



Converged communications for intelligent highways: efficiency today, flexibility for the future

White paper

By using a single converged network architecture for all the communications needs of intelligent highways, highway agencies can provide safe, on-time, connected journeys, while increasing operating efficiency and reducing costs. This optimized communication infrastructure also offers the flexibility to meet growing demand for mobile connectivity — allowing agencies to prepare for automated driving and support a wide range of advanced services that promote safety and keep travelers informed and entertained on their highway travels. The benefits include greater efficiency today and a cost-effective foundation for the future.

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Introduction

Highway agencies face significant challenges in achieving their mission of maintaining traffic flow and road safety: There are more vehicles on the road, high numbers of traffic fatalities, and a world of technological changes driving growing demand for mobile connectivity.

To address these challenges, highway agencies are turning to intelligent transportation systems (ITS). These systems incorporate information and communications technology (ICT) into the highway's infrastructure to improve traffic flow, reduce pollution, and enhance traffic safety and travelers' experience.

When choosing communications technology to enable ITS, highway agencies must keep two crucial goals in mind: streamlining operations today – and providing a flexible foundation for the future of intelligent transportation.

Streamlining operations

During the past decades, highway agencies have added new, more-demanding ITS applications with additional communications technology to their roads. As a result, many agencies are currently using a fragmented and inefficient communications infrastructure. But there is a more effective way to improve traffic flow and highway safety now, while keeping costs down. Agencies can rely on a single converged and ultra-broadband network architecture that meets all the communications needs of their various ITS applications in parallel.

Preparing for the future

One major change is now underway that requires preparation — the emergence of connected cars and trucks, as well as a growing demand for infotainment on the road. Vehicle-to-everything (V2X) communications offers a range of advanced capabilities that can improve traffic safety, for example by avoiding accidents through recognition of hazards, even at high speeds; and it enables new mobility services for auxiliary and convenience.

To take advantage of such features, however, highway agencies must understand the new demands on their communications infrastructure. To get ready for the future a flexible communications architecture is needed. The right technology choices will make it easy to add the latest advanced communications capabilities — such as V2X — and offer streamlined growth to satisfy the future bandwidth demands of travellers and intelligent transportation.

The challenges of providing safe, on-time, connected travel

Highway agencies are facing intense operational pressures now while working to fulfill their mission to the public. These challenges include:

- **More vehicles**

An estimated 1.2 billion vehicles are on the road today, worldwide, with expected growth of 66 percent by 2035.¹ Consequently, the costs of air pollution and traffic delays keep climbing. For instance, in 2010, the estimated cost of air pollution from transport emissions reached \$1 trillion in Organization for Economic Cooperation and Development (OECD) countries.²

1 Navigant Research

2 OECD

- **Traffic-related fatalities**

An estimated 1.25 million traffic deaths occurred in 2013,³ with 90 percent caused by human error.⁴ World Health Organization (WHO) forecasts that traffic crashes will become the seventh leading cause of death by 2030, without sustained preventive action.

- **Rapid growth in connected vehicles**

Two-hundred and fifty million connected vehicles are expected to be on the roads in 2020,⁵ which will increase demand for mobile services that enhance passenger convenience and safety.

Highway agencies are deploying technology to their roads to help meet these challenges. To build an intelligent highway, roadside equipment is interconnected with central applications, as well as vehicles, road workers, and travellers. Communications technology is the crucial link tying ITS applications to the physical highways infrastructure. Its role began with emergency roadside call systems in the 1970s, then progressed to today's managed lanes and active traffic management systems — and will link automated vehicles tomorrow. Network connections are used to deliver voice, video, and data services that are designed to improve traffic flow, reduce pollution, and enhance traffic safety and travelers' experience.

Today, however, highway agencies are suffering from the inefficiencies in their communications infrastructure, which result from ITS growth and change over the years. These inefficiencies prevent the agencies from further improving traffic flow and reducing road fatalities.

Inefficient communications infrastructures

Despite the intensity of today's operating issues, many agencies are still relying on a communications infrastructure that is a patchwork of different networks, deployed over many years, so they now operate in parallel with limited interconnectivity. These voice, video, and data networks could leverage different transport technologies, and typically support different ITS applications, with each having unique requirements. In addition, old roadside equipment often uses legacy interfaces.

As a result, they cannot work truly effectively and efficiently to maintain safe, on-time journeys. Instead, their fragmented approach often lacks the ability to make optimal use of network resources and react to network events fast enough. Thus, they cannot guarantee to meet the requirements for each ITS application and traffic type, end to end.

In addition, it is often difficult — and sometimes impossible — to incorporate emerging communication capabilities smoothly into a diverse array of existing systems. So highway agencies cannot easily address either the opportunities or challenges of some new advanced ITS applications. For instance, V2X simply cannot be realized with today's communications infrastructure.

3 WHO

4 McKinsey & Company

5 Gartner

The solution: A single converged communications infrastructure

Meeting the challenges of safe, on-time, connected travel — **cost-effectively** — requires an optimized communications infrastructure. The key is to choose a single, converged and ultra-broadband network architecture for all ITS applications. While further promoting safe and on-time journeys, this integrated approach increases interconnectivity between the various ITS applications, allows greater collaboration between the highway's stakeholders, and enables greater operating efficiency. It provides valuable improvements by avoiding a patchwork of networks, simplifying network operations, and using remote monitoring and configuration for roadside equipment. These capabilities also lower the costs of maintenance, training, and network downtime for repairs.

An optimized infrastructure helps enhance efficiency today, while establishing a foundation for meeting future connectivity demands, with V2X communications and 5G technologies in mind. As a result, highway agencies can take full advantage of the potential of an increasing mobile broadband demand and automated driving. That includes adding new ITS applications faster — with less additional investment — whether the infrastructure is used to improve highway safety, enhance passenger convenience, or monetize new service offerings.

For instance, Highways England turned to Nokia for assistance in building a new end-to-end communications solution that offered greater efficiency than their patchwork of more than 30 voice, video, and data networks. While promoting greater safety for travelers, the simplified solution has optimized operational costs and increased flexibility for meeting the future demands of intelligent transportation.

Communications requirements to build an optimized communications infrastructure

The following communications requirements are based on Nokia's 25 years of experience working with the highways industry. To build an optimized communications infrastructure for intelligent highways, these requirements must be fulfilled over a single, converged network architecture.

- **Service requirements**

Each ITS application and traffic type has unique requirements that must be supported. The full service mix may include data, voice, and video services with individual QoS, bandwidth, latency, jitter, and availability requirements — along with critical services, such as emergency roadside call systems, and less-critical services, such as data from roadside sensors. The right technology choices will address all these requirements in parallel.

- **Transport technologies**

Various transport technologies need to be integrated. Most existing ITS services have used SDH, PDH, SONET, or TDM technology. Now, IP-based applications have more stringent demands, and may operate in parallel.

- **Roadside equipment**

Older equipment often uses legacy interfaces, including serial (RS232, V35, or X21), E&M, E1, or dry contacts — which must all be supported on the single infrastructure.

- **Long life cycles**

Some critical services may need to maintain a life cycle of 15 to 20 years, and the optimized infrastructure should allow for flexible support throughout the life cycle.

- **Monetization**

An optimized communication infrastructure also presents the opportunity to offer valuable new services or resell backhaul capacity.

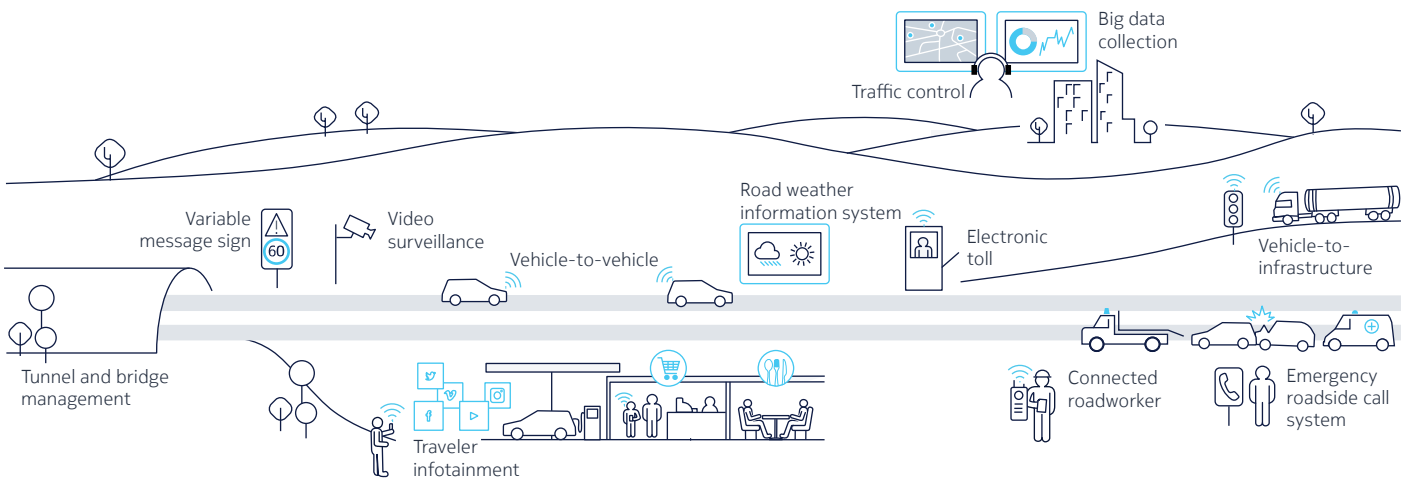
- **Future uncertainty**

A converged infrastructure for intelligent highways should also have the flexibility to support a range of emerging ITS communication needs, such as enabling automated driving and V2X capabilities. Preparing for these capabilities is an important investment in the future — and helps extend the life of capital expenditures.

Use cases for intelligent highways

Here is a sampling of how a highway agency can put an intelligent highway with ITS to work, as illustrated in Figure 1 and described in the following sections. All these applications will share the same optimized communications infrastructure.

Figure 1: Example: ITS use cases applied to highways



Keeping traffic safe

A single network architecture can help reduce accidents and fatalities and provide faster incident response times. To achieve these goals, it supports a wide variety of tools and services that can all work together more effectively, including video surveillance, emergency roadside call systems, and tunnel and bridge management.

For example, Nokia enables high-definition video protection everywhere through network support for thousands of high-quality IP video cameras along highways — with interconnection to local and centralized traffic control centers. This crucial real-time information helps highway agencies detect incidents and emergency situations faster, for quicker response times.

Effective emergency roadside call systems also help reduce the number of injuries and accidents on the road. A reliable communication infrastructure is crucial to connect roadside telephones to emergency response agents for faster assistance to drivers.

Keeping traffic on time

Communications infrastructure for intelligent highways helps improve traffic flow, reducing travel times and decreasing pollution. To achieve these goals, it integrates a wide variety of roadside systems, including variable message signs, road weather information systems, advanced traffic management, and electronic toll collection.

For instance, traffic management systems collect data from roadside equipment, such as loop sensors, laser scanners, and video cameras, to monitor traffic conditions in real time. The data enables faster responses to congestion, emergency situations, weather, and other conditions — and helps keep traffic flowing smoothly.

Keeping traffic connected

Looking ahead, an optimized communications infrastructure for ITS will also use emerging technologies – such as V2X – to enable a wide range of connected capabilities. Nokia offers special expertise in these new capabilities, based on the company's cooperation with the automotive industry, research at Nokia Bell Labs, and in-house product development.

The following examples briefly illustrate the potential of V2X, including vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P), and vehicle-to-network (V2N) communications. Some will improve safety. Others will keep travellers informed, offer new entertainment services, or help highway agencies prepare for automated driving.

- **Safety-critical V2X**

Low-latency connectivity will be leveraged for applications such as collision warning, emergency electronic brake light, overtaking assistant, and vulnerable road user warning.

- **Situational awareness**

V2X communications will enable applications such as queue warning and hazardous road condition warning.

- **Mobility services**

Connecting vehicles to each other and to their environment allows the creation of new value-added services such as automated parking and tolling systems, traffic advisories, and dynamic ride sharing.

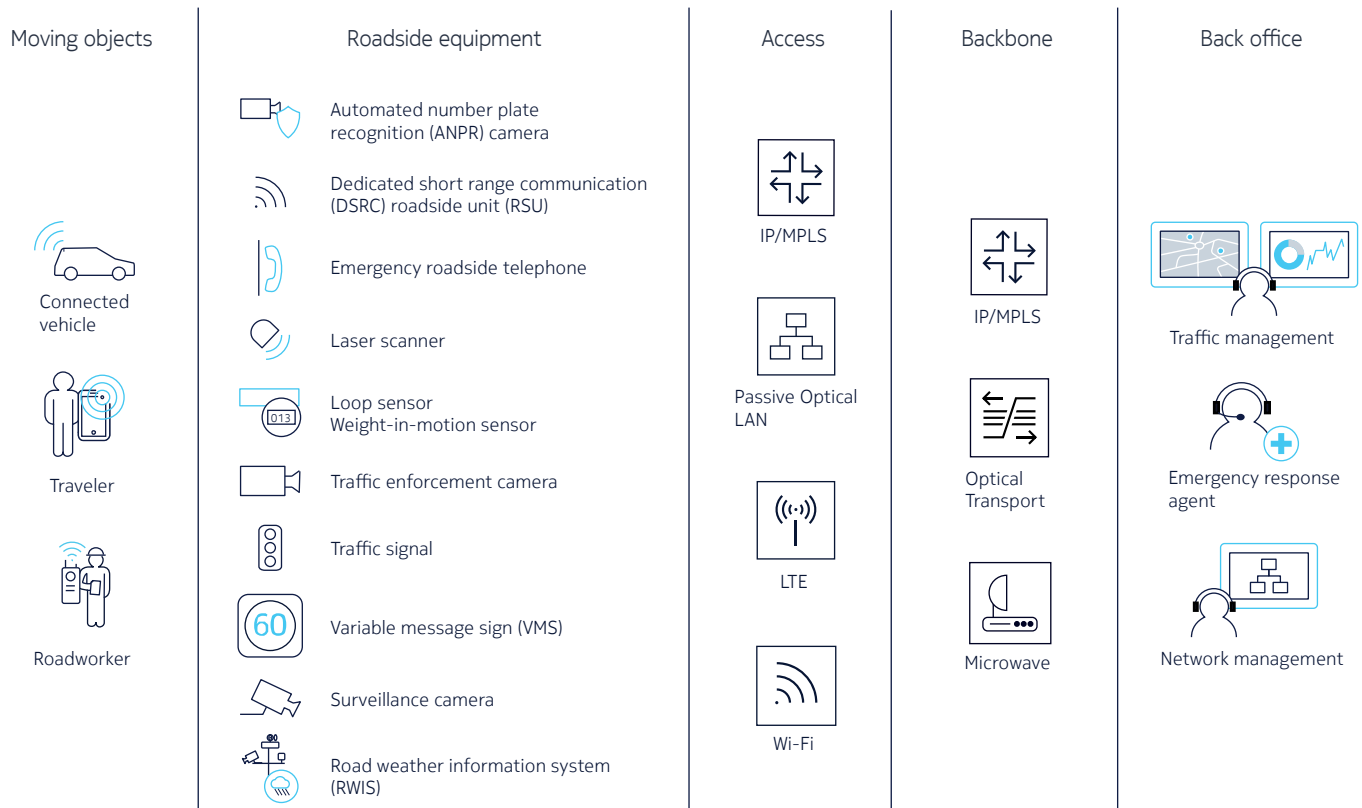
- **Auxiliary and convenience**

Broadband V2X communications has the potential to create a new traveller experience including infotainment, local information, and route planning.

Technologies for building an optimized communications infrastructure

Figure 2 provides a conceptual view of an optimized communications infrastructure for highways, including the highway travellers, roadside equipment, access network elements, backbone network elements, and back-office equipment, applications, and staff. Nokia has a complete portfolio of technologies and solutions for building this kind of infrastructure. Our offerings fulfill the communications requirements outlined earlier in this white paper

Figure 2: Conceptual network architecture of the communications infrastructure for highways



The following list provides a brief overview of the key elements that may be used. With expertise in mission-critical networks and ultra-broadband communications — combined with relevant highways industry experience — Nokia can help agencies map appropriate technologies to their specific use cases.

Access

- Hardened IP/MPLS access routers and switches connect equipment along the roadside and provide legacy interfaces for existing equipment as well as support for SCADA systems.
- Passive optical LAN (POL) technology provides cost-effective access for modern IP/Ethernet roadside equipment.
- LTE-4G technology improves mobile network coverage on highways for travellers and for vehicle-to-everything communications.
- Wi-Fi provides broadband connectivity that improves the traveller experience and supports roadside operations.
- Edge computing processes content at the very edge of the communications networks, right at the roadside.

Backbone

- IP/MPLS technologies can support all ITS communication needs over a single network architecture.
- Optical transport provides high-bandwidth WDM packet transport.
- Microwave packet radio provides connectivity where fiber is not available or is expensive to trench.
- A network services platform includes management tools for easy configuration and control of the end-to-end network.

Network security

- Security management is used to govern and manage access to networks, data, and systems. It also measures security compliance and initiates responses.
- IP/MPLS portfolio elements include network group encryption, firewall, and other protection mechanisms.
- Optical transport and microwave packet radio portfolio elements include layer 1 transport encryption, and centralized key management, among other protection mechanisms.
- Elements can include behavioral analytics, encryption, firewalls, and other protections.

Network services

A full range of services is available to help highway agencies plan, optimize, deploy, operate, maintain, and upgrade a converged communications network for an ITS.

Nokia advantage for intelligent highways

A network infrastructure built from Nokia portfolio elements offers several compelling advantages over other communications solutions for highways, including:

- A safe and smooth migration path from older technologies to MPLS, which supports both IP-based and legacy-based roadside equipment — from 1970s weather stations to new-generation surveillance cameras
- Seamless support for multiple critical services, such as emergency roadside voice calls, as well as less-critical services like data from roadside sensors
- Greater network capacity in access and backbone networks, which enables data analytics in real time
- Mobile broadband connectivity for advanced traveller experience and automated driving
- High availability and network resiliency
- Cyber attack protection with a wide range of embedded security features
- A unified network management platform with simple, effective management tools.

Business benefits of an optimized communications infrastructure

Using a single converged and ultra-broadband network architecture for mission-critical communications not only helps highway agencies enable safer, on-time, connected journeys. It can also produce operational benefits in both the near and longer term.

The immediate benefits include more cost-effective operations, through using a simplified infrastructure, rather than a patchwork of diverse networks. This converged approach reduces operating, maintenance, and training expenses and minimizes downtime for network repair.

In the longer term, highway agencies can add new V2X-enabled capabilities that support highly responsive connected services. These advances can be used to boost safety on the road, enhance the traveler experience, improve automated driving, or generate additional revenues with information and entertainment services for travelers.

Conclusion

With the challenges highway agencies are now facing, an optimized communications infrastructure supporting ITS is a critical foundation for serving the public effectively — at lowest cost. The right solution can be developed to meet each organization's unique needs for efficient operation today, using a flexible architecture that can also satisfy growing demands for mobile connectivity in the future.

This simplified, integrated approach offers the most advantageous way to streamline operations, while preparing for the future of intelligent transportation.

To learn more, go to <https://www.nokia.com/networks/industries/highways/>.

Abbreviations

ICT	Information and Communication Technology
IP/MPLS	Internet Protocol/Multiprotocol Label Switching
ITS	Intelligent Transportation Systems
LTE-4G	Long-Term Evolution Fourth Generation
PDH	Plesiochronous Digital Hierarchy
POL	Passive Optical LAN
SDH	Synchronous Digital Hierarchy
SONET	Synchronous Optical Networking
TDM	Time-Division Multiplexing
V2I	Vehicle-to-Infrastructure
V2X	Vehicle-to-Everything
V2N	Vehicle-to-Network
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle

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