deployed in each location, including CBTC equipment, SCADA remote terminal units (RTUs), telephony systems, information display systems and other ICT systems. All of these require reliable, constant connectivity. Due to the critical nature of the applications, it is crucial that connectivity still be available even under severely unfavorable situations.

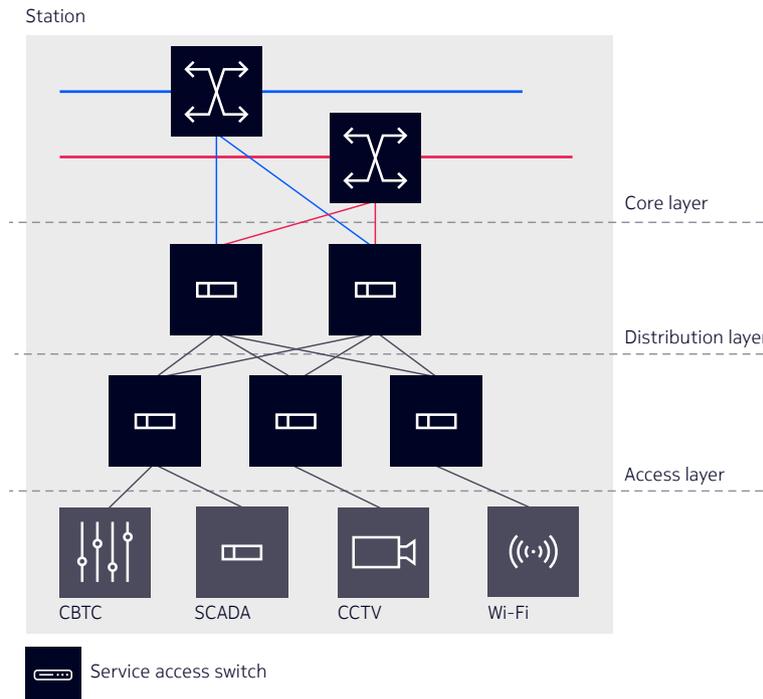
The Nokia IP/MPLS solution blueprint is based on a dual-loop (blue and red) topology using a trackside optical fiber system with discrete cables connecting the two geo-redundant OCCs, train stations and stops as well as other locations (see Figure 2). With IP/MPLS topology flexibility, the network can evolve to a more resilient topology to attain ultra-high availability if necessary. (For details, see “Uninterrupted operations with ultra-high network availability” in the Benefits section).

Figure 2. Nokia converged IP/MPLS network blueprint topology



Inside a train station, there are two IP/MPLS service nodes connected to either the blue or red loop. To effectively connect all subsystems deployed across the facility, a hierarchical network in the station is needed to extend connectivity everywhere in the station with the necessary port fan-out (see Figure 3).

Figure 3. In-station network blueprint



The in-station blueprint typically includes service access switches, forming the distribution and access layers. The access switch provides high port fan-out in a compact form factor and often also powers the attached application subsystems, such as VoIP phone and CCTV camera, through PoE technology.

The distribution switch aggregates traffic onto the core network layer while providing any-to-any in-station connectivity as required by the applications. For example, a video stream from a CCTV camera can be distributed to both a centralized and a local video management system as well as to the local staff station monitor.

Nokia solution benefits

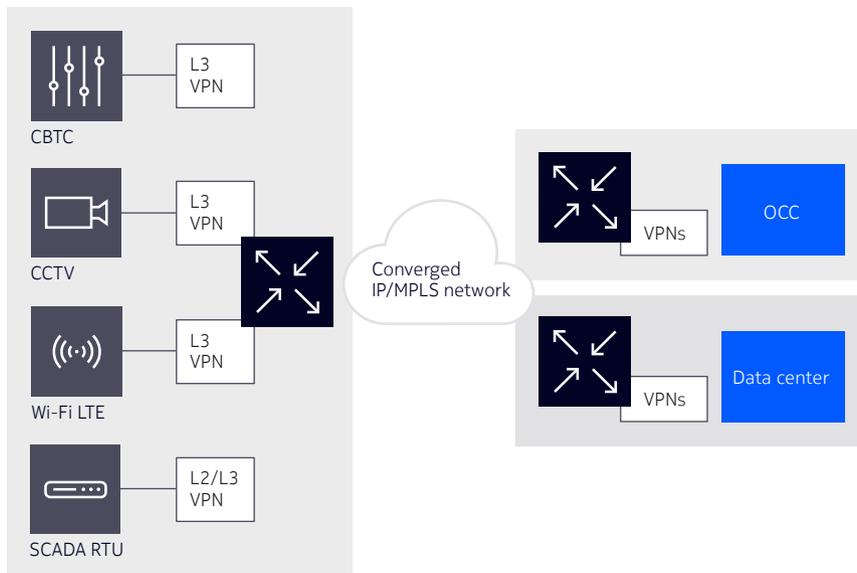
The Nokia Converged IP/MPLS Network for Urban Railways solution capitalizes on IP/MPLS capabilities to offer urban railway operators a wide variety of benefits.

High network efficiency with service convergence

Railway operators can achieve high network operations efficiency with a Nokia IP/MPLS network, which provides full service convergence by supporting multiple applications. The network's flexible IP/MPLS VPN service capability supports IP, Ethernet and TDM communications in both point-to-point and multipoint manner to meet the communications requirements of different applications. Each application is carried over a dedicated VPN, segregated from all other VPNs (see Figure 4).

The network's native IP routing and TDM capabilities eliminate the need for external routers and TDM multiplexers, achieving equipment efficiency while minimizing management efforts, equipment power consumption, sparing and footprint. As a result, a converged network can greatly improve operations efficiency when compared to legacy purpose-built networks. A Nokia IP/MPLS network also prepares urban railway operators to embrace emerging applications such as LTE.

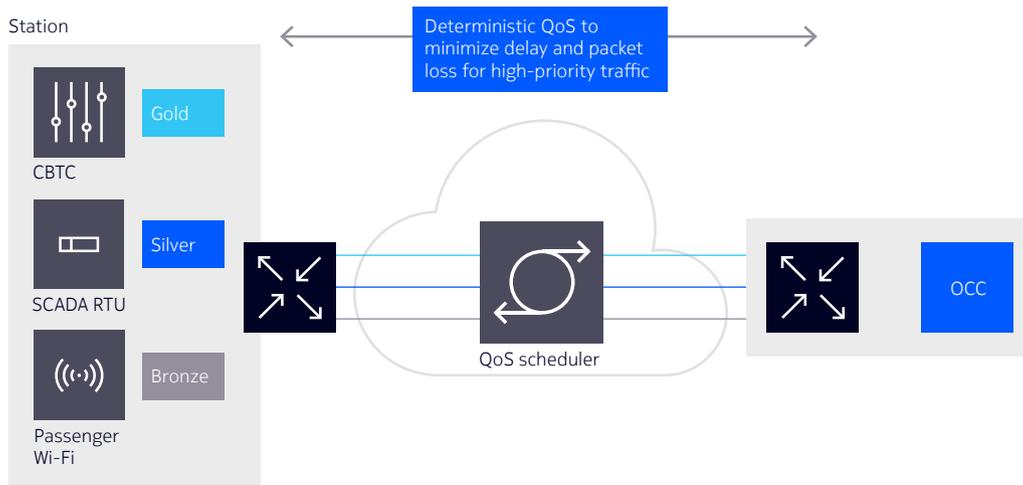
Figure 4. A converged IP/MPLS urban railway network



Assured application performance with deterministic QoS

With a proper network QoS policy, urban railway operators can be assured of network performance for their critical applications. Based on a rich set of classification attributes at layers 1, 2 and 3, the QoS policy can classify all traffic and prioritize traffic transmission accordingly, with extensive advanced queuing and scheduling, in a hierarchical manner. With multiple levels and instances of shaping, queuing and priority scheduling, performance parameters (such as bandwidth, delay and jitter) for different applications can be met constantly (see Figure 5).

Figure 5. Deterministic IP/MPLS QoS provides assured application performance

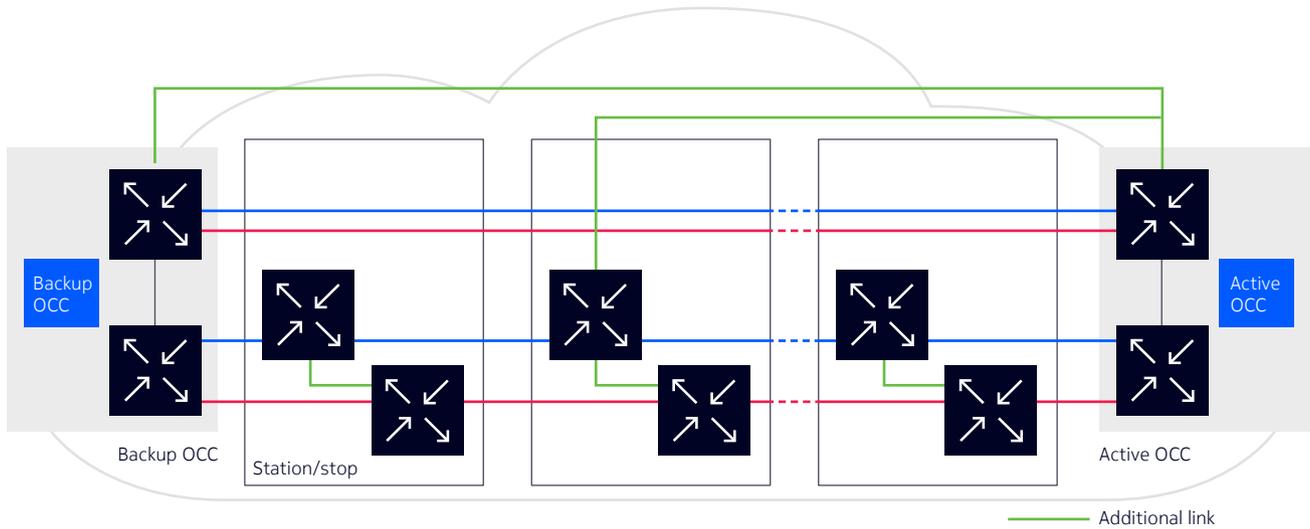


Uninterrupted operations with ultra-high network availability

The Nokia IP/MPLS network can provide ultra-high resiliency by turning the traditional dual-loop topology shown in Figure 2 into a meshed network. As shown in Figure 6, an additional link connects the two core nodes at each station.

At strategic stations, such as a hub location and OCCs, operators can further improve resiliency through a third fiber pair (either fibers along other railway lines or third-party leased fibers). Equipped with additional connectivity and resiliency mechanisms that include fast reroute (FRR), pseudowire redundancy and non-services capability, an IP/MPLS network can recover from even a serious incident at the station or a fire at an active OCC. This allows operators, and first responders if necessary, to continue to attain high situational awareness by receiving data of safety- and security-related applications such as CCTV in order to formulate an appropriate response plan.

Figure 6. A meshed IP/MPLS network provides ultra-resiliency

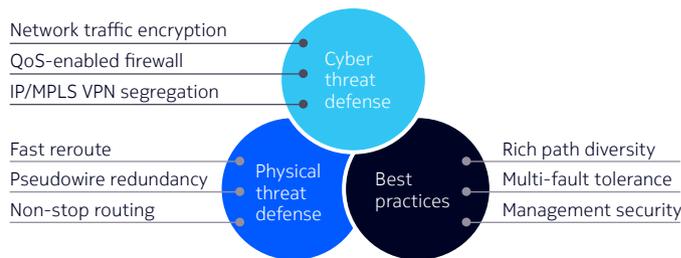


Strong network defense for secured operations²

As a railway infrastructure becomes interconnected and its operations depend heavily on ICT, its attack surface expands significantly. The attacks range from cyber attacks trying to eavesdrop, interrupt and infiltrate, to physical attacks that sabotage communications facilities and sever cables.

A Nokia IP/MPLS network is an integral part of a comprehensive defense framework to protect from cyber and physical threats. It offers a wide range of security capabilities, including encryption and a firewall. Its resiliency (already discussed) is a bulwark against physical threats. Coupled with security best practices, a Nokia IP/MPLS network can effectively deter attacks, enabling the infrastructure to operate without compromise (see Figure 7).

Figure 7. Comprehensive network security with a Nokia IP/MPLS network

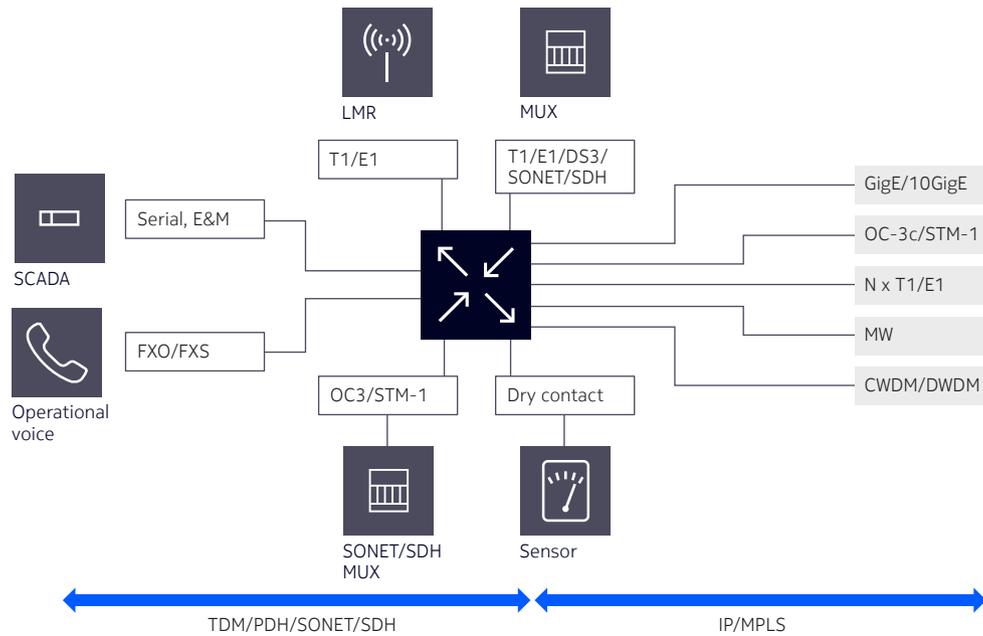


² For more details on security, read the white papers “Cyber Security for Railways”, “Network group encryption: Seamless encryption for mission-critical networks” and “Impregnable network defense for critical infrastructures.”

Bridge from the past to the future

As ICT advances, newer applications systems have evolved to become IP/Ethernet-based. However, some urban railway infrastructures still have older SCADA and emergency voice communications systems based on communications interfaces such as RS-232/V.24 or E&M 4-wire interfaces. With a long useful life, these legacy systems will continue to be in use in the foreseeable future. With its large portfolio of supported interfaces (see Figure 8), the Nokia IP/MPLS network has proven to be interoperable with many older systems and can support migrating application traffic gracefully.³

Figure 8. Wide legacy interface support



Simplified management, increasing operations speed

The Nokia NSP takes urban railway operators beyond the traditional boundaries of network management. Unifying service, network and element management layers across IP/MPLS and transport domains, the Nokia NSP greatly simplifies management tasks. It supports fast, easy and highly flexible provisioning, proactive service assurance that helps to resolve problems early on, and intelligent alarm correlation capabilities that simplifies troubleshooting. The Nokia NSP is also ready to evolve to a software-defined networking (SDN) controller, ushering in new network optimization, automation and programmability capabilities when necessary.

The Nokia NSP greatly simplifies operations, attains optimal efficiency and supports continued network evolution to address emerging requirements.

³ For migration details, read the white paper “Transformation of mission-critical communications networks: Migrating from SDH/SONET to IP/MPLS networks.”

Conclusion

Urban railway operators are at a critical juncture. Urban populations are expanding at a rapid pace and will continue to do so in the foreseeable future. The expansion poses great challenges to operators to provide reliable, sustainable and safe urban mobility. Operators need to be prepared to serve the current and future needs of the urban population, attain eco-sustainability, and for some, continue delivering improved shareholder value.

To meet these challenges, operators need to explore and embrace new innovations and technologies to transform the railway infrastructure into a modern railway system. A converged IP/MPLS network is the nexus of this new digital, smart, always-interconnected railway infrastructure, linking all facilities reliably and delivering information when and where needed.

Nokia's broad communications product portfolio spans IP/MPLS and SDN, packet optical, microwave and LTE. This portfolio is complemented by a full suite of professional services, including audit, design and engineering practices. With this broad range of products and services, Nokia has the unique capability and flexibility to help operators plan and transform their urban railway networks, to be ready for the future.

To learn more about Nokia solutions for railways, visit our [Railways](#) web page.

Abbreviations

CBTC	Communications-based train control
CCTV	Closed circuit television
GSM-R	Global System for Mobile Communications – Railway
ICT	Information and communications technologies
IP	Internet Protocol
LMR	Land mobile radio
LTE	Long term evolution
MPLS	Multiprotocol label switching
MUX	Multiplexer
NSP	Nokia Network Services Platform
OCC	Operations control center
PDH	Plesiochronous digital hierarchy
PIS	Public information system
PoE	Power over Ethernet
PTC	Positive train control
QoS	Quality of Service
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition
SDH	Synchronous Digital Hierarchy
SDN	Software-defined networking
SONET	Synchronous Optical Network
TDM	Time Division Multiplexing
VPN	Virtual private network

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.

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.

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Nokia Oyj
Karaportti 3
FI-02610 Espoo, Finland
Tel. +358 (0) 10 44 88 000

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