NordicWay

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List of abbreviations

AMQP	Advanced Message Queuing Protocol
CAM	Cooperative Awareness Message
CCAM	Connected, Cooperative and Automated Mobility
C-ITS	Cooperative Intelligent Transport System
DATEXII	Standard developed for information exchange between traffic management centres, traffic information centres and service providers
DENM	Decentralised Environmental Notification Message
EIP	European ITS Platform
GNSS	Global Navigation Satellite System
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
ITS	Intelligent Transport System
ITS-G5	Set of protocols and parameters for wireless point to point communication as specified in ETSI ES 202 663 V1.1.0
KPI	Key Performance Indicator
LPWAN	Low-Power Wide-Area Network
LTE	Long Term Evolution
MaaS	Mobility as a Service
MNO	Mobile Network Operator
OBD-II	On-Board Diagnostics
OEM	Original Equipment Manufacturer
QoS	Quality of Service
PPI	Public Procurement of Innovation
PSAP	Public Safety Answering Point
RWW	Road works warning
SP	Service Provider
SPaT	Signal Phase and Timing
SRTI	Safety Related Traffic Information
SSL	Secure Sockets Layer

TLS	Transport Layer Security
TMA	Truck Mounted Attenuator
TMC	Traffic Management Centre
V2X	Vehicle-to-Anything (X=V : Vehicle ; X=I : Infrastructure)

Executive Summary

NordicWay was an EU project to test and demonstrate the interoperability of cellular C-ITS (cooperative ITS) services both for passenger and freight traffic, piloting continuous services offering a similar user experience in the whole NordicWay network in Denmark, Finland, Norway and Sweden. NordicWay was a real-life deployment pilot, aiming to facilitate a wider deployment in the Nordic countries and in Europe in the next phase. The project followed the policy guidance of the European Commission, and was supported via the Connecting Europe Facility (CEF) programme managed by INEA.

The NordicWay pilots included both the testing and piloting of the chosen common key services as well as the additional national services and C-ITS application domains following the national needs covering the defined NordicWay network. The common key services were:

1. cooperative weather and slippery warning
2. cooperative hazardous location warning
3. cooperative road works warning
4. probe vehicle data.

NordicWay had the following general objectives:

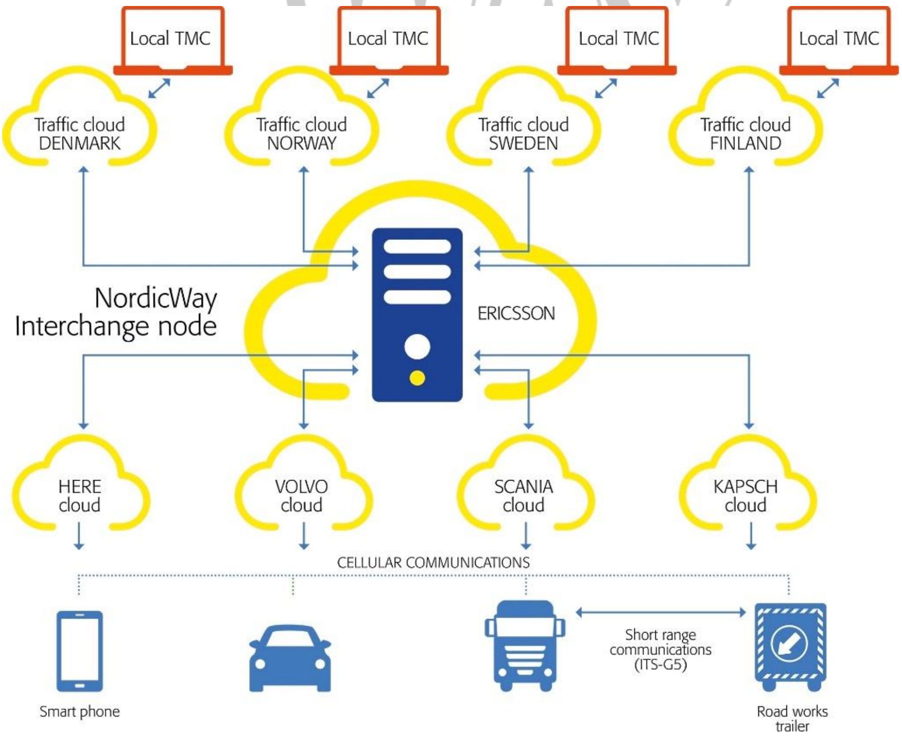
1. To improve road network performance (efficiency, environmental impact, safety and security) through deployment of cooperative services. This will make better use of existing infrastructures and bring reduction of congestion and fatalities.
2. To improve the quality and coverage of key safety services (road weather warning and hazardous location warning) by using C-ITS. This is achieved through acquiring and using probe data from the vehicles, and also by additional and complementary data from other sources such as vehicle fleets and navigation devices and smartphones. Probe data also extends the coverage to parts of the road network where no data is currently available.
3. To demonstrate C-ITS benefits to users, by providing them with accurate traffic and travel information and improved services through cellular communications and collection of probe data, making their journeys safer and more environmentally friendly as well as making the travel times shorter and more predictable.
4. To establish C-ITS markets for commercial value-added services and to move towards new concepts such as MaaS (Mobility as a Service) and automation.

The key innovations of NordicWay were the following:

1. It was the first large-scale pilot demonstrating the technical feasibility and as a proof-of-concept of probe data collection and C-ITS service delivery using cellular communication (3G and LTE/4G) in combination with ITS-G5 communication.

2. It offered to the users continuous interoperable services with roaming between different mobile networks and cross-border, offering C-ITS services with similar user experience in all four countries.
3. It was a business – industry/promoter oriented project, with the emphasis of building a sustainable business model and ecosystem for the data value chain and stakeholders (public sector – road authorities, C-ITS operators, automotive industry, telecom operators, and content and service providers).
4. It was built on the large investment of the public sector in the priority services of the ITS Directive 2010/40/EU (real-time traffic information and safety-related information) in improving the service provision and presentation parts of the value chain by delivering the services in a personalised way in real-time to the road users, in their vehicles on in-vehicle displays and on smart devices, and also offering an open content access point for the data.
5. NordicWay demonstrated real improvements in the quality of key safety services (road weather warning, hazardous location warning, road works warning) over the currently deployed services due to use of C-ITS and related probe data.
6. NordicWay was fully based on European and global standards, and was geared towards achieving full interoperability in the four participating countries with cross-border testing, and later extension to other regions in Europe.

A key result of the project is the NodicWay Interchange network concept.



The NordicWay solution, the Interchange Network, is an interoperable cellular cloud based C-ITS solution, which is scalable to Europe and beyond. The solution is based on the transfer of information between different service provider clouds and traffic clouds, combined with low-latency transfer over cellular networks between vehicle and service operator. Messages exchanged between clouds are based on existing standards, using the DATEX II data model and the AMQP queuing protocol. The NordicWay system worked well during the pilot. The Interchange Node was demonstrated to work well, and the architecture was proven to suit the services, also in the cross-border demonstrations carried out. The related assessment indicated that the value of interoperability depends on a penetration rate of at least five percent.

The project also resulted in an ecosystem supporting the OEMs and service providers' customer relationships. The end-user is connected to a service provider or OEM, which takes care of security and privacy of the communications.

The median end-to-end latencies in the system were in most cases well below 1 second, which is sufficient for the type of messages involved, which are mainly targeted at increasing situational awareness of the driver. Further, the same evaluations examined success rates in message delivery. Overall, message delivery rates were very high, but some messages were not delivered or returned. The NordicWay Interchange Node did not increase the latency by more than 14 milliseconds. One critical issue was the packaging of DATEX-II messages into AMQP messages. The use of the different standards should be further harmonized, e.g. by providing guidelines on the use of location referencing by the different stakeholders in DATEX II and on the event lifecycle management. In addition, some issues with the AMQP headers were noticed during the preparations for the interoperability demonstration. Hence, further work, similar as the work performed in C-ROADS on profiling is needed. Furthermore, the HMI should be further harmonized, as different stakeholders use currently different icons for the same messages. The in-vehicle warnings need to be consistent with information provided from the roadside, e.g. variable message signs.

The technical evaluations also found insufficiencies in vehicle sensor based slippery road detection for developing decision support for winter maintenances The indicative communication range forITS-G5 was found to be less than 500 meters with a clear line of sight.

The impact evaluation results indicate that receiving hazardous location warnings influences choice of speed and route, as well as focus in traffic. These impacts result in positive road safety impacts of the service, particularly relating to warnings of slipperiness, animals or people in the road. Impacts lead to reductions in traffic accidents, improved travel efficiency, and benefits to the traffic management centres, who receive more information.

The system was piloted successfully in four countries, with more than 1 800 users. In Finland, drivers were highly satisfied with the service, and wanted to use it after the end of the pilot. Their satisfaction was especially prominent with how far ahead of an incident the users received the warning. The Norwegian evaluation focused on the attitudes of maintenance contractors and road authorities towards a hypothetical support system for winter road maintenance (i.e. acceptability), and found the acceptability to depend on the data upon which the system is based.

The Finnish evaluation also presented a socio-economic assessment to identify expected costs and benefits related to full-scale implementation of the C-ITS service tested in the Finnish pilot, and to determine the expected cost-benefit ratio. Socio-economic evaluation resulted in a benefit-cost ratio for the period 2019-2030 to be at least 2.3.

The barriers and success factors identified in the pilots are to some degree specific for the C-ITS service that was piloted, but also included issues transferrable to the establishment and delivery of any C-ITS service through the NordicWay Interchange Node. Critical issues included infrastructures and integration, standardisation, network coverage, information reliability, data quality, stakeholder involvement, and private-public partnerships with defined roles and responsibilities. Concerning security, provisions should be put in place to ensure that data is only provided to the intended partners. Barriers and facilitators for deployment are further described in a specific NordicWay roadmap for next phase deployment.

The Swedish evaluation discussed fundamental issues for making the Interchange Node available to a larger market. Allowing access to a multitude of data is expected to increase market potential. Market potential could be further increased through facilitating scalability and interoperability with other central service nodes, and through allowing other data and service providers to join the NordicWay community. Establishing the NordicWay Interchange Node requires private-public partnerships in which public authorities play a leading role in the early phase. This involves defining roles and responsibilities of all actors. Because of little experience with business models and willingness to pay, this is particularly important to ease insecurities related to long-term operation of the NordicWay Interchange Node.

The next phase is to go to the full deployment of the Interchange Node. For this purpose, mechanisms for compliance (e.g. for taking on board new stakeholders) have to be defined. As a single Interchange Node may not fulfil the needs of all stakeholders, a more federated architecture including multiple Interchange Nodes may be required.

The NordicWay solution relies on existing standards, such as DATEX II and AMQP. A specific event can be coded in many ways in DATEX II, dependent on country or operator specific preferences for e.g. location referencing. Profiling is needed to make the messages exchanged by the different actors more uniform, and this is fully in line with the conclusions of the European Commission and the C-Roads Platform.

The results of the NordicWay project will be used by the NordicWay 2 project, which will take the system still closer to large-scale deployment. NordicWay 2 will bring much more services to more users on a larger part of the road network, and also address cloud-to-cloud connectivity for automated driving.

Both short-range and medium-/long-range cellular communications have a place in C-ITS, with short-range communication allowing extreme low-latency for safety critical operations, and cellular communications for covering the whole road network with almost all C-ITS services.

Cooperative ITS or C-ITS has been one of the priorities for ITS deployment for many years, and especially during the past few years. It is evident that the quickest way for reaching maximum road network coverage and vehicle fleet coverage is to use a solution based on existing cellular connectivity of vehicles in combination with already existing cellular networks. Hence, the solution provided now by NordicWay, with proven interoperability, low latencies, high user acceptance, considerable benefits, and low costs is now offering the way to go forward on the European, and also the global scale to deploy C-ITS in the large scale.

1. Introduction

1.1. Objectives and scope

The main objective of the NordicWay project was to test and demonstrate the interoperability of cellular C-ITS (cooperative ITS) services both for passenger and freight traffic, piloting continuous services offering a similar user experience in the whole network. NordicWay was a real-life deployment pilot, aiming to facilitate a wider deployment in the Nordic countries and in Europe in the next phase.

The NordicWay pilots included both the testing and piloting of the chosen common key services as well as the additional national services and C-ITS application domains following the national needs covering the defined NordicWay network.

C-ITS services can today be provided over either 5.9 GHz (ITS-G5) or over cellular technologies (3G/4G). One of the major targets of the NordicWay project was to assess how current cellular technology and existing cellular networks can be used to provide C-ITS services, hence avoiding the need for substantial dedicated C-ITS communication infrastructure investments.

Basically, NordicWay pilots C-ITS via hybrid communications, where similar services are provided both by ITS-G5 and by cellular communications. Such pilots have been and are carried out also elsewhere, but there the basic solution has been ITS-G5 with cellular communications in a complementary role. The NordicWay partners had a different starting point, where cellular communications are the basic solution for C-ITS with full road network coverage, and ITS-G5 complements it in specific “hot spots”.

For compatibility and interoperability reasons, in-vehicle platforms can be equipped with hybrid communications, which complement the cellular communications with ITS G5. This allows access to and continuity of services across geographical borders as long as one of the communication technologies has been in use in the neighbouring countries.

In the different pilots, three C-ITS services were commonly piloted or supported, allowing to offer the opportunity to test the interoperability of services through the whole corridor. The NordicWay Pilot common key services were originally:

1. cooperative weather and slippery warning
2. cooperative hazardous location warning
3. probe vehicle data.

In practice, road works warning was added in the list of common services during the project.

NordicWay had the following general objectives:

1. to improve road network performance (efficiency, environmental impact, safety and security) through deployment of cooperative services. This will make better use of existing infrastructures and bring reduction of congestion and fatalities.
2. To improve the quality and coverage of key safety services (road weather warning and hazardous location warning) by using C-ITS. This is achieved through acquiring and using probe data from the vehicles, and also by additional and complementary data from other sources such as vehicle fleets and navigation devices and smartphones. Probe data also extends the coverage to parts of the road network where no data is currently available.
3. To demonstrate C-ITS benefits to users, by providing them with accurate traffic and travel information and improved services through cellular communications and collection of probe data, making their journeys safer and more environmentally friendly as well as making the travel times shorter and more predictable.
4. To establish C-ITS markets for commercial value-added services and to move towards new concepts such as MaaS (Mobility as a Service) and automation.

Assessment of the benefits and user acceptance of C-ITS services was in a clear focus of NordicWay. The assessment results were the basis for next phase of the project and full deployment of cellular C-ITS in Nordic countries. NordicWay verified the performance, effectiveness and benefit/cost of cooperative services also in difficult winter and weather conditions.

In general, the C-ITS services have been set up and operated primarily by private sector stakeholders. For this reason, the services throughout the NordicWay corridor were provided by the private sector stakeholders, whereas the beneficiaries facilitate this by funding specific additional costs due to piloting and evaluation. The private stakeholders used the pilot for their own product and service development, deployment and marketing in several ways.

The key innovations of NordicWay were the following:

1. It was the first large-scale pilot demonstrating the technical feasibility and as a proof-of-concept of probe data collection and C-ITS service delivery using cellular communication (3G and LTE/4G) in combination with ITS-G5 communication.
2. It offered to the users continuous interoperable services with roaming between different mobile networks and cross-border, offering C-ITS services with similar user experience in all four countries.
3. It was a business – industry/promoter oriented project, with the emphasis of building a sustainable business model and ecosystem for the data value chain and stakeholders (public sector – road authorities, C-ITS operators, automotive industry, telecom operators, and content and service providers).
4. It was built on the large investment of the public sector on the priority services of the ITS Directive 2010/40/EU (real-time traffic information and safety-related information) in improving the service provision and presentation parts of the value chain by delivering the services in a personalised way in real-time to the road users, in their vehicles on in-

vehicle displays and on smart devices, and also offering an open content access point for the data.

5. It demonstrated real improvements in the quality of key safety services (road weather warning and hazardous location warning) over the currently deployed services due to C-ITS and related probe data.
6. NordicWay was fully based on European and global standards, and was geared towards achieving full interoperability in the four participating countries with cross-border testing, and later extension to other regions in Europe.

NordicWay pilot acted as the last mile between C-ITS research and development and wide-scale deployment. Therefore, it was geared towards solving all the barriers towards deployment, analysing the performance of the system, assessing the scalability, cost-benefit and user acceptance and changes in driver behaviour, plus developing a business model and a detailed scenario for the roll-out.

1.2. Project Structure

The project was built up on 2 Activities, and several sub-activities:

Activity 1. Management and preparation

- Sub activity 1.1 - Management and coordination
- Sub activity 1.2 - Architecture and services
- Sub activity 1.3 Conformance, interoperability and standards
- Sub activity 1.4 Information and dissemination
- Sub activity 1.5 Evaluation of the results and definition of the next phase

Activity 2. NordicWay pilot

- Sub activity 2.1 Finnish pilot
- Sub activity 2.2 Swedish pilot
- Sub activity 2.3 Norwegian pilot
- Sub activity 2.4 Danish pilot

1.3. Reading guide

During the project, the activities on Architecture and Interoperability were performed in close collaboration with each other. Ensuring interoperability was the key topic in the design of the architecture. Hence, in this report, the relevant tasks will be reported together.

Chapter 2 of the report deals with the architecture and interoperability, with the general aspects driving the design of the different pilots.

Chapter 3-6 reports on the execution of the different national pilots, country by country.

Chapter 7 provides an overview of evaluation activities in NordicWay. This includes i) definition of KPIs and the evaluation guidelines, ii) evaluation of the results, and iii) definition of the next phase.

Chapter 8 gives an overview of the dissemination and communication activities in the NordicWay project.

Chapter 9 gives an overview of the management activities.

Chapter 10 provides conclusions.

2. Architecture, services and interoperability

This chapter reports on the results of the sub activities 1.2 (Architecture and services) and 1.3 (Interoperability). The report describes first the different services and use cases, which are demonstrated in the different NordicWay pilots (sub activity 1.2.2), and then describes the major communication technology selection (task 1.3.1). The architecture (sub activity 1.21), ensuring interoperability (sub activity 1.3.3) is discussed in section 2.3, and a discussion on the standards (task 1.3.2) is provided in section 2.4. Reflections on security and privacy (task 1.3.4) and on certification (task 1.3.5) are provided in section 2.6

2.1. Services and use cases

The main type of service addressed in NordicWay was the delivery of Day 1 Safety Related Traffic Information (SRTI) with low latency to vehicle drivers. This includes both the detection of dangerous situations by vehicle sensors or reported situations by drivers.

NordicWay piloted three core services and their interoperability in the participating countries. These Day-1 core services were chosen based on priorities of the partners, estimated performance/cost-benefit, and technical readiness. The selected services were:

- cooperative hazardous location warning. Drivers are warned of the following events :
  - animal, people, obstacles, debris on the road
  - unprotected accident area
  - reduced visibility
  - short-term road works
- cooperative weather and slippery road warning. The driver is warned of a slippery road or of exceptional weather conditions (e.g. fog, heavy rain, heavy wind).
- Probe vehicle data, i.e. the collection of data from vehicles directly from sensor data, is used to support the services mentioned above.

In addition, road works warnings became an additional service, including also other than short-term road works. Table 1 gives an overview of the Day 1 and Day 1.5 services, identified in the work of the C-ITS platform [1] piloted in the different NordicWay pilots

Table 1: Day 1 and Day 1.5 C-ITS services tested or piloted in the Nordic Way project

Day 1/1.5 Service	DK	FI	NO	SE
Day1; 3 Slow or stationary vehicle(s)	✓		✓	✓
Day1; 5 Hazardous location notification	✓	✓	✓	
Day1; 6 Road works warning	✓	✓	✓	✓
Day1; 7 Weather conditions	✓	✓	✓	✓
Day 1; 10 Probe vehicle data		✓	✓	✓
Day1.5; 6 Zone access control for urban areas			✓	

The following use cases were implemented:

- Road authority reports about dangerous situation on the road or inclement weather
- Vehicle detects slippery road
- Smart phone use informs on dangerous situation on the road
- Road works trailer informs about road works

The sequence flows of the different use cases are described in more details in the « Architecture, Services and Interoperability » [2] and the « System Design » [3] deliverables.

2.2. Communication technologies

The main technology used for communication in the NordicWay project between vehicles and infrastructure was cellular communication. Hybrid communication, using both ITS-G5 and cellular communication was used for the roadworks warning by trailers use case.

During the last years, OEMs have developed connected vehicle services. In 2015, about 50% of cars globally sold were connected (either by embedded, tethered or smartphone integration) [4], and their drivers are hence continuously connected to a cloud, which can provide them with real-time information on traffic. The European OEMs are promoting the « extended vehicle » concept, providing access to vehicle data in accordance with clearly defined technical, data protection and competition rules through interfaces and a data server platform provided by vehicle manufacturers [5]. The extended vehicle is currently being standardised in ISO 20077, 20078 and 20080. ACEA is promoting the neutral server concept, by which service providers have the choice to access data directly from the vehicle manufacturer's server or via neutral servers, which gather the data from vehicle manufacturers' servers [6].

The NordicWay approach builds on this infrastructure. A major benefit of this approach compared to the ITS-G5 oriented approach is that the end user only communicates with a single trusted actor. This actor takes care of, among others, security and privacy related issues, using industrial standard tools and agreements. The approach is also agnostic towards the Mobile Network Operator.

Latencies for cellular network communications are larger than for ITS-G5. The services addressed by the NordicWay project were mainly advisory and not time-critical. The first proof-of-concept tests performed in August 2015 in Finland indicated that end-to-end latencies were in the range of 1 to 4 seconds, dependent on the paths followed by the message flow [7], thereby the latency corresponded to a quite usual distance between two cars following one another in highway conditions. This is also within the limits set for similar cooperative applications, such as informing conceptual speeds to drivers (ISO/TS 17426). As cellular communications evolve, the latencies of the mobile link will decrease significantly, with 5G having as target 1 ms air interface delays and 5 ms end-to-end latency [8].

2.3. Architecture for interoperable services

The architecture of the NordicWay system was designed with interoperability in mind. The development of the architecture and the detailed architecture are reported in the deliverable "Architecture, Services and Interoperability" [2].

A major objective of the NordicWay project was to test and demonstrate interoperability of C-ITS (cooperative ITS) of services both for passenger and freight traffic, piloting continuous services offering an equivalent user experience in the four countries involved (Finland, Sweden, Norway, Denmark).

2.3.1. Understanding Interoperability (IOP section 4.2)

Interoperability is a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, at present or future, in either implementation or access, without any restrictions. The term was initially defined for information technology or systems engineering services to allow for information exchange [9].

With reference to C-ITS, full interoperability can be understood as the capacity of a vehicle to exchange information with any other relevant system (vehicle or roadside) in order to obtain or provide the C-ITS service intended. This means that interoperability requirements depend on the specific needs of the services concerned. Whether the vehicle exchange also other information that is not relevant for the intended services has no impact on its interoperability quality.

It can also be understood that restrictions concerning which systems that can exchange information will reduce the level of interoperability.

Hence, interoperability can be measured e.g. ranging from 0% to 100% where 0% interoperability means that the vehicle systems cannot communicate with any other system in relation to the intended services, while full (100%) interoperability means that the vehicle can communicate with all other relevant systems.

It is also important to understand that the interoperability definition does not take into account in which manner e.g. information is exchanged. As long as systems can work together and the interfaces are understood, interoperability can be achieved.

2.3.2. NordicWay and C-ITS Interoperability measures (IOP chapter 5)

With reference to C-ITS, full interoperability can be understood as the capacity of a vehicle to exchange information with any other relevant system (vehicle or roadside) in order to obtain or provide the C-ITS service intended.

Hence, we understand the vehicle as a system, and full interoperability is achieved when all vehicles can work with all other vehicles and systems to the level, which is required to achieve the quality requirements of the intended services.

2.3.2.1. C-ITS service quality requirements

The Level of Quality Parameters used, with reference to the architecture report [2], are:

1. Timeliness, which is the capacity of the system to detect and validate situations with a minimum delay
2. Location accuracy, which is the degree to which the stated location conforms with the correct location.
3. Latency, which is the delay before a transfer of data begins following an instruction for its transfer.
4. Error rate, which is the probability that the stated information is not correct
5. Event coverage, which is the probability that an event is reported through the service

Timeliness

The timeliness is decided by the presence of sensors and their capacity to record an occurring event and the capacity of the receiving body to correctly understand the information. The introduction of e-call is a good example of a service that has been designed for maximum timeliness and minimum latency through the systems used and the organization of PSAP´s.

The best timeliness is achieved when there is a large number of sensors well distributed over the road network that communicate the detected information with minimum delay, in combination with an application capable of correctly understanding the information at the reception point.

Table 1: Service quality parameters and values for NordicWay

	Level of Quality Parameters						
	Timeliness (95%)		Latency (contents) (95%)	Location accuracy (95%)		Error Rate	Event Coverage
	Start	Update/end		Area	Road		
All SRTI events/conditions, except wrong way driver							
* (Basic)	Best effort	Best effort	< 10 min	Admin. Regions	Link between intersections	<15%	Best effort
** (Enhanced)	Validation after first detection < 10 min	Best effort	< 5 min	Admin. Regions	Link between intersections	<10%	>90% of all validated events
*** (Advanced)	Detection & Validation < 5 min after event occurrence	Detection & Validation < 10 min after event occurrence	< 3 min	Geographic area; 10 km accuracy	< 5 km	<10%	>80% of all occurring events

Latency

The latency describes the time between detection and validation of an event and the application of appropriate measures to cope with the event. Latency is at first hand dependent on the capacity to manage incoming information e.g. to a traffic centre.

Location accuracy

Location accuracy is the degree to which the stated location conforms with the correct location.

Location accuracy reflects the capacity of sensors and applications to register the location of an event with satisfactory precision, and to report the event with appropriate precision. Whereas a specific event can be registered with high precision, it can be relevant to describe its impact with another dimension. Location accuracy requires a harmonized way to express locations (using same location referencing system) to maintain precision and avoid errors.

Error rate

The error rate is the probability that the stated information is not correct.

A key to low error rate is a combination of high quality sensors and the possibility to validate and correctly interpret received information. This is done by either checking the information received, or by receiving the same information from many separate sources.

Event coverage

Event coverage is the probability that an occurring event is reported through the service.

Planned events can be reported by their organizers (road works, dispensation transport …) prior to their occurrence and offer good conditions for high service quality. Un-planned events (road hazards, accidents …) must be detected and reported by dynamic sensors and managed by a service provider.

2.3.2.2. NordicWay Interoperability measures

In order to meet the service quality requirements through the implementation of interoperable systems a number of measures need to contribute:

Number, distribution and quality of sensors

A key to fast detection of events (whether it is adverse road conditions, accidents or other events) is a high number of well distributed and connected sensors.

Road network communication coverage

The need for connected sensors means that the road network needs to be connected. Either through fixed installations or through cellular network and combinations of these. Good sensors that cannot immediately (timeliness!) communicate sensor data does not support service quality.

Harmonized interfaces (protocols)

To allow for messages and information to be exchanged, connected systems must use interoperable protocols. The more open, well used and standardized the better.

Harmonized information (geo-reference, messages…)

The information / data that is communicated in the system must be readable and understood correctly by all parties involved. It is critical to use agreed (standardized) methods to describe messages, positions (geo-referencing) etc.

Security and trust

Managing data involving infrastructure, vehicles and drivers puts high requirements on the actors involved and the systems engaged. Systems have to be designed with high security requirements and include measures that ensures that only trusted entities have access to the system and that data provided is reliable.

An architecture and an ecosystem supporting scalability and interoperability

All features of the system must be supported by an architecture that allows for evolution and adaptation to various business conditions between actors.

Time to implementation has to be short

C-ITS is developing fast. Initiatives that strive for interoperability have to offer solutions that are mature enough to allow for implementation now.

2.3.3. NordicWay Concept

The NordicWay concept builds on the following elements :

- cloud-to-cloud communication for the communication between the different service providers and Traffic Data providers involved ;
- the NordicWay Interchange Node is the key element to assure interoperability, allowing different service providers and traffic data providers to communicate with each other.;
- cellular technologies for the transmission of SRTI messages with low latency, complemented with Infrastructure-to-Vehicle communication based on ITS-G5 for specific use cases.

Figure 1 shows the NordicWay concept architecture.

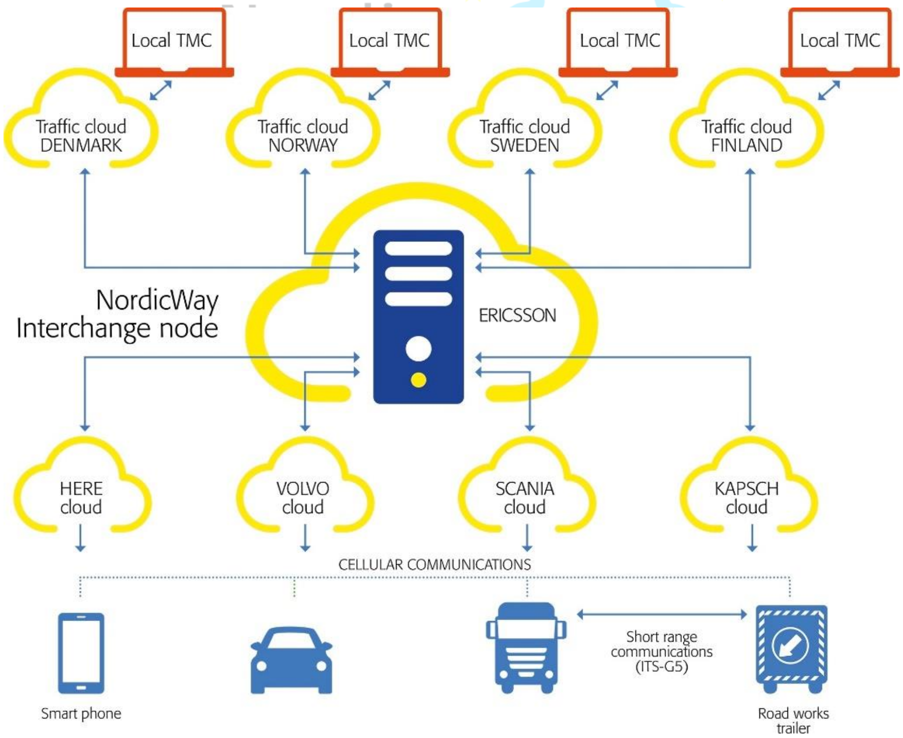


Figure 1. Overview of the NordicWay system

End-users, either vehicle drivers with an OBU integrated in the vehicle or with a smart phone, are always connected to a service provider. Vehicles can report events, based on sensor values, or drivers can report events on their smart phones. The data is then processed at the cloud of the service provider and through the Interchange Node sent to the local traffic cloud and to service providers, who are interested in this information. Traffic clouds send information on dangerous events through the NordicWay Interchange Node to service providers, who transmit this information to vehicles nearby the event.

The key element in the NordicWay concept is the Interchange Node. The NordicWay Interchange Node is a broker, which directs the messages published by the different actors to actors, based on predefined selection criteria, such as the type and location of the event in the messages. The NordicWay Interchange Node has a geo-lookup functionality, which determines the country based on location information in the message, allowing to route messages to e.g. the Traffic cloud of relevance (Figure 2).

The Interchange node receives all types of messages and information from different sources, and Users can choose which specific types of information to subscribe to. The Interchange node sorts the incoming messages and makes the requested information instantly available for the users. New users should be able to easily connect to the Interchange node.

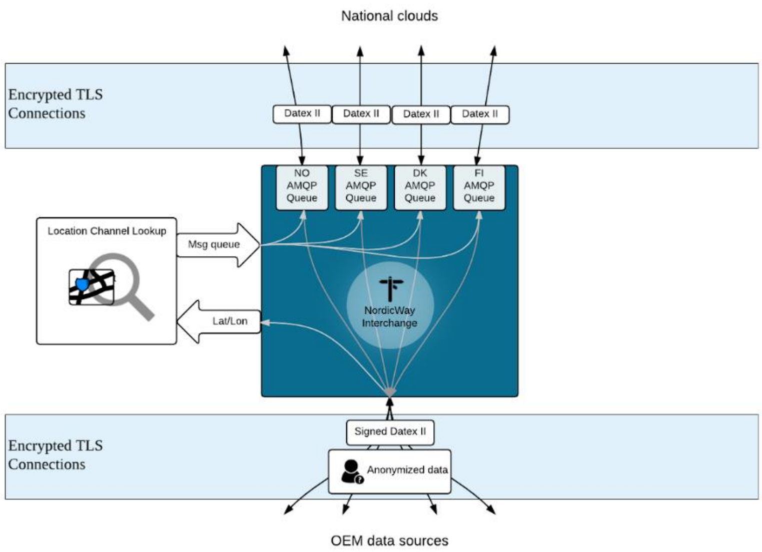


Figure 2. NordicWay Interchange Node concept

The architecture is conceptually compatible with ACEA's Neutral Server concept [6]. The only difference is that in the neutral server concept, the communication between an OEM cloud and the neutral server is based on ISO 20078 REST/HTTP, whereas NordicWay used AMQP.

The NordicWay approach does not require additional infrastructure investments, and is available within mobile network coverage. The architecture builds on existing systems, and allows the different stakeholders to maintain their own relationships and interfaces to their customers.

2.3.4. NordicWay Ecosystem

During the project, an ecosystem was created, in which different public and private partners exchange Safety Related Traffic Information; co-opetition where market actors create new enhanced ecosystem with cooperation and competition, yet enabling them to maintain and develop their own businesses and business models. Table 2 lists the actors involved in the ecosystem. The NordicWay Interchange Node was operated by Ericsson.

Table 2. Actors in the NordicWay pilots

	Finland	Sweden	Norway	Denmark
Service Provider/OEM	HERE	Scania, Volvo Cars, Kapsch	Volvo Cars	
Traffic Data Provider	Infotripla	Ericsson, Swedish Transport Administration	Vegvesen	Danish Road Authority
TMC/Road Authority	Finnish Transport Agency	Swedish Transport Administration	Vegvesen	Danish Road Authority

The NordicWay project did not reach the implementation of a full and mature Ecosystem but achieved to identify and implement a solution that supports the basic requirements on an ecosystem for C-ITS interoperability:

- It allows for very different organizations (authorities, service providers, vehicle OEM´s, communication providers,…) to participate within the same ecosystem
- It accounts for very different driving forces behind these organizations (road safety, profit from services, profit from vehicles, …)
- The solution allows for all kinds of relations (also bi-lateral) between organizations involved, each relation with its own business agreement
- All roles within the organization can be subject to competition
- The ecosystem is designed to be inclusive – easy to join and select your preferences – and stimulate business (service) development
- Which requires an architecture that is “relation agnostic” as developed and demonstrated in NordicWay.
- The ecosystem must support short time to deployment (open for aftermarket solutions, easy to join …) in order to prevent disaggregation. C-ITS is under rapid development and need solutions for interoperability that works now.
- The ecosystem should support further innovation (beyond Day 1,5 services)

A main challenge for deployment of the system is how to get the actors exchange the data with each other.

2.3.5. Scalability - allowing for growth

Scalability was a design requirement for NordicWay and implemented through the selected architecture. Scalability of C-ITS services means that already existing services, devices and users can be connected to the C-ITS clouds, which makes it possible to scale up C-ITS services faster. The interchange node has been developed to fit with the North European road transport system, and to be scalable to European level. The architecture has been designed to accommodate hybrid C-ITS communication, and to be border and relation agnostic. To support further development and to shorten time to full C-ITS implementation, the interchange builds on standards and makes use of existing structures

NordicWay also considers scalability in terms of increasing the number of C-ITS services associated and entities connected. The architecture can incorporate already existing services, devices and users through existing C-ITS clouds, which makes it possible to scale up C-ITS services very fast.

The next step will be to work further on the architecture, as a single Interchange Node may not fulfil the requirements of all stakeholders, and a more federated architecture consisting of multiple Interchange Nodes can be required.

Figure 3: Federation of Interchange nodes

2.3.6. ALLOWING FOR FULL ROAD NETWORK AND EVENT COVERAGE

The NordicWay approach relies on already deployed mobile communication systems, and is agnostic towards the mobile network operator (i.e. serves all vehicles with mobile communications, not only the customers of a specific MNO).

Hence, there may be areas, e.g. mountainous areas, in which there is no coverage but a basic characteristic of the selected solution is that it allows for service provision also in very remote areas and on very low-class roads.

2.3.7. SHORTENING TIME TO INTEROPERABILITY

NordicWay is based on existing and well distributed technologies under continued development and supported by widely accepted and used standards.

Hence, the NordicWay approach does not require additional infrastructure investments, and is available within mobile network coverage.

2.3.8. SUPPORTING CROSS-BORDER OPERATIONS

The NordicWay Interchange Node is by itself border agnostic. Services and information are communicated cross border, only depending on the agreements between partners defined and implemented in the Interchange Node.

Passage of national borders may cause problems with roaming cellular networks, which was demonstrated in NordicWay.

2.4. Standards for data exchange

The application and use of standards has been a key characteristic of NordicWay. The NordicWay Interchange Node, delivering C-ITS Day 1 SRTI messages, has been developed and implemented using already existing and widely acknowledged and used standards as AMQP 1.0, TLS and DATEX II.

The main effort in NordicWay was on the interfaces between the different clouds. The link between the service provider and the vehicle was - for cellular communications - under the responsibility of the service provider. The communication protocol between the service provider and the vehicle was thereby under the responsibility of the service provider. The service provider was continuously aware of the location of the vehicle, allowing to efficiently communicate with the vehicles in a specified geographical region. CAM messages [10], which are used in ITS-G5 communications for informing other road users of the vehicle's status, are not optimised for cellular transmission and can cause network overload [11]. DENM messages [12] have been specified for ITS-G5 transport mechanisms, and cannot be used as such for cellular communications. In the Finnish pilot, the DENM data content was used in the communication between the service provider cloud and the vehicle.

The NordicWay project utilised the following standards:

- ETSI C-ITS standards for the ITS-G5 communication (for the roadworks use case between road side unit/trailer and vehicle). Communication between service provider and smart phone was based on the data content in DENM messages.
- DATEX II. This is the main standard used for the communication between different clouds, and also recommended in the delegated acts of the EU ITS Directive. In the NordicWay project, DATEX II version 2.3 data model was used, with "supplier push" mode to guarantee low latencies. The standard DATEX II exchange mechanisms were not used, instead message queuing over AMQP was used. DATEX profiles for the Road Works Warning and the Slippery Road warning message were generated.
- AMQP. The **Advanced Message Queuing Protocol** (AMQP) provides a platform-agnostic method for ensuring information is safely transported between applications, among organizations, within mobile infrastructures, and across the Cloud. AMQP 1.0 is used for transmission of messages between clouds. The payload (in NordicWay, a DATEX II message) is encapsulated with a AMQP header, allowing the Interchange Node to direct the message to the relevant subscribers.

Of particular importance is the implementation of the agreement to common use of DATEX II for all messages distributed. By the application and use of DATEXi II NordicWay can also be developed to cover a vast number of different events and services. By using DATEX II message standard, messages can also be made language independent, supporting cross-border functionality.

A key learning from the project is however that these standards are not enough. The DATEX II standard provides multiple options for road and service operators to provide information on a specific event. For instance, different location referencing mechanisms can be used (ALERT-C, OpenLR, coordinates…) and there are several methods for the event lifecycle (i.e. to indicate when an event stops).

Hence, the use of the different standards should be further harmonized, e.g. guidelines on the use of location referencing by the different stakeholders in DATEX II and on the event lifecycle management. In addition, some issues with the AMQP headers were noticed during the preparations for the interoperability demonstration.

2.5. Security and privacy

An advantage of the architecture is that the vehicle is in contact with only a single actor (for vehicle integrated systems the OEM through the OEM cloud and for smart phone systems the smart phone app provider), which simplifies the security provisions that are required.

For the connection between the Interchange node and the clouds of the different actors' industrial proven tools can be used. NordicWay used TLS 1.2 to secure the transport between the clouds. The instance of the Interchange Node, demonstrated in the NordicWay project, does not include a fully secure implementation of the Interchange. This development is foreseen for NordicWay 2.

Security and privacy of the communications between the vehicle and the service provider were under the responsibility of the service provider.

Provisions should be put in place to ensure that data is only provided to the intended partners (e.g. no leaks due to problems with e.g. AMQP header information) in accordance to the specific agreements set.

2.6. Certification

The NordicWay tests and demonstrations were based on two set of interoperability guidelines:

- Agreed service definitions (specifications with implementation guides)
- Staged tests (agreed procedures) for interoperability verification

The performance of these demonstrations constituted NordicWay Compliance Assessment. No formal certification was applied as the tests and demonstrations were restricted to NordicWay partners.

3. Finnish Pilot

3.1. Objective

NordicWay Coop was the Finnish national pilot of the NordicWay and demonstrated a 3G and 4G/LTE based Vehicle-to-Infrastructure (V2I) solution for sending/receiving safety critical messages as described in the Commission Delegated regulation No 886/2013. The main aim of the NordicWay Coop pilot was to enhance traffic safety and its primary objectives were to study the functionality of traffic safety messages via 3G and 4G/LTE cellular network, to assess user behaviour when sending and receiving safety critical messages, and to verify the system's readiness for wider use as well as commercial potential and required supporting ecosystem.

3.2. Actors

3.2.1. Roles and responsibilities of the different actors

The main actors in the pilot were:

- Finnish Transport Agency (FTA) and Finnish Safety Transport Agency, coordinators of the pilot. The Traffic Management Centre (TMC) is operated by FTA.
- HERE Technologies, technology supplier and main contractor
- Infotripla Ltd, subcontractor to HERE and FTA, providing the interface between the HERE cloud and the TMC, and the user interface to the TMC. Infotripla was also responsible for the recruitment of the test users.
- VTT Technical Research Centre of Finland Ltd, performing the evaluation in Finland and assisting FTA in coordination.

3.2.2. Agreement on partnership models

For the Finnish part of the NordicWay corridor, project Coop, the Finnish Transport Agency (FTA) and Finnish Transport Safety Agency Trafi made a joint procurement, a public call for development and piloting of specified C-ITS services. This was not done as a notice of public procurement or call for tender, but as a call for private companies to express their willingness to develop the service in cooperation with the Procurers. Procurement was made as R&D procurement which included service providers own investment in the development and large-scale piloting. The procurement model is a Finnish way of Public Procurement of Innovation (PPI). The Procurers co-financed the extra costs caused by the pilot. The selection of the service provider was not based on price but on the service provider's expertise and plan on the productization of the C-ITS service.

FTA, Trafi and HERE made up a contract, stating the responsibilities for the different partners regarding the reimbursement of the extra costs caused by the pilots, including the services to be developed, timetable, amount of users, impact assessment and technical evaluation.

FTA and Trafi made two additional R&D procurements for the NordicWay project's technical coordination and analysis and for the Finnish Coop Pilot’s Impact assessment and technical evaluation. Both procurements were won by the VTT Technical Research Centre of Finland.

3.3. Pilot Concept

Figure 4 gives an overview of the Finnish pilot. Events reported by the driver are received by the HERE service provider cloud, which processes the data, and transmits reported events as single-user events both to vehicle drivers near the event area and forwards it to Infotripla’s ITS server. At the HERE cloud, the information is aggregated with messages from other users and sources, and validated events are transmitted to both vehicles and Infotripla’s server, which forwards it to the TMC. SRTI events from the TMC are sent by Infotripla to the HERE cloud, which transmits it to vehicles approaching or in the event area.

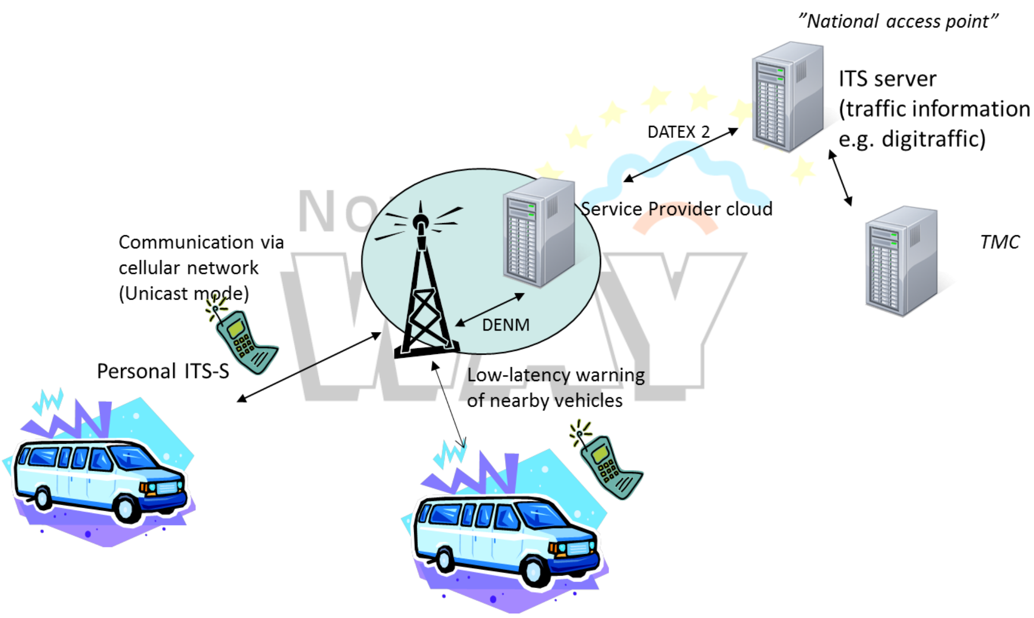


Figure 4. Overview of the Finnish pilot

3.3.1. Services

At the user’s side, the system was implemented on the driver's personal mobile device operating with Android OS 4.4 or newer. After registration for the pilot, the driver received instructions on the procedure to downloads the “DTI app”, developed by HERE.

The following services were piloted:

- **Cooperative hazardous location warning.** The following hazard classes are supported (hazards in bold can be reported by the user; the other hazards can only be viewed):

- **animal, people, obstacles, debris on the road**
- **unprotected accident area**
- short term road works (later all road works)
- **reduced visibility**

- **Cooperative weather and slippery road warning.** The following hazard classes are transmitted by the TMC to vehicles near the event area:
  - temporary slippery road
  - exceptional weather conditions

- **Probe data services** involve the transmission of aggregated probe vehicle data on vehicle position and speed from the HERE cloud to the Road Authority.

3.3.2. PILOT AREA AND TIMING

The pilot area was the E18 highway between Helsinki and Turku, and the Ring Road I and Ring Road III in Helsinki. In November 2016 the pilot test site was enlarged with the E12 between Helsinki and Tampere, and the ring roads round Tampere including the 2.4 km long Rantatunneli tunnel, the E75 between Helsinki and Lahti and the Road 51 between Helsinki and Kirkkonummi.

The pilot consisted of several phases:

a) Pre-pilot: Proof-of-concept

A proof of concept validating technical functionality was demonstrated in August 2015. During the proof of concept both messages generated by an ITS cloud server, and messages generated by mobile users, were transmitted with low latency to mobile users in the neighbourhood. The results of the proof of concept have been reported by Kauvo & Koskinen [7].

b) Checkpoint 2: start of pilot

Prior to starting the pilot, the final solution was validated. This validation included a check of the HMI usability, according to the guidelines of the Car Connectivity Consortium, and a check of the functionalities. A second technical validation took place in the beginning of April, where messages were both generated by ITS cloud server and be mobile users, driving on the E18 motorway, and received by mobiles moving along the E18 motorway.

c) Ramp up to 1000 users

The pilot started officially on 11 May 2016, and ended on 31 April 2017.The ramp-up to 1000 users is performed in several phases:

- Week 1 : friendly test users, with request to use service as much as possible. TMC does not validate messages.
- Week 2 : TMC goes live, and 100 additional users

- Week 4 : 200 additional users.
- Week 5 : full scale pilot which advanced in two major communication waves in November 2016 and February 2017, when the pilot test area was enlarged.

In total 1270 users successfully completed the registration procedure.

d) NordicWay interoperability

Interoperability testing was performed during the Finnish Coop project together with the NordicWay public and private partners. During the interoperability work the HERE DTI application were validated to receive SRTI messages from the NordicWay Interchange Node. The solution was demonstrated in May 2017 together with the NordicWay partners, and is described in more detail in section 4.4.

3.4. Autonomous Driving and Mobility as a Service pilot

Benefits in traffic safety and traffic fluency are expected when Connected, Cooperative and Automated Mobility (CCAM) advances. Among the benefits are new mobility services, especially those that connect the first and last mile of the transport and mobility travel chain. Studies of autonomous driving and Mobility as a Service (MaaS) was included in the Finnish pilots. Following chapter summarize Road Transport Automation Road Map and Action Plan 2016–2020 and autonomous bus pilot.

3.4.1. Road Transport Automation Road Map and Action Plan 2016–2020

Progress in road automation challenges and provides new opportunities for the society and infrastructure owners. Challenges such as required infrastructure, e.g. landmarks and connectivity, and opportunities such as enhanced traffic safety and fluency. A study was conducted with an aim to provide transport authority guidance, activities and resource needs to prepare for the road automation in next few years [13]

The study methodology composed from concise literature review, expert discussions, working sessions, and stakeholder and authority workshops as well as of the study's authors' experience and knowledge on the domain.

Planning and implementation were divided into five domains: infrastructure, road superstructure and equipment, vehicle systems, services and functions, and driver. These five domains were again divided to action cards and timetable for the authorities to implement in next years. The action cards are presented in the table below. More detailed information can be found in [13].

Table 3 Action cards related to the introduction of automated driving [13]

Infrastructure	Gradual deployment of road network for automated driving
	Guidelines and verification of road network for automated driving
	Design guidelines for junctions
	Railway level crossings
	Impact on traffic management strategies
	Deployment of communication infrastructure
	Availability of communication infrastructure
	Data content of digital maps
	Back-office systems and related data collection
	Movable roadside infrastructure (for road works, special events, etc.)
Road superstructure and equipment	Visibility and condition of road markings and traffic signs
	Location databases for automated driving
	Alternative routes and detours
	Harmonisation of road traffic control
	Sensors or beacons embedded into road pavement
	Consequences on road structure and surface wear
	Posts and poles for guidance and positioning
Vehicle systems	Positioning of vehicle
	Environmental sensing
	Enhanced sensor technologies for snow and ice conditions
	Radio frequency allocations
	Hybrid communications
	Reception of cooperative I2V messaging
	Requirements for traffic status information
	Properties and impacts of SAE level 3 automated driving
	Identification of abnormal and hazardous transports
	Functionalities of signal control
	Type approval of automated functions
	Changes in inspection of vehicles' roadworthiness
	Provision of in-vehicle safety data to authorities
	Aftermarket device connectivity with vehicle
	Safe use of information while driving
	Access to in-vehicle resources and data
	Personalisation of automated function parametres by users
	Availability of data on vehicle features and equipment
Services and functions	Test areas
	Test vehicles and fleets
	Activation of and support for stakeholders in testing and piloting
	Impact assessment
	Required quality of real-time traffic information services
	Truck and bus platooning
	Automation in travel chains
Driver	Right to drive and examination in transition phase
	Driver training and instruction
	Privacy and security
	Information to user segments, media, channels

3.4.2. AUTONOMOUS BUS PILOTS IN CITY ENVIRONMENT

To study first and last mile mobility services and automated driving in city environment, an autonomous bus pilots were implemented in the SOHJOA project between 2016 and 2017 in Helsinki, Espoo, Tampere and Vantaa areas in Finland [14]. The aim was to provide experiences on autonomous bus operational use in city environment and find the best near-term application objects to autonomous buses. The project was implemented in Public and private collaboration by the Metropolia University of Applied Sciences as a part of the NordicWay and Finnish cities' collaborative 6Aika project.

The first two years of trials were successfully completed in open traffic. The results indicate that the autonomous bus EZ10 used in the pilot is not ready to operate on public roads without special attention of the operator. Obstacles such as illegally parked cars cause issues as the bus stops in its pre-set route. Also, the arctic weather conditions such as snow and ice prevent the bus usage. Problems with low speed, sensor sensitivity, predictability of events and signalling to the users could be solved with better connectivity, i.e. Cooperative ITS services. More testing is also needed with the bus positioning as indicated by the GNSS RTK or 3G/4G correction data tests during the pilot.

To conclude, better connectivity is needed to connect the automated buses to the Cooperative ITS systems and to the new mobility services. Also, clear and wide city roads are needed in order for the autonomous bus to operate freely. The autonomous bus pilot will continue in 2017–2018 in the ROBUSTA project [15]. Aim of the ROBUSTA project is to study automated bus with advanced 4G/LTE connectivity in a new service ecosystem.

Figure 5. EZ10 autonomous bus used in the SOHJOA project to study autonomous bus operational use.

4. Swedish Pilot

4.1. Objectives

The aim of the Swedish pilot was to demonstrate the possibility to communicate between vehicles, infrastructure and clouds and to show the interoperability, scalability and flexibility of the NordicWay interchange network.

4.2. Actors

4.2.1. ROLES AND RESPONSIBILITIES OF THE DIFFERENT ACTORS

The main actors in the pilot were:

- The Swedish Transport Administration (STA), also coordinator of the Swedish pilot, responsible for the connection of the pilot with national traffic management centre database. The STA also provided Road Works vehicles to be used in the pilot.
- Ericsson AB, responsible for the development and operation of the NordicWay Interchange server and the Swedish Traffic Cloud
- Volvo Car, provider of demonstration vehicles and test drivers. Developing DATEX harmonized DATEX II messages and interfaces for the services
- Scania CV, provider of demonstration vehicles and test drivers. Developing DATEX harmonized DATEX II messages and interfaces for the services. ITS G5 station in test vehicles.
- Kapsch Trafficom, provider of hybrid equipment for RWW demonstration. Developing DATEX harmonized DATEX II messages and interfaces for the services
- SWECO, supporting STA with the planning and management of the pilot

4.2.2. AGREEMENT ON PARTNERSHIP MODELS

The Swedish pilot was co-financed by all participating partners. It was established based on a cooperation established for the development of a national C-ITS Road Map developed through the Swedish Innovation Agency. STA has established bilateral development agreements with each partner (except SWECO who works under a framework agreement contract) which also defined the relations between the partners through the Swedish Pilot Project Plan.

4.3. Pilot concept

The Swedish pilot differed from the other NordicWay pilots in its ambition to focus on the build-up of an authentic C-ITS ecosystem based on available technologies and relevant organizations. This means that, as far as possible, existing organizations contributed with their available solutions and technologies. As important OEMs (Volvo Car, Scania) had already developed in-vehicle solutions for data collection and information to drivers, these elements of C-ITS were not assessed within the Swedish pilot. The argument being that what has been considered as commercially and technically relevant for an OEM to build into the vehicles should not be put at trial in the Swedish pilot. In addition, due to the limited size and period of the NordicWay pilot, it is unlikely that any change in safety levels or network performance could be measured. The strength of NordicWay is its cross border dimension and the Swedish Pilot focus on how interoperability and market measures can contribute to the overall project goals. Hence, the Swedish Pilot accommodated the development of the interoperability dimension of the NordicWay project to the benefit of all pilots.

In addition, the Swedish pilot included demonstrations based on the use of OEM clouds and their connection to the Interchange server.

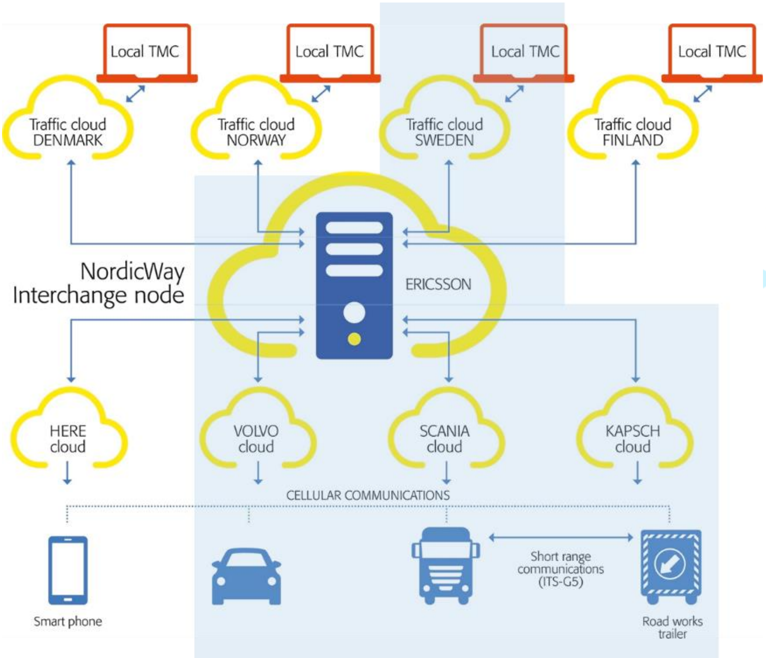


Figure 5. Swedish pilot in the context of the NordicWay architecture

4.3.1. SERVICES

4.3.1.1. DESCRIPTION OF THE SERVICES

The Swedish pilot delivered the functionality required and provided the system required in order to conduct NordicWay interoperability demonstrations (i.e. execution of the common NordicWay Use Cases). The services concerned (defined by the C-ITS platform as Day 1 services) were separated into different tasks although they were coordinated in execution.

Cooperative hazardous location warning

The Swedish pilot focused on one of the sub-services of Hazardous Location Warning in order to meet the interest from the project partners and to establish a realistic eco-system, which includes a greater variation of systems and services. The service concerned (defined by the C-ITS Platform as a Day 1 service as part of the Hazardous Location notifications) was carried out as a separate task however linked to the Hazardous Location service common for NordicWay.

Cooperative Road Works Warning

This was demonstrated by implementing a Road Works Warning (RWW) use case consisting of a RWW unit on a road works vehicle sending a notification to the road user. In this setup, a Truck Mounted Attenuator (TMA) on the road works vehicle is activated which triggers a RWW DENM [12] (decentralized environmental notification message) to be broadcasted over ITS-G5 and can then be received by approaching vehicles. The message is also transmitted to the RWW backend via cellular networks where the message is transformed into the DATEX II format for RWW and forwards the message to the Nordic Way interchange node. The Interchange node distributes the RWW message to all subscribing service providers. The Service Provider then sends an alert message to subscribed users in the event area through the cellular network. In the Swedish pilot ten road works vehicles were equipped and transmitted messages to twelve Volvo cars and four Scania buses.

Figure 6. The Swedish roadworks warning pilot setup.

4.3.1.2. *PILOT AREA AND TIMING*

In the Swedish pilot the vehicles were used in their normal daily routines and driving in the city of Gothenburg and Södertälje. In addition, controlled tests were carried out to be able to perform repeated measures and study events in a more controlled way than what was possible when the vehicles where roaming during normal operation. In total, more than 7000 events were recorded during the trial period.

The tests and demonstrations were carried out between November 2016 and September 2017. A major test and demonstration took place May 10, 2017, at the Swedish Norwegian boarder demonstration.

4.3.1.3. *PILOT MAINTENANCE AND OPERATIONAL ISSUES*

The pilot used cellular networks (through OEM cloud) and ITS-G5 to communicate between road works vehicles (that signals when the shock absorbent equipment is activated) and client vehicles that receive the RWW-messages and presents them to the driver. The aim is to include both stationary and moving road works. Information on active and planned road works is also provided by Swedish Transport Administration and included in the information package provided by cellular networks through the OEM cloud.

The solutions were evaluated in two trials:

1. a free driving study using only CN-communication
2. a trial with controlled parameters using both ITS-G5 and CN communication

The ***driving study*** :

Tests near Södertälje involved first two, with a ramp up to three road works vehicles. Receiving vehicles were four buses travelling a fixed itinerary. Both the Scania cloud and the Scania vehicle destinations were logged. Tests in the vicinity of Gothenburg involved eight road works vehicles and twelve receiving cars roaming freely in performing their day-to-day business. Both the Volvo cloud and the Volvo vehicle destinations were logged. Tests of the STA cloud only logged the STA cloud destination.

The trial with ***controlled parameters:***

The trial with controlled parameters took place on September 19 and September 25 on the test track of Eskilstuna airport, testing the Scania equipment. Testing of the Volvo equipment took place on September 26 in Gothenburg in the vicinity of Lindholmspiren. Tests involved sending of more than 20 messages from one location. The trial was carried out with one road works vehicle (from Kapsch TrafficCom) and two client vehicles (from Scania and Volvo cars respectively) on a dedicated test track. It compared precision and functionality between the two communication methods under study.

In order to eliminate external unknown factors in the measurement of send/receive latency, the driving study was complemented by a completely supervised and controlled measurement campaign with logging of parameters and computation of latency and of message success rate done in the same way as described in the driving study but with a limited time period.

4.4. Interoperability demonstration

This section describes the interoperability demonstrations performed in the NordicWay project, which was an important project achievement in itself.

4.4.1. Introduction to interoperability demonstration

What did we want to demonstrate?

- Cross-border
- Cross-company
- Cross brand
- Cross organization
- Multiple services

- Cross technology – hybrid

Concluding roaming in cellular networks and hand over between operators is a challenge at national borders, a corner case, but relevant to integrated EU-nations.

Why did we want to demonstrate?

- Communication of the interoperability demonstration to decision makers, C-ITS professionals and public audience
- The demonstration as such puts high requirements on the performance of the systems involved: Everything has to work simultaneously.

4.4.2. Demonstration scenarios

The main interoperability demonstration was held on 10 May at the Swedish-Norwegian border in Svinesund. During the event, the system was demonstrated at Svinesund to invited guests and transmitted live to Helsinki, Oslo, Trondheim and Stockholm, with in total about 100 participants.

Additional demonstrations were held at Stora Holm near Gothenburg for slippery road use case and at the Danish-Swedish border between Copenhagen and Malmö.

During the demonstrations, vehicles and equipment transmitted messages on events to the Interchange Node, which was received by vehicles approaching the events. The following scenarios were demonstrated:

- Hazard light alert from Volvo Car to both Scania truck and HERE app (Svinesund)
- Cross-border road works warning: TMAs in Sweden and Norway transmit data to the Interchange Node, which is received by Scania and Volvo Car vehicles crossing the border, and to the national road authorities (Svinesund)
- Cross-border hazardous location warning (Blocked road warning): NPRA equipment sends message to the Interchange node, which is received by the HERE app and national road authorities (Malmö-Copenhagen)
- Slippery road warning exchange between Volvo Car and Scania (Stora Holm)

4.4.3. Demonstration documentation

The video taken at the demonstration is available at YouTube via link https://youtu.be/gTrrl4ymvyc

Links to other videos and all material related to the demonstration is available at www.NordicWay.net.

5. Norwegian Pilot

Norway piloted cellular communication based C-ITS services on the Norwegian part of the NordicWay network. In addition, ETSI ITS G5 communication was included at a few selected locations.

The Norwegian network covered the section of the E6 from Oslo to the border of Sweden where it was linked to the Swedish part of the NordicWay network. The Norwegian pilot had its main focus on this road section since it is an important corridor connecting the rest of Norway to the European core road networks.

Norway has also a vast road network where large parts are located in sparsely populated areas with limited traffic. Like in Sweden, Norway needs to employ technologies that make use of existing infrastructure and systems. Hence cellular networks (e.g.: 3G, 4G, LTE) was the major technology employed whereas ETSI standardized ITS G5 (5.9 GHz) hotspot technology was be utilized at specific locations.

5.1. Objective

The Norwegian part of the pilot encompassed:

- 300 connected vehicles in total around the Oslo and Gothenburg areas using dongles connected to the OBD-II-port
- 4000 connected cars using only native equipment and production Volvo cars
- Demonstration of cooperative ITS services between infrastructure and vehicle in August 2016 – intelligent road works warning sign, based on Raspberry Pi, communicating through the NordicWay Interchange and showing warnings with countdown directly in the dashboard of oncoming car
- A mobile app that could be used to signal road works warning or hazard warning light to the NordicWay Interchange
- A web-based map showing all messages on the Interchange
- Equipment for making intelligent signs
- Test on weight declaration from Heavy Goods Vehicle using ITS stations communication over ITS-G5 and DENM messages, with Scania and Aventi[1]
- Active role in development and testing of the NordicWay Interchange
- Technical evaluation of the NordicWay Interchange Node
- Quality assessment of Slippery Road Alerts from vehicles
- Delivery of data from pilot vehicles/users to support impact evaluation

[1] https://www.youtube.com/watch?v=GIYEyPn-Q00&feature=youtu.be

- Demo of creating a zero-emission zone in Oslo using geofencing and powertrain management of plug-in hybrid vehicles in cooperation with Volvo Cars on 19.-20. October 2017
- Development of an add-on to QGIS for coverage assessments (cellular and ITS-G5, with possibilities to expand to other communication forms such as LPWAN) with SINTEF.

5.2. Actors

5.2.1. Roles And Responsibilities Of The Different Actors

The pilot consists of the following main actors:

- The Norwegian Public Road Authority (NPRA): Coordinators of the pilot
- Volvo Car Corporation: Main contractor for research, development and implementation
- NTNU: Quality assessment and verification of data
- SINTEF: Framework for evaluation for NordicWay, evaluation of the Norwegian Pilot
- Aventi: Contractor for ITS station for G5 test, in cooperation with Scania

5.2.2. Agreement On Partnership Models

The Norwegian Public Roads Administration entered into a standard agreement for research and report assignments with Volvo Car Corporation (internal reference: 2014/082868). The Norwegian and Swedish road authorities has contributed with equal funding for the cooperation with Volvo Car Corporation to provide probe data from vehicles including friction estimation.

The agreement with Aventi was signed in the fall of 2016 after an intention announcement.

5.3. Pilot concept

The core idea of the Norwegian Pilot, as illustrated in the below diagram, is that a Volvo vehicle can estimate friction based on its on-board sensors and pass this on to the Volvo back-end. The information can then be used to warn other drivers, and to regulate winter maintenance.

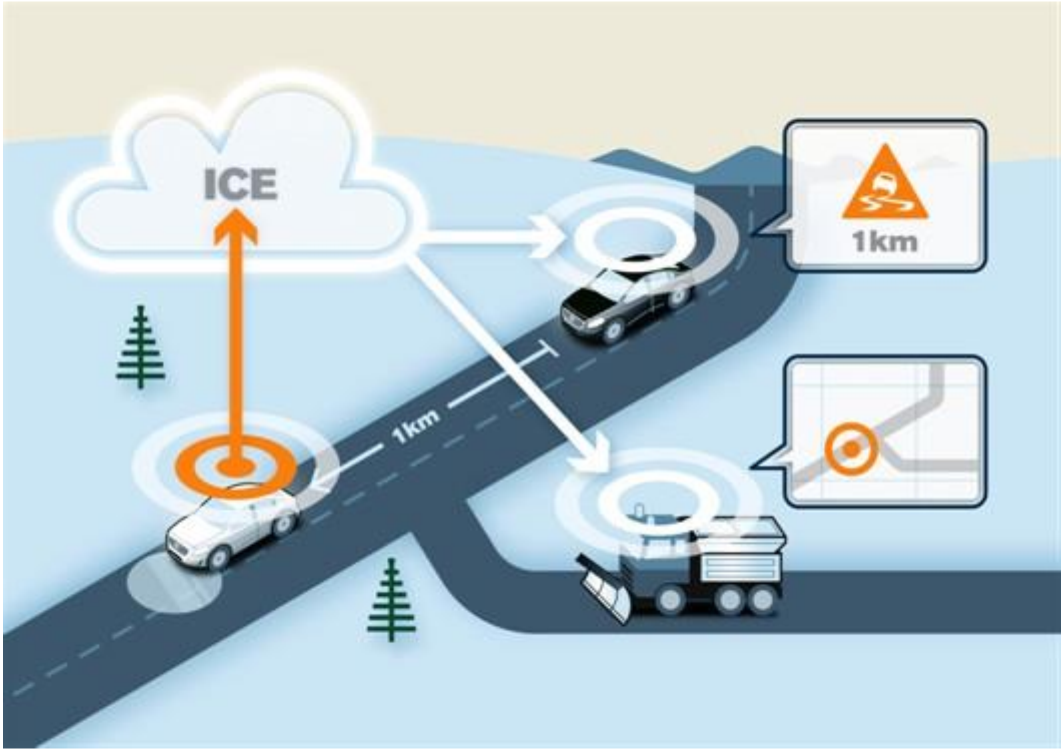


Figure 7 : Core idea of the Norwegian pilot: slippery road condition is detected by vehicle sensors, and warning about it is passed to other drivers and winter maintenance.

In the Norwegian pilot, several sources of friction measurements were used to assess the quality of the different providers. The quality of the friction estimations was used to determine further research and use of data from fleets of cars.

5.3.1. SERVICES

5.3.1.1. DESCRIPTION OF THE SERVICES

The Norwegian Pilot will cover the three core services in NordicWay.

- Cooperative Hazardous Location Warning: Hazard warning lights. Demonstrated in August 2016 with Volvo Cars, as well as the common demo for all countries in May 2017. This data is also planned to be shared through a new cooperation under completion per December 2017 between Volvo Cars and the NPRA, for data from the production fleet.

- Cooperative Weather and Slippery Road Warning: The pilot was up-and-running ahead of schedule, and reached 300 cars, not the 500 as intended. However, the switch from a fleet requiring dongles to communicate with the cloud to fully self-contained production cars was made. This far succeeds the original aim, making available a fleet of approximately 4000 production cars, and growing.

- Probe Data Services: The Norwegian Pilot has shown a long-running and successful early adoption of the fleet, giving the NPRA has a vast data set from car fleets. ITS-G5 (CAM, DENM): At selected hot spot in E6 Oslo-Svinesund.

In addition to the 3 NordicWay Pilot common key services, Norway piloted and studied the following C-ITS applications: road status information (covering all the common applications), heavy goods vehicle (HGV) non-stop control (covering the probe vehicle data application).

- The road status information consisted of collecting slippery road conditions from the vehicles on the road. Good indications on slippery road conditions can be used to improve winter maintenance operations. This will improve safety on Norwegian roads, which are often narrow, winding along fjords, and up and down mountains and hilly terrains, with a nice mix of cars and heavy goods vehicles. National Public Roads Administration (NPRA) had a very successful cooperation with the automotive industry representatives using the car as a sensor to extract information about the slippery road conditions. This information was analysed to find the quality of measurements, and is planned to be used in decision support for both the public and road authorities.

  Privacy is be an issue for a road status information system collecting data from individual vehicles. Hence, privacy concerns has been handled with great care throughout the project.

- In several European countries, the weight of heavy trucks is controlled, in order to ensure compliance with weight regulations. Today, this is done by passing a weight station where the trucks have to stop at a scale. HGV control based on C-ITS enables at least partly non-stop operations of such control functions, thus improving more efficient operations for both road operators and hauliers. In the Norwegian Pilot tests were carried out to transfer the HGV weight and dangerous goods information directly to the road administrator via roadside ITS stations.

Testing with ITS stations on-board units and road side, using ITS-G5 and DENM were performed throughout 2017. Testing encountered numerous problems with both retrieving data from the trucks, as well as using the DENM standard. DENM has no support for weight declaration, so creative methods had to be used to be able to send axle based measurements from the vehicle to the road side unit. More details can be found in [16].

5.3.1.2. Pilot Area and Timing

The Norwegian project had the following milestones:

- NO1 Definition and scope 29.05.2015
- NO2 Piloting 29.02.2016
- NO3 Demonstration 31.08.2016
- NO4 Evaluation report 31.08.2017

All milestones were met. The evaluation report was delayed due to increased complexity of the task and internal reorganisation.

5.3.1.3. *Service Level And Quality Requirements*

The technology used is new, and the aim of the pilot was to gain experience with it as well as assess its potential for the NPRA. It has provided the possibility to gain much needed experience with this new data type, enabling us to build in-house as well as external knowledge in how to utilize probe data efficiently for the transportation sector. Advances made in the project are partly responsible for changes in the curriculum in the Master degree education for transportation engineers at the local university.

The quality was assessed by using the friction measurement trucks of the NPRA as reference. The data produced by the Volvo cars will be evaluated against this reference by two independent partners; SINTEF and NTNU. Friction estimations from the cars were compared to a Road Analyzer and Recorder friction measurement truck, in operation for the NPRA, as well as optical mobile friction measurement units such as the Teconer RCM411. Extensive field testing was performed to create data sets for comparison and research. The results of the assessment show that the friction estimation has potential. It is however not accurate enough to be used to safe guard that requirements of friction thresholds are met, as per winter maintenance contracts. However, there is use already in warning drivers. Slippery Road Alert is in production for Volvo Cars' latest generation of cars. Furthermore, the data is considered valuable as input for decision support systems. These can be:

- Winter maintenance in general – optimization
- Decision support for closing mountain passes, or other exposed parts of the road network
- Traffic Management Centrals
- Road condition forecasting, national system Vegvær
- Professional drivers – use alone or as part of decision support system. Plan to be tested in Borealis and NordicWay2 projects
- General public when cohesive and known information can be provided
- 3rd party products
- Statistics and analysis for research, education and internally in the NPRA to further understand, fleet data, probe data, the vehicle as a sensor, big data, road condition forecasting, etc.

5.3.2. Additional services

The cooperation with Volvo Cars evolved into harvesting new datatypes such as signage and lane markings, and has been very fruitful for both sides. In addition, a demo was performed showing how the powertrain of a plug-in hybrid can be controlled so that a hybrid vehicle behaves as an electric vehicle in a designated area. This was demonstrated in October 2017 in Oslo. Geofences were drawn up directly in the production system for road and infrastructure management, National Road Database[2] and pushed out to the NordicWay Interchange Node. Volvo Cars picked it up from the Interchange Node, passed it on to the vehicles in the vicinity of the geo-fence and controlled the powertrain so that only the electric drive was used within the area. Functions of this demo include charging the batteries outside zones, to make sure enough power is available, and reporting to NPRA on any emissions produced in the area. A video of the demonstration is available at https://www.youtube.com/watch?v=5ErEZa7kkxw

Norway also made an app for reporting road works warning or hazard warning to the NordicWay Interchange Node. A web-based map solution for showing Interchange Node events. And in cooperation with SINTEF developed a coverage model, applied as an add on in QGIS for making coverage assessments for cellular and ITS-G5 communication. This might be developed further to be more refined, and to include LPWAN technology or other communication ranges. It is open source, and can be found at: https://github.com/hjelkrem/Hybriddekning

[2] https://www.vegvesen.no/en/professional/Roads+and+transport/National+Road+Data+Bank+NRDB

6. Danish Pilot

6.1. Objective

The Danish Pilot was designed to measure the performance of the transfer of SRTI (Safety-related Traffic Information) messages from the Danish TMC and back again (and to other nodes) via the NordicWay Interchange Node. The measurements were used for assessing the quality of the End-to-End exchange of SRTI messages in the NordicWay Network.

The use cases for testing were divided into functional tests and performance tests.

Furthermore, verification of end-to-end functionality (communication all the way from one vehicle over national clouds and NordicWay Interchange Node to another vehicle and TMC) was carried out as a part of the Danish pilot.

6.2. Actors

Implementation of the general use cases required that all actors in the uplink and downlink operations was involved. These actors included the Danish Node (TMC and Cloud), other national Nodes and the NordicWay Interchange.

For the restricted use cases without vehicles, the required actors included one or more of the national Nodes and the NordicWay Interchange Node.

6.2.1. Agreement on partnership models

Testing required the participation of the NordicWay partners, who were responsible for providing and operating the various links of the uplink and downlink connections of the use cases. Data analysis was carried out by the Danish Road Directorate.

6.3. Pilot concept

The focus of the performance testing was the integration of the Danish Node into the NordicWay Network and the exchange of SRTI messages in the form of DATEX II messages to and from the Danish TMC via a pre-production version of the NordicWay Interchange. The purpose of the assessment was to assess performance behaviour - not to test performance requirements in terms of absolute numbers.

Beside the performance testing, end to end functionality was also verified through demonstrations.

6.3.1. SERVICES

6.3.1.1. DESCRIPTION OF THE SERVICES

The Danish Pilot included the cooperative services, which were deployed by NordicWay, complemented by data collection and analysis services.

6.3.1.2. COOPERATIVE SERVICES

The cooperative services provided for producing, consuming, communicating and distributing safety-related traffic messages (hazardous location warnings and weather and slippery road warnings) in the NordicWay environment.

6.3.1.3. DATA COLLECTION SERVICES

The purpose of the data collection services was to collect data to be used for analysis and evaluation of the QoS parameters. The services included:

- Logging services for recording the activity at the various links involved in uplink and downlink operations.
- Services for delivering the logged data to the data analysis services.

6.3.1.4. DATA ANALYSIS SERVICES

The data analysis services provided for analysing the logged data in order to determine and evaluate the QoS parameters.

6.3.1.5. PILOT AREA AND TIMING

The Danish Pilot covered the Danish part of the NordicWay corridor.

The period of operation of the logging services for test over time covered one-month period (from 2017-07-07 to 2017-08-07)

6.3.1.6. SERVICE LEVEL AND QUALITY REQUIREMENTS

The cooperative services and the associated logging services were subject to the following service level and quality requirements.

- The cooperative services and the logging services should be available and operational at the various links of the uplink and downlink connections for the testing period – except for outtakes due to planned maintenance and possible errors and failures.
- Logging of data must be implemented at the various links. The logged data should be standardized in order to make data comparable across links.

7. Evaluation and definition of the next phase

This chapter presents the main evaluation results from the NordicWay project and main issues in defining the next phase.

7.1. Definition of KPIs and evaluation guidelines

The first evaluation task in NordicWay was the development of the NordicWay Evaluation Handbook [17]. The Evaluation Handbook provides definition of KPIs and guidelines for evaluation of C-ITS services within the NordicWay project. The guidelines were developed to comprise C-ITS services within three core services;

i. Cooperative hazardous location warning
ii. Cooperative weather and slippery road warning
iii. Probe data services (sub-system for i and ii)

The NordicWay Evaluation Handbook used the European ITS platform (EIP) quality assessment methods and Quantis methodology for assessment of technical performance and quality assessment, the EasyWay evaluation framework for assessment of impacts and benefits and Technology Acceptance Models for evaluation of user acceptance.

The evaluation approach was designed to cover a) technical performance and quality assessment, b) impacts and benefits, and c) user acceptance. The Evaluation Handbook included a data collection guide, an evaluation methodology guide and a description of the evaluation process.

The evaluation approach presented in the Evaluation Handbook underlined evaluations of all NordicWay pilots.

7.2. Evaluation of the results

Every national pilot documented their evaluation set-up and results in a national evaluation outcome report [18][19][20][21]. These reports followed the approach prescribed by the NordicWay Evaluation Handbook.

Additionally, the main results of national evaluations were extracted and summarised in the NordicWay Evaluation Outcome Report [22]. The national evaluation outcomes provided useful input to discussing full-scale deployment of C-ITS services. Eight presents issues included in the evaluation of NordicWay pilots. The evaluation of any single pilot did not include all of these issues. By juxtaposing and collocating the evaluations, however, a comprehensive evaluation of C-ITS services based on cellular networks was possible.

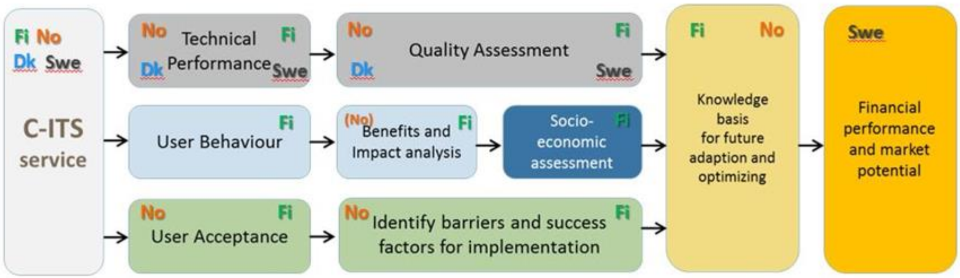


Figure 8. Evaluation aspects in NordicWay

In the Danish, Finnish and Swedish pilots, **technical performance** assessment concentrated on *latencies* for messages transmitted between different servers and systems. Whereas the Danish evaluation tested latencies for messages of different volumes, the Finnish evaluation tested latencies of messages transmitted between the Finnish service cloud, the Finnish node and the mobile users involved in their pilot. The Swedish evaluation presented latencies for messages transmitted between a Road Works Warning vehicle (TMA), and clouds and vehicles belonging to OEMs Scania and Volvo. The evaluations found that latencies increase with increasing size of DATEX-II messages. Latencies further depended on what systems messages were transmitted between. For instance, the median latency in the mobile link, as measured between transmission of a message at the user's phone and the receipt at the Finnish cloud of message at a user's smartphone, reflected at the service provider cloud was 0.3 seconds. The median latency between the receipt at the service provider cloud and the receipt at the Finnish traffic cloud was 0.7 seconds. For the messages from RWW vehicles and the Volvo cloud in the Swedish evaluation, the median latency was 0.9 seconds, and between the RWW vehicle and the receiving vehicles in the order of 2 seconds. The evaluations also indicated that the latencies in LTE networks were generally clearly lower than in 3G networks.

Further, the same evaluations examined success rates in *message delivery*. Overall, message delivery rates were high, but it proved difficult to identify the reason why some messages were not delivered or returned. Server downtime or setups for registration or logging of events underlying messages were commonly reported as probable causes. In order to determine the cause of lost messages, a test of the NordicWay Interchange Node was conducted: a client in a cloud outside the Interchange sent one million messages through the interchange with a payload of 2 kilobytes. No messages were lost, and messages were sent at a rate of 16 messages per second. The NordicWay Interchange Node did not increase the latency by more than 14 milliseconds. Although it did not cause messages to be lost, the test did reveal a message leak caused by disk swapping, which must be resolved in next phase development. Another critical issue was the packaging of DATEX-II messages into AMQP messages.

The use of the different standards should be further harmonized, e.g. by providing guidelines on the use of location referencing by the different stakeholders in DATEX II and on the event lifecycle management. In addition, some issues with the AMQP headers were noticed during the preparations for the interoperability demonstration. Hence, further work, similar as the work performed in C-ROADS on profiling is needed.

Also, the HMI should be further harmonized, as different stakeholders use currently different icons for the same messages. The in-vehicle warnings should be consistent with information provided from the roadside, e.g. variable message signs. Such standards need to be developed in a wider network of partners than NordicWay.

NordicWay evaluations also examined technical performance and quality assessment in relation to friction data and the communication range of ITS-G5. In studying *friction data*, the Norwegian evaluation showed that vehicle system's ability to detect slippery road conditions is not sufficient and data quality not sufficient for developing decision support for winter maintenances. The Swedish evaluation examined the *communication range of ITS-G5*, and found the maximum range to be less than 500 meters with a clear line of sight.

User behaviour was mainly evaluated based on the Finnish pilot of a mobile application which provided drivers with cooperative warnings of hazardous situations ahead. The evaluation found that receiving such warnings influences choice of speed and route, as well as focus in traffic.

The potential **benefits** of C-ITS relate directly to the characteristics of the C-ITS service. The Finnish evaluation found a direct safety impact of the service, particularly relating to warnings of slipperiness, animals or people in the road. Impacts result in reductions in traffic accidents, travel efficiency, and benefits to the traffic management centres who receive more information.

The Norwegian evaluation discussed potential benefits of using road surface information (RSI) to design a support system that aids contractors on winter road maintenance. Benefits included opportunities to prioritise maintenance tasks and to follow up on maintenance contracts. The Swedish evaluation found that the value of interoperability depends on a penetration rate of at least five percent.

Two of the national evaluations in the NordicWay project examined **user acceptance**. The Finnish evaluation focused on users' acceptance of the mobile application and its function, and found that users were overall satisfied with the service. Their satisfaction was especially prominent with how far ahead of an incident the users received the warning. The Norwegian evaluation focused on the attitudes of maintenance contractors and road authorities towards a hypothetical support system for winter road maintenance (i.e. acceptability), and found the acceptability to depend on the data upon which the system is based.

The **barriers and success factors** identified in the pilots are to some degree specific for the C-ITS service that was piloted, but also included issues transferrable to the establishment and delivery of any C-ITS service through the NordicWay Interchange Node. Critical issues included infrastructures and integration, standardisation, network coverage, information reliability, data quality, stakeholder involvement, and private-public partnerships with defined roles and responsibilities. Concerning security, provisions should be put in place to ensure that data is only provided to the intended partners (e.g. no leaks due to problems with e.g. AMQP header information). Barriers and facilitators for deployment are further described in the NordicWay roadmap for next phase deployment [23] (see also 7.3).

The Finnish evaluation also presented a **socio-economic assessment** to identify expected costs and benefits related to full-scale implementation of the C-ITS service tested in the Finnish pilot, and to determine the expected cost-benefit ratio. They found a conservative estimate of the overall benefit-cost ratio to be 2.3, with a yearly increase between 2019 and 2030.

The national evaluations provided **knowledge basis for future adaptation and optimising** of the C-ITS services, which were piloted. The Finnish evaluation emphasised advances in the design and functionality of the mobile application, solutions for verifying or disabling messages, and integration into navigation systems. The Norwegian evaluation highlighted the need for accumulating experiences with the technology, incremental development of the technology solution and validation in close cooperation with stakeholders. The Swedish evaluation calls for better definition of roles in the ecosystem and a viable business model, as well as closer definition of requirements for large-scale deployment.

The Swedish evaluation discussed fundamental issues for making the Interchange Node available to a larger **market**. Allowing access to a multitude of data is expected to increase market potential. Market potential could be further increased through facilitating scalability and interoperability with other central service nodes, and through allowing other data and service providers to join the NordicWay community. Establishing the NordicWay Interchange Node requires private-public partnerships in which public authorities play a leading role in the early phase. This involves defining roles and responsibilities of all actors. Because of little experience with business models and willingness to pay, this is particularly important to ease insecurities related to long-term operation of the NordicWay Interchange Node.

7.3. Definition of next phase

Based on evaluations of national pilots and overall experiences in the NordicWay project, the definition of next phase has been discussed and presented in the NordicWay Deployment Roadmap [23]. The roadmap was produced through deliberate discussions and collection of input from all parties involved in the national NordicWay pilots. The list below presents the main steps in developing the roadmap.

1. **Unstructured input** on barriers and facilitators for next phase deployment, from the NordicWay Evaluation group
2. **Structured input** on categorised barriers towards deployment and solutions, by means of an on-line survey distributed to all participants in Nordic Way project
3. **Workshop** on evaluation and roadmap for next phase deployment in Helsinki, October 23.-25. 2017, with participants from all involved countries, and with technical staff via Skype for specific session

4. **Roadmap draft** distributed for partner review
5. **Final Roadmap**

The discussions leading up to the roadmap were organised according to the following categories: i) data related issues, ii) technical issues, iii) legal issues, and iv) commercial and organisational issues. The purpose of the process listed above was to identify barriers towards further deployment of C-ITS services using mobile phone networks, and possible solutions and way to mitigate these barriers.

Among the **data-related issues**, data sharing, standardisation and data quality issues were identified as the three main barriers towards further deployment. These barriers are related to each other: Data sharing is needed to improve data quality: To share data, we need standardisation. We should not wait for standards, but work on data sharing and data quality in parallel with standardisation. The need for enhanced profiling of standards, e.g. to further refine specific topics such as description of location within the DATEX II standard, was prominent in the discussions.

Interoperability, maturity and standardisation issues were identified as the three main **technical issues**. We should initiate large-scale real-life performance tests (24/7 over longer periods of time) to refine standards, to enhance interoperability as well as to build critical mass with trust in service and willingness to get involved and to invest.

Liability, Privacy and Access to data were identified as the main three **legal issues** which form barriers towards further deployment. Recommendations are to test and identify best practices for data security and liability related to C-ITS services.

Among the **commercial issues**, user needs, benefits/costs and business models were assessed as the main three barriers towards further deployment. we should identify relevant use cases based on real user needs, and then assess benefits and costs to justify (or not) the C-ITS services in question. We should start with safety-related traffic information (SRTI) services to create a critical mass, and then add other (commercial) services to this later.

Through a survey and a workshop, the NordicWay partners discussed how road users, road authorities and commercial stakeholders can **benefit** from C-ITS Day1 SRTI services over cellular networks, and what must be in place to ensure benefits to all of these groups. An important common benefit is that of an improved shared situational awareness and a common operational picture, which enables better coordination of activities of the various stakeholders (car drivers, traffic managers, first responders, etc.). To ensure realisation of benefits, mobile network coverage and seamless cross-border functionality, access to and willingness to share data, as well as well-working business models, mutual trust and rules of engagement must all be in place in order to establish a viable eco-system for deployment of C-ITS services over the mobile network.

The NordicWay project has piloted selected Day 1 services identified in the work of the C-ITS Platform Phase I [1]. The roadmap therefore provided comments to C-ITS Platform Phase I and

Phase II [24] recommendations, which fall within the scope of the NordicWay project. The comments were based on experience from the NordicWay project.

8. Dissemination and Communication

NordicWay has conducted numerous activities on dissemination to external parties via a range of communication channels. An overview is given in **Error! Reference source not found.** on the next p ages, which clearly demonstrates a commitment to disseminate results to external stakeholders and the C-ITS community.

The NordicWay web site **www.Nordicway.net** was used to show press releases, major test results, key milestones, and results etc. during the project. The NordicWay videos (three versions with different lengths) are on the web site as well.

The NordicWay template for documents to ensure visibility of EU funding

All partners have used the NordicWay template for documents, deliverables and presentations. Hereby, it has been ensured that the obligation to include the EU logo "Co-financed by the European Union, Connecting Europe Facility" is fulfilled. The template can be found at the NordicWay Workspace.

Internal communication

NordicWay partners have used a Sharepoint workspace to exchange documents and drafts etc. The NordicWay Workspace can be found at http://www.vtt.fi/workspace

The Sharepoint access rights to the NordicWay Workspace has been the responsibility of the project manager and the Coordinator.

The following access rights were granted:

1. Beneficiaries and implementing bodies with their supporting consultants had full rights.
2. Industrial partners had full rights to their national pilot related material and access to all general NordicWay documents (applying to all)
3. Other stakeholders had access (read only) to the public documents.

Table 4 NordicWay external communication

Type of Information	Description	Time of delivery/launch
NordicWay Web site	NordicWay web site www.Nordicway.net	Launched September 2015
PR materials	First NordicWay Brochure Second NordicWay Brochure NordicWay video on Interoperability demonstrations (3 different versions/length of videos for various purposes/contexts) Third NordicWay Brochure	- October 2015 (on display at ITS World Congress 2015) - March 2017 (for Connected and Automated Driving conference 3-4 April 2017) - June 2017, launch at ITS Europe in Strasbourg and 3 versions at ITS World in Montreal + NordicWay Final Event - November 2017 at NordicWay Final Event
Presentations	Various presentations at congresses, seminars etc. 1. ITS Word Congress Bordeaux 2015, 5 presentations a) Road status information, a new paradigm for road authorities b) My cloud, your cloud, our clouds - NordicWay c) Cellular C-ITS pilot: NordicWay d) ITS Activities in Sweden and Finland - NEXT-ITS and NordicWay e) Making sense of the big data behind the connected vehicle 2. NordicWay at FOT-NET Data Sharing, Field Operational Test Network 3. TAIEX Workshop on Cooperative Intelligent Transportation Systems 4. Helsinki Urban Node Regional Conference 5. ITS Finland and ITS Russia seminar 6. SIGCHI Finland – The Future of Cars, Driving and Traffic Spring Seminar 7. Federation Internationale de l'Automobile (FIA) delegate visit	 5-9 October 2015, Bordeaux 8 March 2016, Brussels 22 March 2016, Tel Aviv 6 April 2016, Helsinki 14 April 2016, St Petersburg 21 April 2016, Vantaa, Finland 10 May 2016, Helsinki

Type of Information	Description	Time of delivery/launch
	8. European Navigation Conference 2016	30 May, Helsinki
	9. International Symposium of Enhancing Highway Performance (ISEHP)	June 2016, Berlin
	10. ITS Europe Congress Glasgow a) Improving road safety, efficiency and sustainability in Europe b) C-ITS National Approaches	6-9 June 2016, Glasgow
	11. Animals on the road seminar	2016, Jyväskylä
	12. ITS World Congress Melbourne 2016, presentations a) Cooperative Systems – Stakeholder Contribution and Cooperation	10-14 October 2016, Melbourne
	13. Compass4D webinar,	16 Dec 2016
	14. ATEC ITS Congress, a) Streamlining V2X road works warning with hybrid communication – a concrete example of implementation	24-25 January 2017, Paris
	15. The Nordic Road Association (NRA) Digitalization committee meeting	8 Feb 2018, Helsinki
	16. Connected and Automated Driving conference	3-4 April 2017, Brussels
	17. ITS Europe Congress Strasbourg a) Cross-border interoperability of C-ITS services transmitted over cellular networks	19-22 June 2017, Strasbourg
	18. Connecting Europe Conference,	21-22 Sep 2017, Tallinn
	19. ITS World Congress Montreal October 2017, presentations and exhibition (video)	29 Oct-2 Nov 2017, Montreal
	20. NordicWay Final Event, (full-day event, see below)	21 Nov 2017, Brussels
	21. EU EIP C-ITS/C-Roads Workshop,	22 Nov 2017, Brussels
	22. Danish national congress "Vejforum", interactive presentation and video in exhibition	Dec 2017, Copenhagen
Presentations for Amsterdam Group and CODECS	• NordicWay status presented 15 September 2015 • NordicWay status presented 26 April 2016 • NordicWay status presented 14 February 2017 • CODECS hybrid communication meeting, NordicWay, 19 May 2017	

Type of Information	Description	Time of delivery/launch
C-ITS Platform	• WG Business models, September 2016 • WG Compliance, 29 March 2017 • Hybrid Communication/input, Brussels, 11 July 2017	
Presentations at C-ROADS meetings	• NordicWay – Cellular/Hybrid C-ITS Corridor, 30 March 2017 • NordicWay at C-Roads meeting, Milan, Nov 2017	
Articles, notices etc.	• Traffic Technology International, "Misconnected vehicles?" Article on NordicWay and other C-ITS pilots, April/May 2016 • NordicWay in Swedish Rise Victoria Newsletter, 30 June 2017 • Norwegian Technical Magazine "Teknisk Ukeblad" Article on connected and automated driving and the NordicWay Interchange https://www.tu.no/artikler/norske-veier-ma-bli-klar-for-de-selvkjorende-bilene-dette-er-utfordringene, 23 August 2017	
Press releases	• Norwegian Public Roads Administration Press release • Finnish Transport Agency (FTA) and Finnish Transport Safety Agency Trafi´s Press release • HERE Press release • Press release in Finland: Road users on the Ring Roads and the Helsinki-Turku Motorway: Participants wanted for trial aimed at improving traffic safety • Press release in Finland: Finland's largest vehicle pilot, open to all road users, now also includes the approach roads to large cities in southern Finland • Press release in Finland: Calling all drivers: Finland's largest traffic trial open to all now covers all of southern Finland • Press release: Cloud-to-cloud vehicle connectivity improves road safety	February 2015 (in Norwegian) 30 June 2015 30 June 2015 11 May 2016 17 Nov 2016 7 Feb 2017 21 Nov 2017

Type of Information	Description	Time of delivery/launch
PR Events and demonstrations	• Launching events arranged to announce the start of the pilot services in the different countries • Interoperability demonstration, Norwegian pilot • NordicWay Interoperability demonstrations, all partners, May 2017 (Videos have been produced to document the demonstrations – 3 version of various lengths) • Final Event (see below)	2016 31 August 2016 10 May 2017 (SWE-NO border, Svinesund) + live streaming 18 May 2017 (Copenhagen/ SWE-DA border)
Final event	Large workshop to publish the results to the partners, EC, C-ITS stakeholders etc., 21 November 2017, Brussels • A full-day workshop with 11 presentations on the NordicWay approach covering C-ITS Service highlights, Evaluation results and the way forward, also including industry panel and round table (All presentations and videos are on Nordicway.net)	21 November 2017, Brussels

9. Management

The governance of the project was detailed in the Project Governance Handbook [25], which also included guidelines on communication procedures, quality control and the risk management plan.

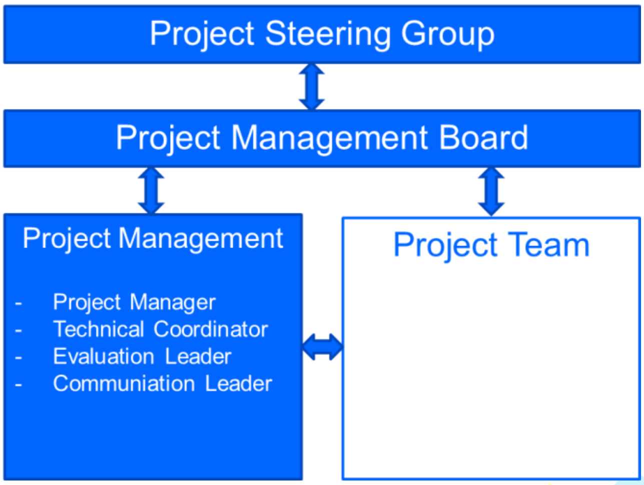


Figure 9. NordicWay project organisation

The main bodies were:

- Steering Committee was responsible for all major strategic decisions, final approval of the work programme, relations to the EC and member states, approval of work, deliverables and main reports. The Steering Committee consisted of authorised representatives of the different official beneficiaries.
- Project Management Board was responsible for the daily management and governance of the project. The Project Management Board discussed progress and issues of strategic nature in the PMB meetings, which were held quarterly (22.5.2015 Helsinki, 31.8-1.9 Helsinki, 8-9.12.2015 Copenhagen, 16-17.3.2016 Stockholm, 15-16.6.2016 Oslo, 26-27.9.2016 Helsinki, 12-13.1.2017 Copenhagen, 6-7.3.2017 Stockholm, 24.8.2017 Oslo, 4.12.2017 Helsinki) .

10. Conclusions

This report provides an overview of the work performed in the NordicWay project, of the achievements of the project and on the planned way forward.

The NordicWay project demonstrated the provision of C-ITS Day 1 services using cellular networks. The NordicWay solution is an interoperable cellular cloud based C-ITS solution, which is scalable to Europe and beyond. The solution is based on the transfer of information between different service provider clouds and traffic clouds, combined with low-latency transfer over cellular networks between vehicle and service operator. Through the use of existing commercial cellular networks, the solution allows for full road network C-ITS coverage and, as it is based on either smart phones and connected vehicle devices, for a fast deployment of the piloted services.

The median end-to-end latencies in the system were in most cases well below 1 second, which is sufficient for the type of messages involved, which are mainly targeted at increasing situational awareness of the driver. Also, hybrid communications were demonstrated, where ITS-G5 (or LTE V2X) used for short-range communications at hotspots between roadworks trailers and vehicles and cellular communications for warning drivers approaching the trailer. Both ITS-G5 and cellular system have a place in C-ITS, with short-range communication allowing extreme low-latency for safety critical operations, and cellular communications covering the whole road network.

The project also resulted in an ecosystem supporting the OEMs and service providers' customers relationships. The end-user is connected to a service provider, which takes care of security and privacy of the communications.

The system was piloted successfully in four countries, with more than 1 800 users. In Finland, drivers were highly satisfied with the service, and wanted to use it after the end of the pilot. Socio-economic evaluation resulted in a benefit-cost ratio for the period 2019-2030 to be at least 2.3.

The NordicWay system worked well during the pilot. The Interchange Node was demonstrated to work well, and the architecture was proven to suit the services. The next phase is to go to the full deployment of the Interchange Node. For this purpose, mechanisms for compliance (e.g. for taking on board new stakeholders) have to be defined. As a single Interchange Node may not fulfil the needs of all stakeholders, a more federated architecture including multiple Interchange Nodes may be required.

The NordicWay system relies on existing standards, such as DATEX II and AMQP. A specific event can be coded in many ways in DATEX II, dependent on country or operator specific preferences for e.g. location referencing. Profiling is needed to make the messages exchanged by the different actors more uniform.

The results of the NordicWay project will be used by the NordicWay 2 project, which will take the system a step closer to large-scale deployment. NordicWay 2 will bring more services to more users on a larger part of the road network, and also address cloud-to-cloud connectivity for automated driving.

Cooperative ITS or C-ITS has been one of the priorities for ITS deployment for many years, and especially during the past few years. It is evident that the quickest way for reaching maximum road network coverage and vehicle fleet coverage is to use a solution based on existing cellular connectivity of vehicles in combination with already existing cellular networks. Hence, the solution provided now by NordicWay, with proven interoperability, low latencies, high user acceptance, considerable benefits, and low costs is now offering the way to go forward on the European, and also the global scale to deploy C-ITS in the large scale.

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