Evaluation Outcome Report, Sweden

SE5
NordicWay Evaluation of the Swedish Pilot

NordicWay

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TABLE OF CONTENTS

Summary

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. 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 (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 server. The Interchange server 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.

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 driving in a more naturalistic way. In total, more than 7000 events were recorded during the trial period.

The pilot showed that both technologies are viable solutions for transforming messages. The send receive latency in the controlled test ranged from 1.25 to 2.48 seconds from source to vehicle depending on which scenario that was studied. This is considered as "good enough" for most services but the Swedish pilot emphasize that the ITS-G5 and cellular have different strengths and weaknesses and that the best solution should be selected depending on the specific requirements for the specific service.

In addition to the technical pilot the Swedish pilot included a study on business models. In that study, all the Swedish industrial partners as well as all the road operators where interviewed on how they see the business models for an interchange node like the one developed in NordicWay. A special focus was set on how to get things started and what roles they saw that they had in the ecosystem. Overall there was a large agreement that public - private cooperation was needed since both are needed and both have something to gain. There was also an agreement on the various roles needed in the ecosystem and what role each player had as well as all agreed that it was hard to identify any direct monetary profits to be gained. There is however a difference in how this is best financed and who takes the lead in this. To summarize the Swedish pilot managed to identify the similarities and differences between the involved actors but the best way forward remains to be agreed on.

A third part of the Swedish trial was to elaborate on the value of interoperability. This was done by analyzing the time it took for a connected vehicle to detect an event and pass the

SE5 - NordicWay Evaluation of the Swedish Pilot

information on to proceeding vehicles. This was studied for various penetrations rates by using Vissim microsimulation. The conclusion was that for a penetration rate less than 5% there is a limited value of having communication between vehicles but the effect increases rapidly for every vehicle and already at 5% and above the effect has saturated to some degree. This mean that all brands except the top three would benefit from interoperability between brands.

Further work based on the findings from the Swedish pilot includes a better definition of the roles in the ecosystem and the business models for this. That requires further studies of costs and benefits to have better information to base the decision on. There is also more work needed on the requirements for large scale deployment.

1. Introduction

The Swedish Pilot is dedicated to two specific aspects within the service delivery chain aiming at enhancing the result and impact of the services by enhancing the available source of information brought into the service and enhancing the range of service recipients, through the introduction of interoperability and seamless service provision.

Interoperability and continuous access to data as input for the service will increase the information base on which the services are provided. By adding additional sources of information, including extension of the vehicle fleet that provide sensor data for the services, will improve the quality of the service provided. Interoperability and seamless provision of the services, including the use of multiple channels for service provision and distribution, will enhance the service coverage (increase the number of potential users). Both these aspects will contribute to improvement of the Result of the service and in the end the Impact of the service.

As NordicWay is based on a uniform set of services, and the road transport systems of the Nordic countries are quite homogenous, it is reasonable to expect that the Result of the service, i.e. the reaction of the individual driver in response to the same service, is similar within the NordicWay area. Hence the Result and Impact assessments from the Norwegian and Finnish pilots can be used as the basis also for the Swedish evaluation, whereas the Swedish results concerning improvements of data quality and enhancement of service exposure can be used for impact assessments in all NordicWay pilots.

The Swedish pilot differs from 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 will contribute with their available solutions and technologies. As important OEM´s already have developed in-vehicle solutions for data collection and information to drivers, these elements of C-ITS will not be assessed within the Swedish pilot. The argument being that what has been considered as commercially and scientifically relevant for an OEM to build into the vehicles should not be put at trial in the Swedish pilot. Instead the focus will be on demonstrating the functionality of the ecosystem as well as interoperability and market issues.

For the development of the ecosystem three services has been used as a means for proof of concept: Slippery Road Warning, Hazard Warning Lights and Road Works Warning (RWW). These have been demonstrated on proving ground in Hällered as well as in the Nordic Way demo carried out in Svinesund at the Border between Sweden and Norway on May 10th, 2017. For the more detailed measurements of how well the communication within the Swedish ecosystem has worked the RWW service has been used. The communication within the ecosystem does not differ for the various services and the RWW was the easiest to stage and most interesting to demonstrate, thus it was chosen as the use case for the detailed evaluation.

2. Description of the RWW C-ITS implementation

A RWW unit on a road works vehicle sends a notification to the road user through the following steps:

· The Truck Mounted Attenuator (TMA) on the road works vehicle is activated (to protect workers and equipment from traffic)
· TMA activation triggers a RWW DENM message to be broadcasted over ITS-G5. Vehicles approaching the trailer receive the message.
· The message is also transmitted to the RWW backend via cellular networks.
· The RWW backend transforms the message into the DATEX II format for RWW and forwards the message to the Nordic Way interchange server
· The Interchange server distributes the RWW message to all subscribing service providers (the information is interesting for the Swedish Transport Administration as well and might be integrated in their systems in future developments).
· The Service Provider sends an alert message to subscribed users in the event area.

The vehicle mounted RWW units communicate directly with vehicles using ITS-G5 standardised communications. In the Nordic Way use case for roadworks, the DENM (ETSI EN 302 637-3 V1.2.2) is used.

The DATEX II (version 2.3) is used for the communication between Service Providers, and between Service Providers and Traffic Data Providers. Only the Data Model of the DATEX II standard is used, not the Exchange Protocol.

The DATEX II messages are passed through the Interchange Server. In addition the AMQP v1.0 protocol is used for transmitting the data messages to and from the Interchange Server.
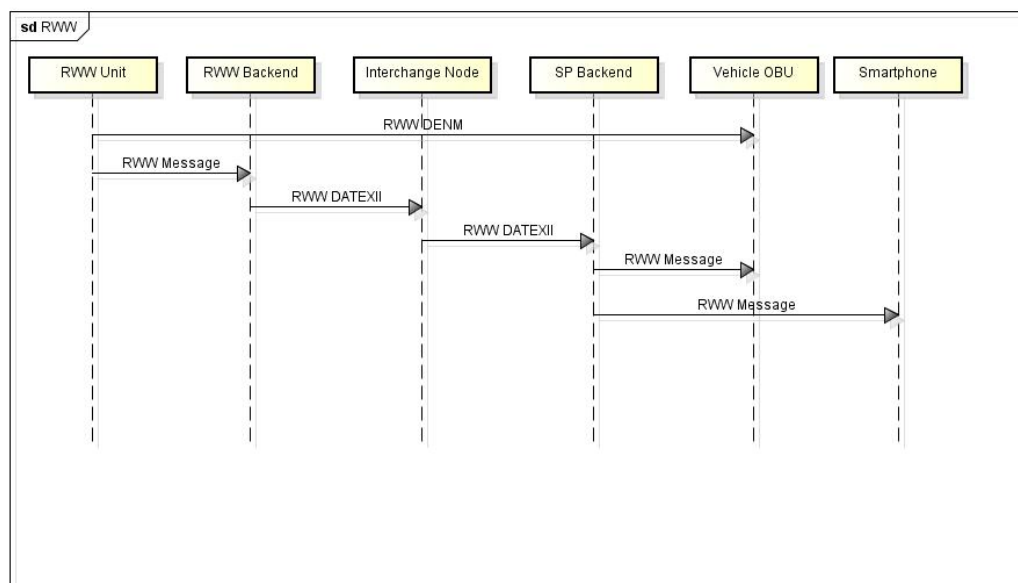

Figure 1 Sequence diagram of the Road Works Warning use case

3. Evaluation design

The Swedish evaluation has two focus areas where the first is focusing on proof of concept regarding technical performance and quality assessment of the interchange server and the other is focused on business models and the value of interoperability.

3.1. Technical performance and quality assessment

3.1.1. INTRODUCTION

The Swedish evaluation on technical performance of the interchange server will use the Road Works Warning trial as an example. This chapter describes how the RWW trials will be carried out, both the driving study and the trial with controlled parameters. It details which indicators that will be measured, the measurement method and a test plan.

3.1.2. TRIAL OBJECTIVES AND INDICATORS

The objective of the RWW trials is limited to evaluation of technical performance. The following is a description of the indicators chosen.

3.1.2.1. DRIVING STUDY

The **driving study** involved several vehicles in normal day-to-day usage. It evaluated the road administration operational integration of the solution as well as proving that the solution can cope with real world conditions.

The indicators chosen to reflect this are:

· Send/receive latency of road works messages
· Message success rate

The driving study focused exclusively on the cellular communication link.

3.1.2.2. TRIAL WITH CONTROLLED PARAMETERS

The **trial with controlled parameters** was carried out with one RW-equipment (from Kapsch TrafficCom) and three client vehicles (one from Scania and two from Volvo Cars) on dedicated test tracks. It verified the sufficient timeliness and communication range of the two communication methods under study.

The indicators chose to reflect this on the cellular link were:

· Send/receive latency of road works messages
· Message success rate

In addition the communication range under beneficial conditions was measured for ITS-G5.

3.1.3. MEASUREMENT METHOD FOR INDICATORS

3.1.3.1. SEND/RECEIVE LATENCY

During the measurement period all RWW DATEX messages were logged with the following key parameters:

n	message ID given by the DATEX tag "situation" by concatenating the attributes "id" and version, separated by a "-".
	Example:
	<q1:situation id="12341140_209" version="7"> gives n="12341140_209-7"
$tsend_n$	publication time of the message n as given by the tag "publicationTime"
$treceive_{n,d}$	Reception time of message n in the destination d. Destinations are clouds or end clients.
	The time source should be sufficiently synchronised with a GNSS time source.
	Example of destinations: "volvo-cloud", "scania-vehicle", "sta-cloud"

Send/receive latency was computed in the following way:

$$\mathbf{srlatency_{n,d}= tsend_n - treceive_{n,d}}$$

For cloud destinations latency for all messages was computed. For vehicle destinations, only latencies for the received messages were computed (as there is a geographic filtering mechanism from cloud to vehicle that suppresses those messages that are irrelevant for the specific vehicle location).

3.1.3.2. MESSAGE SUCCESS RATE

During the measurement period, all RWW DATEX messages were logged with the following key parameters:

$totsent_d$	Total number of sent messages that should have been received by the destination d.
	For cloud destinations:
	total number of sent messages during the measurement period from the Kapsch RWW cloud (ie also those describing a situation in a different region of Sweden)
	For vehicle destinations:

	messages describing situations within the detection radius of a vehicle which have consequently been forwarded to that vehicle from the vehicle cloud
totreceived$_d$	Total number of received messages at the destination d

Message success rate was computed in the following way:

messagesucessrate$_d$= totreceived$_d$/totsent$_d$

3.1.3.3. *COMMUNICATION RANGE OF ITS-G5*

The ITS-G5 communication range (**comrange**) was measured by determining the maximum distance behind a RWW vehicle that a DENM or a CAM message can be received in a situation where there is a line of sight.

3.1.4. TEST PLAN

3.1.4.1. *TECHNICAL SETUP*

The technical setup is described in Annex A.

3.1.4.2. *DRIVING STUDY*

Tests near Södertälje involved first two, with a ramp up to three RW-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 Göteborg involved eight RW-vehicles and twelve receiving cars roaming freely in performing their day-today business. Both the Volvo-cloud and the Volvo-vehicle destinations were logged.

Tests of the STA-cloud only logged the sta-cloud destination.

The send/receive latencies (**srlatency$_{n,d}$**) shall be computed for all specified destinations as well as their mean and standard deviation.

The message success rate (**messagesucessrate$_d$**) shall be computed for all specified destinations

3.1.4.3. *TRIAL WITH CONTROLLED PARAMETERS*

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. Both send/receive latencies (**srlatency$_{n,d}$**), with associated mean and standard deviation was computed as well as the message success rate (**messagesucessrate$_d$**).

The trial with controlled parameters took place on September 19 and September 25 on the test track of Eskilstuna flygplats, testing the Scania equipment. In these tests the ITS-G5 communication range (**comrange**) was also measured.

Testing of the Volvo equipment took place on September 26 in Göteborg in the vincinity of Lindholmspiren. Tests involved sending of more than 20 messages from one location.

3.2. Business models

3.2.1. AIM, METHOD AND PROCEDURE

The purpose of the study of business models was to get a better understanding of how open data can be made available and exchanged between relevant actors and how this best can be implemented. In NordicWay a technical solution has been implemented and demonstrated but how this should be done in practise is still unsolved. There are potentially different scenarios for this and the actors involved can have different roles and different view of their, and others, roles. The actors involved however have hands on experience from implementing the technical solutions in NordicWay and they have all discussed this within their organisations.

In this task the main Swedish partners involved in NordicWay was interviewed separately. Each partner was represented by two to four persons, all with technical and/or strategical insight in exchange of open data. The interviews were for practical reasons carried out through Skype and they were done by two persons where one acted as the main interviewer and the other as support and secretary. In addition, the Norwegian, Finnish and Danish road associations where interviewed using the same interview material as for the Swedish interviews. They were however carried out by local personnel and may have differed somewhat in setup.

The interviews set out to answer questions on how the implementation of data exchange between connected vehicles may take place and what the various roles required are, potential scenarios for this and how the actors see their and others role in this. The aim is to identify differences in how actors view this and if there are overlaps or gaps in the roles required. The outcome of this is recommendations, even though it is recommendations on what need to be dealt with rather than recommendations on how to deal with this.

The interview was structured into four parts (each described below):

· Agreeing on the preconditions for the interview

· Describing the general focus of the discussion

· Describing the NordicWay architecture as a starting point for the discussion

· Open discussion / interview

The preconditions for the interview was shown to the interviewees on a Power Point Slide as follows:

· The scheduled time is 90 minutes but we aim for one hour.

- The interviews are recorded to make analysis easier.

- The interviewees get to see the transcript before it is made available to the consortia. There is a possibility to add or remove information

- The reporting of the interview is kept as general as possible, i.e. we only mention organisations when that information is relevant

- Individual persons are never mentioned by name

- There are several questions prepared but the focus of the discussion depends to a large degree of the interest of the interviewees.

  These preconditions were shown to the interviewees and agreed upon before the interview began.

  The focus of the discussion was described as:

- How can a model for exchange of data look? (starting from the present idea in NordicWay

o Both in terms of the technical architecture and how it can be implemented,

o and in terms of the administrative issues (of how data can be exchanged)

- How do you (note: the interviewed actor) look at roles and responsibilities (requirements and control, building and operating)

o From the viewpoint of your organisation

o What is your view on other organisations roles and responsibilities.

- The questions above can be viewed from a Swedish, Nordic and European perspective

To start the discussion, and to make sure all interviewees had the same starting point the NordicWay architecture was shown and described, usually by the interviewees themselves. After that the open discussion was initiated, usually by asking the general question what their view is on the NordicWay architecture.

Figure 2 The slide on preconditions (in Swedish) as it was shown to the interviewees

Figure 3 The focus of the interview as presented to the interviewees (in Swedish).
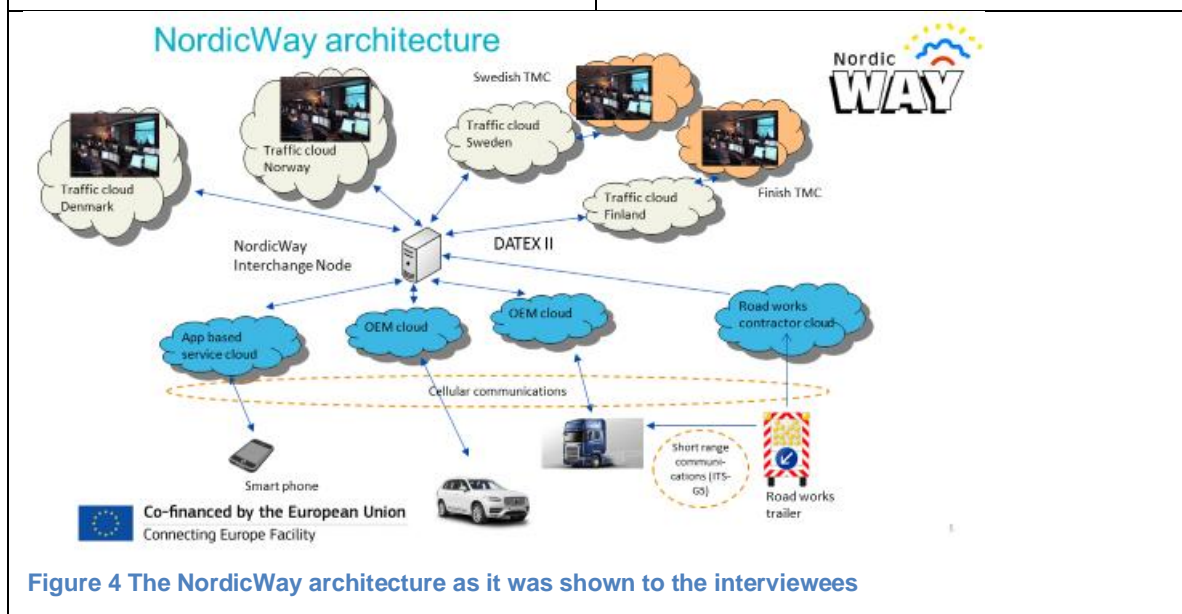
Figure 4 The NordicWay architecture as it was shown to the interviewees

3.3. The value of interoperability

This task aims at elaborating on what the added value of interoperability is, i.e. how much does the fact that information can be shared between different brands of vehicles or between vehicles from different countries effect the size of data volume and/or rapidness in data collection. What the value of this in terms of improvement of a specific service will differ between services. For this study Hazard Warning has been used as example since it represents a service where the rapidness of data collection is of importance.To evaluate what the added value of interoperability is a microsimulation study has been performed and in addition a literature review on the effect of penetration rate was carried out.

3.3.1. IMPACT OF PENETRATION RATE – A MICROSIMULATION STUDY

To observe the value of interoperability a micro simulation study using Visim was performed. The study looked at three different scenarios:

- 3-lane Motorway, 110 km/h with 1200 vehicles/hour
- Rural road, 70 km/h with 1200 vehicles/hour
- Rural road, 70 km/h with 120 vehicles/hour

Each scenario was simulated 10 times for the penetration rates 1, 3 and 5 percent and then in increments of 5 up to 40%.

The simulation focused on hazard detection and the two measures that were of interest was "Time to detection", i.e. time for the first vehicle to detect and communicate information and Gap time V1/V2, i.e. time to the second vehicle that receives the information (T1 and T2 in Figure 5 below). This time, and standard deviation of time, will vary depending on the traffic flow and penetration rate. In the simulated example, it is assumed that the hazard appears instantaneously rather than developing over time. It is illustrated here by an oil spill causing low friction on the road.
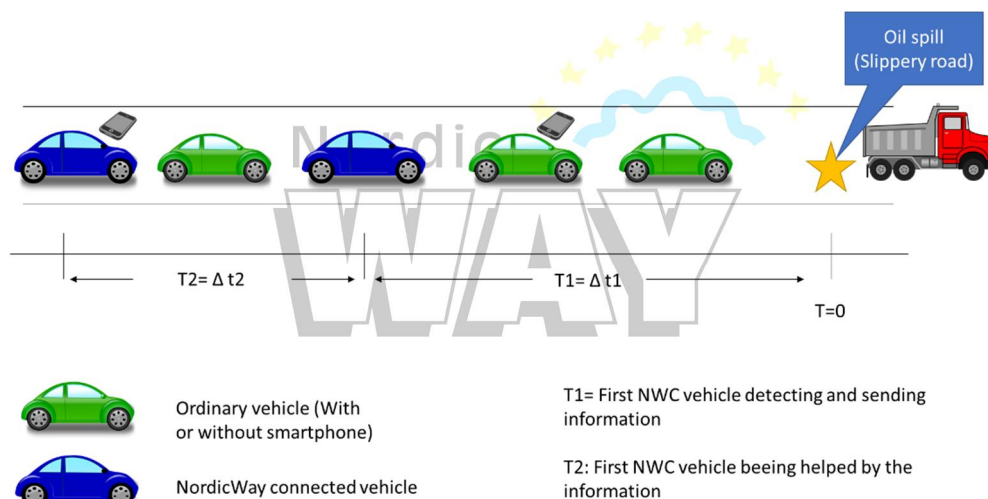

Figure 5 A graphical illustration of the NordicWay simulations

4. Evaluation results

4.1. Technical performance and quality assessment

For definition of metrics etcetera see clause 3.1.

4.1.1. SEND/RECEIVE LATENCY

4.1.1.1. MEASUREMENTS ON MESSAGES TO SCANIA CLOUD AND VEHICLES

The *measurements on the driving study* for the Scania vehicles were in the time period of 2017-08-17 09:07 to 2017-10-12 07:44 and yielded the following results:

	Latency (srlatency) for source to cloud (destination: scania-cloud)	Latency (srlatency) for source to vehicle (destination: scania-vehicle)
Median	2.100 s	2.452 s
Average	4.866 s	11.260 s
Standard deviation	47.807 s	95.285 s
Number of messages	985	251

We can see that the median latency from the road works vehicle to the scania-cloud (passing the Kapsch TrafficCom cloud and the interchange server in between) for the Stockholm/Södertälje area is 2.100 seconds. This is slightly higher than expected. The communication from the road works vehicles to the Kapsch TrafficCom cloud is made over 3G where the establishment of a new connection is in the magnitude of one second. It is possible that congested communication networks account for an extra second. The extra second here is not explained by the time it takes the message to go from the Kapsch cloud to the scania-cloud as that is a much faster process. The average value of 4.866 seconds was not expected. The explanation is that there are several very big outliers. A brief analysis was made to study the reason for these. The main explanation seems to be several malfunctioning periods of the servers involved where the messages could sometimes get stuck for hours. This points clearly to improvement needs in the implementation. However, it should be remembered that this was a pilot system to prototype and test the whole message chain, not to achieve production quality uptime. The median latency time for the message to reach the scania-vehicle is in the expected range since the Scania connectivity solution is based on LTE which has a much faster connection time than 3G.

The *controlled latency measurements* were performed from 2017-09-25 09:23 to 2017-09-25 09:28 and yielded the following results:

	Latency (srlatency) for source to cloud (destination: scania-cloud)	Latency (srlatency) for source to vehicle (destination: scania-vehicle)
Median	1.102 s	1.254 s
Average	1.211 s	1.378 s
Standard deviation	0.352 s	0.354 s
Number of messages	38	38

The median latency value for source to the scania-cloud is shorter than the one in the driving study, and the average value is very different. Under controlled conditions there were no server or other system malfunctions hence no latency outliers. Therefore the average is very similar to the median value and standard deviations are small. We see that the added time for the message to reach the scania-vehicle is quite small (152 ms difference between median values, 167 ms difference between averages). This is as expected with a short processing time on the servers and with a LTE connectivity solution.

4.1.1.2. MEASUREMENTS ON MESSAGES TO VOLVO CLOUD AND VEHICLES

Unfortunately the project only managed to deploy a relatively small number of Volvo vehicles in the area of Gothenburg. This proved insufficient to gather any meaningful amount of latency measurement data for the driving study. Therefore no data is presented for that part. The results and experiences of the driving study with the Volvo cars instead came from overcoming the implementation and integration challenges to create and demonstrate real world working system.

The **controlled latency measurements** were performed from 2017-09-25 09:23 to 2017-09-25 09:28 and yielded the following results:

	Latency (srlatency) for source to cloud (destination: volvo-cloud)	Latency (srlatency) for source to vehicle (destination: volvo-vehicle) [1]
Median	0.879 s	2.486 s
Average	0.882 s	2.444 s
Standard deviation	0.114 s	1.074 s
Number of messages	49	25

The median latency value for the message traveling from the road works vehicle to the volvo-cloud was pretty low. Under controlled conditions there were no server or other system malfunctions and hence no latency outliers. Therefore the average is very similar to the median value and standard

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[1] Including time to send an acknowledgement back from vehicle to Volvo cloud

deviations are small. However we see that the added time for the message to reach the `volvo-vehicle` is rather big (1607 ms difference between median values, 1562 ms difference between averages). One explanation for this is limitations in the measurement setup which made it necessary to include the time for the vehicle to send an acknowledgement message back to the Volvo cloud in the Volvo vehicle latency measurements.
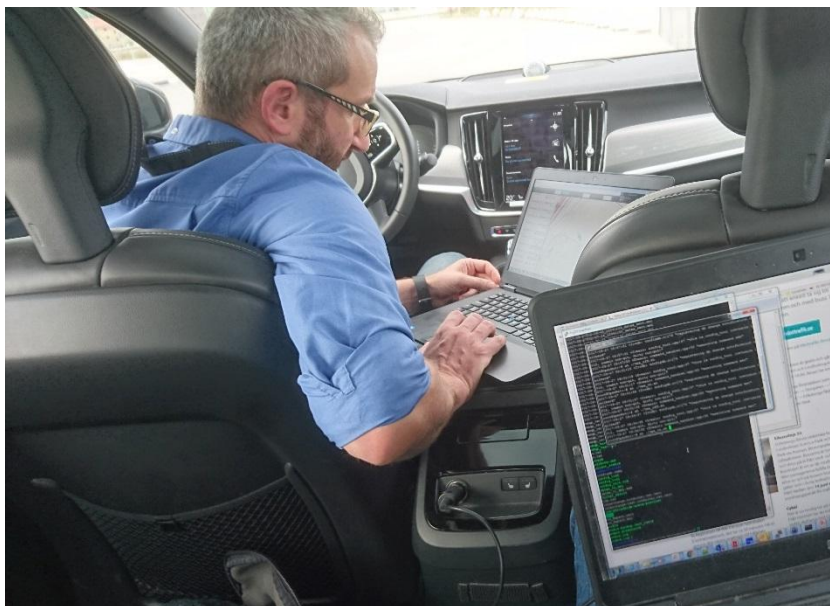

Figure 6 Gothenburg test setup with control of road works message triggering and Volvo Cars backoffice monitoring in the same vehicle

Figure 7 The vehicle receiving the road works warning message on one of the test laps round Jubileumsparken, Göteborg

4.1.1.1. MEASUREMENTS ON MESSAGES TO STA CLOUD

The latency measurements for the STA cloud were from 2017-10-09 12:08:27 to 2017-10-11 00:23:36
 UTC and yielded the following results:

	Latency (srlatency) for source to cloud (destination: sta-cloud)
Median	1.092 s
Average	1.618 s
Standard deviation	3.687 s
Number of messages	940

As we can see the result for the median sta-cloud latency is similar to those for the volvo-cloud and scania-cloud. There were some outliers in the measurement period which explains the difference in median and average values as well as the large standard deviation.

4.1.2. MESSAGE SUCCESS RATE

As could have been expected, the message success rate (parameter **messagesucessrate$_d$**) was 100% percent during the measurements with controlled parameters except for one message where the positioning of the road works failed and in doing so produced a dummy position which caused the message to be silently filtered out in the interchange node.

For the driving study the experience was that once all the systems were up and running the message success rate was also here 100%. But there were several periods of downtime for all server systems involved. Also, the positioning malfunction in the road works vehicle equipment, that was experienced in the controlled tests, occurred several times in the driving study as well.

These experiences can be said to be due to the fact that the Nordic Way road works warning pilot was focused on implementing a complete system as a type of proof of concept. A trial with many actors involved and running over an extended period of time of course increases the complexity and thus the possibility for some part of the system to fail. To achieve production quality service levels it will for example be important to improve the monitoring of the sub-systems (server heart beats, sanity checking reported values etc). Proposed future work is to trim the sub-systems and bring them closer to a production level quality.

4.1.3. COMMUNICATION RANGE OF ITS-G5

The objective of measuring the communication range was to get a real-world number on what communication range that is possible to achieve with typical setups of antennas in a vehicle to vehicle installation. However, there has been no attempt at simulating environmental factors such as when the signal is blocked by the terrain or buildings, interference or other complications. Analysis of the prevalence of such factors is needed to predict real world performance. Such analysis has not been carried out in this report.

The technical setup of the Scania truck is described in Annex A. For the sending of the road works messages a test setup mounted in an ordinary car was used. Instead of triggering the state of the road works by reading the status of the TMA with an inductive switch, manual triggering of an on/off switch was used.

The truck from Scania had two different antenna mountings. One case on top and in one case mounted on the rear-view mirror on the side of the vehicle.

The resulting measurements were the following:

Sending antenna	Receiving antenna	Maximum communication range
SMG6-5900/1575 from Mobile Mark mounted on top of vehicle	Scania vehicle-antenna mounted on top of the vehicle	460 m
MGRM-UMB from Mobile Mark mounted on top of vehicle	Scania vehicle-antenna mounted on top of the vehicle	495 m

MGRM-UMB from Mobile Mark mounted on top of vehicle	Scania vehicle-antenna mounted on the rear view mirror of the vehicle	515 m

Figure 8The Scania test truck at the test site Eskilstuna flygplats

4.2. Business models

The findings below are based on interviews with the public and private stakeholders involved in the NordicWay project.

4.2.1. STRENGTHS AND WEAKNESSES WITH THE NORDIC WAY CONCEPT

With regard to the strengths and weaknesses there is a fairly good coherence between the participants. They find the Nordic Way architecture appealing, given that it is usually unclear how to transfer information, from vehicle manufacturers or road operators, for example safety related data. It is not seen as very attractive to keep track of all member countries' (in Europe) different access points and then this kind of interchange node is much more useful. It is also seen as relevant since it is builds upon practical experience and is in line with actual requirements. It is also well in line with other initiatives and has been discussed in other projects as well. So, there is a strong agreement that this is the way forward.

With regard to weaknesses there are some differences between the participants in respect to what they mention. This doesn't mean that there is a disagreement between the participants but rather reflect different viewpoints and priorities. One thing that is mentioned by several, if not all, participants

is the scalability of the interchange node. The current architecture doesn't show links to the other central service nodes (corresponding to the NordicWay Interchange Node). In addition, other service providers should be able to join the NordicWay community. Service providers and actors mentioned here are municipalities, private road operators, infrastructure providers. Similarly several discus what this will look like on a European level and whether for instance OEM's would have one cloud per country or one per manufacturer and how it will work when a vehicle is driving abroad.

Another thing mentioned by several participants, both from the public and private side is security. There isn't any information on how to manage the interchange node, how to deal with data security and by whom. Further, the current architecture doesn't show how to get redundancy in the network since it's focusing on a single interchange node. Related to security the vehicle manufacturers discuss security connected to ownership of data. How can they guarantee to their customers that the data they generate are handled in a secure manner throughout the process and not ending up being used in a way they have not approved of? Features for filtering of data and how to select which data to share with whom was also discussed here by some participants. Here many participants started talking about business models for this, which is described under its own heading below.

4.2.2. HOW TO IMPLEMENT

When it comes to implementing an interchange node like the one proposed in Nordic Way there are two different aspects that are being discussed. One is to get things started, to get the ball rolling as some expressed it. The other is the long-term operation of the interchange node. There is also the distinction between setting standards, controlling and regulating on one side and providing and operating hardware on the other side.

For getting the ball rolling there was a large agreement between the industry partners and the road operators from all countries that this requires private and public partnerships. The most common view from the industry was that the public sector has a large role to play here. This could be by running projects like Nordic Way but also participating in the standards discussions. There is a need to start setting up the necessary infrastructure (traffic lights given as one example) and running projects is one way to do that. From the industry side one of the main benefits for this is to develop and test standards in practice. One vehicle manufacturer pointed out that there are maybe 25 vehicle manufacturers that covers more or less all vehicles globally while there are many more countries which makes the need for standards much greater on the infrastructure side. From the road operators side there is an agreement that the way to get things started is a partnership between public and private partners. Testing standards is mentioned for road operators as well but maybe more important for them is to get a better idea on what the impacts is on road operators such as what costs are associated with operating an interchange node and what benefits can be expected related to the transport policy goals. This is important input that they feel is lacking today and is needed for future budget discussions. It was hard to distinguish any major differences in opinion between road operators and industry in this respect but possibly there was an expectation that "the other side" should take the lead in this. There was an agreement however that it required collaboration.

For long term operation of an interchange node there was more disagreement between the participants but also more uncertainty of how this should be done. The uncertainty was to a large degree connected to what business models that will apply and what willingness to pay there is for the actors involved. The SRA pointed out that it is important to see what private interests there are in this and how they then should relate to that. There is both the aspect that they should not compete with private interests but also a belief that market driven initiatives have a greater potential than public initiatives. They also had some concerns with regard to being providers of data that is implemented in commercial products since that may mean commitments that are outside the Road Administration's scope. The SRA also pointed out that the role they should have and how much it can cost is something that is being discussed a lot. There is the requirement that they should provide a Single Point of Access (SPA) for data but the interchange node is much more than that and goes beyond the SPA requirement. It was also pointed out that SRA does not have the mandate today to take a more active role in providing data. If they should do that it would require a decision from the government to do so. But before that a thorough analysis of what that would mean in terms of costs and benefits must be carried out. This brings back the need for testing this through various projects.

One participant from a Road operator said "The Road Directorate supports connected vehicles in relation to data provision as many data are made accessible via our national access point. This means at the moment supporting some Day 1 and Day 1.5 services". Another participant, from another road operator said "It is up to the OEMs how they want to connect their vehicles to the outer world (C2X, IoT) and infrastructure. Based on how they do it, the others need to adapt or try to discuss with OEMs what would be the best way to connect with the vehicles. On European level, mandating any specific technology of connecting seems improbable". This indicates that there is a broad view from the road operators that the industry will take the lead in this, but they are willing to be a part of this and participate as, amongst others, a data provider.

From the industrial side, there is also a belief that the market will play an important role but they do express an expectation that it would require public investments, or even substantial public investments, before there is enough substance for the market to be self-sustaining. For instance, each nation would need to invest in connected infrastructure and road side equipment such as connected traffic lights. The road operators are however hesitant to this due to the high costs and unclear benefits. Some industrial partners points out that there is a win-win here since the road operators will get a lot of data back from the vehicles that can be used. This is also acknowledged by the road operators but, as mentioned before, there isn't enough information to decide whether the investment matches the benefits.

Several participants mentioned that the best would be to have an adaptive business model where the "eco-system" is built in an agile and stepwise manner where the partners would build this piece by piece and agree on who does what and to what cost. This would most likely mean that the eco-system would need less public funding the larger it gets.

One difference between the public and the private side here is that the industry is focusing a bit more on services that can be done or are good to have while the road operators are focusing more on which services are directly linked to and will improve the situation with regard to the transport policy goals. Connected traffic lights and prediction of their status is an example mentioned by many

participants which is a service that is of interest for especially the vehicle manufacturers but where the road operators would like to see more evidence on the benefits of this.

4.2.3. ROLES OF DIFFERENT PLAYERS

The interviewees were asked whether they thought that their role in the eco-system was clear and whether they thought that other partner's roles was clear as well.

For roles three groups with similar views could be identified among the interviewees. The road operators, the vehicle and equipment manufacturers and the telecom industry. Starting with the equipment and vehicle manufacturers they thought their role was pretty clear. They see themselves as providers of technology but also as responsible for collecting data and "guardians" of the data their customers provide. They see that they with this are moving into the area of service providers. They do not see that they will build or operate any central infrastructure for interchange of data. They will have to build their own infrastructure and here they believe they are already quite far ahead. They also acknowledge that they need to cooperate with others while they at the same time are competing which mean that they think standards are of high importance.

For the road operator's the role is somewhat similar where provision of data is the main responsibility. They do however not see it in their role as being service providers where they instead anticipate that market forces take care of that. The data they provide will primarily be open data and a focus on safety related data. For other data, it is not obvious that they will provide that unless it can be shown that it is beneficial for the Transport policy goals. They do however state that this is their role as it is today but that may change based on governmental decisions. From their point of view there is information lacking on both what the costs and benefits would be for them depending on what roles they take. Therefore, it is of interest for the road operators to participate in pilots and gain experience that can be a basis for discussions on what role they should have and how much it can cost. For the same reason, they can consider taking a bigger role in the start-up phase than what is expected at a later stage. The way forward from now on in their view is based on trials and cellular-oriented hybrid communication where they do not have to invest in C-ITS specific infrastructure except for specific locations. There were some differences between the road operators observed. One should however note that the road operators have been interviewed by different persons and in slightly different ways so differences between them can be due to methodological differences and should be interpreted with caution. The Swedish Road Association put a rather high emphasis on the market forces and how it was important to not interfere with them. The Danish Road Directorate acknowledges the need for an organization with overview and a coordinating capability to ensure user oriented and compatible solutions. They think that the EC has a central role in this e.g. to work to ensure that connected vehicles (and car industry products) will work across brands etc. The NPRA argues for an increased cooperation between road operators and vehicle manufacturers and they want to explore how they can get access to and be able to use information from the car as a sensor. To enable a business model on interoperability of C-ITS services there should be more cooperation between the national authorities, which are responsible for infrastructure and the TMCs, and the automobile industry, which is responsible for equipping vehicles with the necessary equipment. In Finland FTA

and TRAFI refer to the C-ITS Platform where the roles have been defined on a general level. Finland is no exception to these.

The third group identified was the telecom industry and their role is maybe the most unclear in this eco-system. They are the ones that has the most knowledge and experience when it comes to building and operating an interchange-server and they also have the knowledge of administering payments throughout the chain of partners in the eco-system. At the same time, they do not have any secondary incentives (like selling vehicles, providing safety related data etc.) which mean that there must be a willingness to pay for their services within the eco-system. This willingness to pay is not there yet as they see it which mean that a third party need to sponsor the interchange-server in the start-up phase. Here it is implied that a third party most likely must be a public actor. In the long run when there are enough actors within the eco-system providing data and services it may very well be self-sustaining, but until then it needs financial support.

A fourth group that was also mentioned in some of the interviews was the private road operators and private infrastructure providers. But since they have not been a part of Nordic Way it was not discussed further but mentioned as an interesting group to include in the eco-system for further research.

4.2.4. THE WAY FORWARD

All the participants mention that they have appreciated the work in Nordic Way in that sense that they have learned a lot by doing and testing. Also, the fact that both industry and the public sector has cooperated and shared experiences and their perspectives on things has been appreciated. NordicWay has supported this in creation of common architecture and in collection of experiences. In Nordic Way 2 many of the interviewees want to expand this by bringing in more players like cities, infrastructure providers and service providers and to add another telecom provider to guarantee redundancy of the interchange server.

Another thing that is mentioned by both the industry and road operators is the importance of standards. And here it is stressed that it relates to developing standards but also testing them, and preferably on a European scale.

Many interviewees also discussed what business models to apply and what the business canvas could/should look like. Many had ideas and speculations on what it should like but there was also a great deal of uncertainty related to the business models. It was however something that was pointed out by many partners as something of high importance and the lack of agreed business models was to some degree holding back the progress in this area.

## 4.3. The value of interoperability

4.3.1. INTRODUCTION

The DRIVE C2X project have investigated the effects of Day 1 applications and one of the primary focus areas was the road safety. When the different impacts where rated by the users, the road safety was also classified as one of the most relevant. The analysis revealed that the road safety results

were promising. The result generated in an estimated percentage reduction regarding fatalities and injuries in year 2030. The estimation is based on different car penetration rates; low, medium and high. The penetration rate refers to the percentage of vehicles and infrastructure that are equipped with compatible equipment. The application that could be concluded to have the most impact in facilities and injuries was especially IVS Speed. Other applications that had a measurable impact was WW, TJAW, EEBL and RWW. Additionally, it could be concluded that the penetration rate had a significant influence on the impact. The impact varied depending on the penetration rate, and especially between a low and medium penetration rate. At a low penetration rate the impact is very low in comparison the medium level, and that is shown to be the case regarding all applications. Between the medium level and high level of penetration rate the difference of impact percentage is not merely as high as between low and medium. Regarding RWW, the impact between medium and high level of penetration is as good as the same (see figure 1 for overall impacts based on penetration rate). This result can be applicable to the significance of interoperability. The significance that vehicles will receive the actual information, that is to say if it´s desirable or essential that a certain amount of vehicles will get the information in order to achieve the application´s purpose. For example, there is not as significant that all the vehicles will get the information about RWW in order to achieve the application´s purpose as it is when it comes IVS speed or EEBL. Nevertheless, in general the result from the project indicates that if more people have systems that area able to adapt the pace after certain situations, there will be less disruptions and conflicts which may well lead to an increased road safety. Thus, there is an advantage for all stakeholders if the information will available to all road users as soon as possible.

Overall impact in fatalities with penetrations, 2030
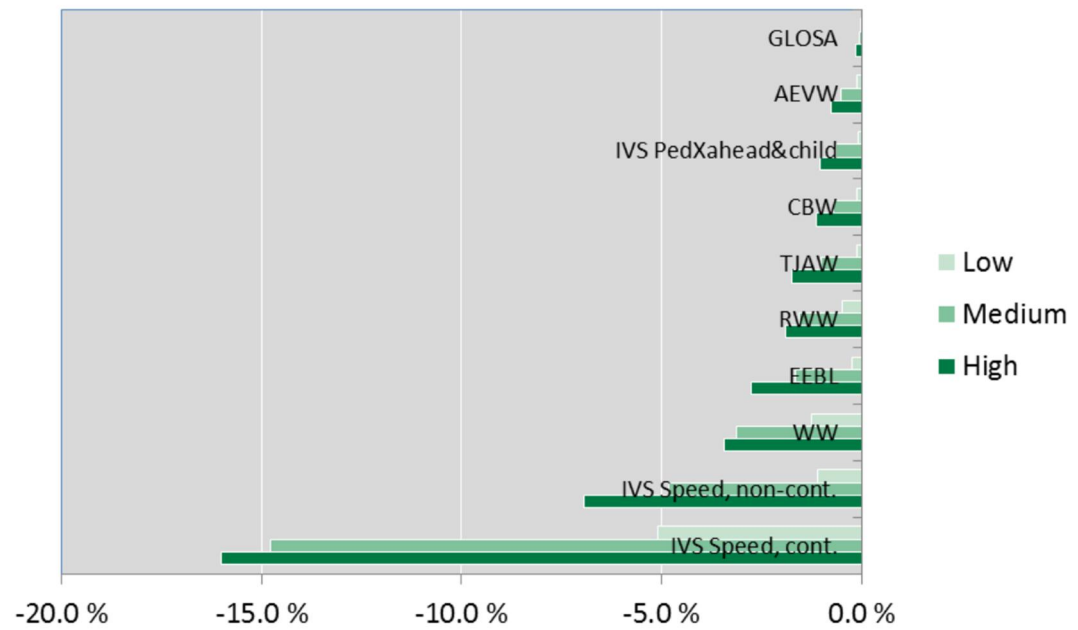
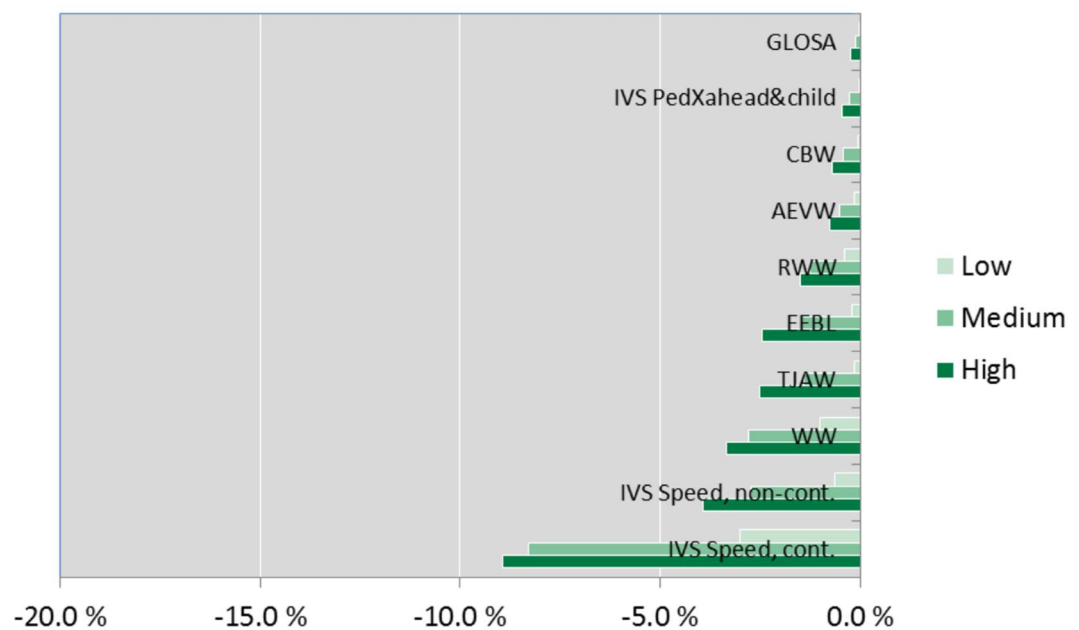Overall impact in injuries with penetrations, 2030

Figure 9 The overall safety impacts of cooperative functions in 2030 with vehicle penetration scenarios: low, medium and high (source: Drive C2X, (2014))

When it comes to traffic efficiency some of the findings were not statistically significant and some of the impacts were not as high as expected. However, greater traffic efficiency due to the applications are expected to be achieved with slight modifications of the functions. For example, no changes in strategic behavior such as route choice could be concluded. Though, by providing information or advice at an earlier stage the driver may have choose another route. This may therefore require that the information is updated at all times, which would motivate interoperability. The project´s result also indicates that the applications in the future may have a greater importance and relevance than what could be measured at this time. The study thereby predicts that the penetration rate may be of great significance to the percentage of impact for the applications IVS and GLOSA. The percentage of impact are predicted to increase for each penetration rate regarding the applications. The differences of percentage of impact between the penetration rates low and medium is substantially tangible, and especially distinctly for GLOSA.   The relevance for interoperability when it comes to traffic efficiency can thereby also be supported by these facts since the percentage of impact, with most certainty, will depended on the penetration rate.

Another aspect which is relevant for the interoperability, is the users´ willingness to purchase these functions. The willingness can thus motivate why OEM: s etc. should invest and prioritize interoperability, or not, since there are in their interest to deliver solutions which is up to standard to their customers. Accordingly to DRIVE C2X project, the applications that the users´ are willing to pay for is primarily GLOSA, TJAW and AEW. If these facts are applied to the road safety and traffic efficiency impacts and the penetration rates, this would motivate an active role for the OEM:s etc. regarding interoperability since the percentage of impact are higher if the penetration rate also are high, or at least at a medium rate.

An additional project that has been taken place is an implementation and testing of a cooperative vehicle-roadside system "Shockwave Traffic Jams A58". The project yielded in positive results. The test demonstrated that the system generated in a reduction of traffic jams. The technologies enable the real-time exchange of information between traffic systems and road users, and thereby made it possible for vehicles to travel faster, safer and with improved sustainability, efficiency and comfort. Another aspect that could be concluded was that vehicles who was equipped with IVS would approach the traffic jam more calmly. However, the participants didn't slow down when the traffic around them was traveling at a higher speed. This fact would support the relevance of interoperability, that the majority of the vehicle fleet will receive the information. Otherwise may the full potential of the applications not occur. Additional fact that also was stated in the project´s result which give more ground to interoperability is "… the more quickly the traffic data is available, the more quickly a shockwave traffic jam can be detected and targeted advice can be transmitted". This means that it´s an advantage that the vehicles equipped with compatible equipment share their data with others, presuppose that the ambition is that the information should distributed to the road users as soon as possible in order to achieve the applications' full potential and purpose.

4.3.2. RESULTS FROM MICROSIMULATION

The Visim microsimulations (ten repeated simulations) resulted in data on how the time to detection varies for different penetration rates and corresponding standard deviation. This is illustrated in the figures below. The figures illustrate the results for a 3-lane motorway with 1200 vehicles per hour and a speed limit of 110 km/h and a rural road, speed limit 70 km/h and a traffic flow of 1200 vehicles per hour and 120 vehicles per hour respectively (see Figure 10 to Figure 15 below)
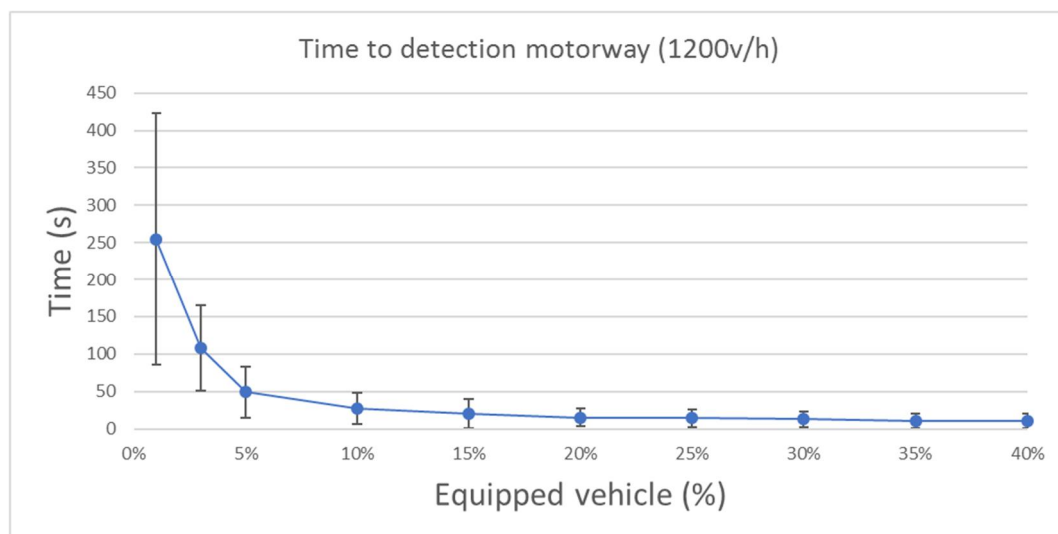

Figure 10 Time to detection on motorway (1200 v/h) for various penetration rates.
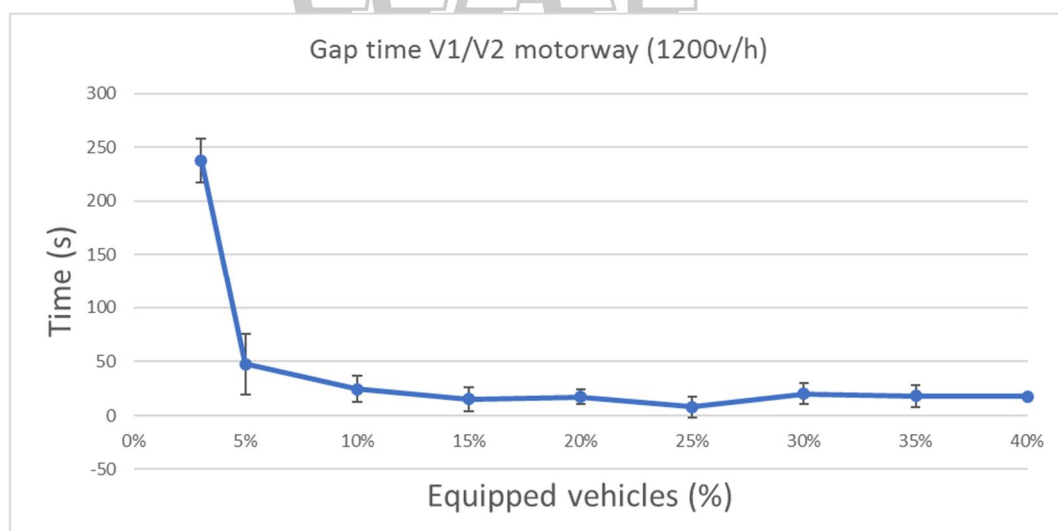
Figure 11 Time from first vehicle detects and reports the hazard until the second vehicle arrives at the hazardous location for motorway (1200 v/h).
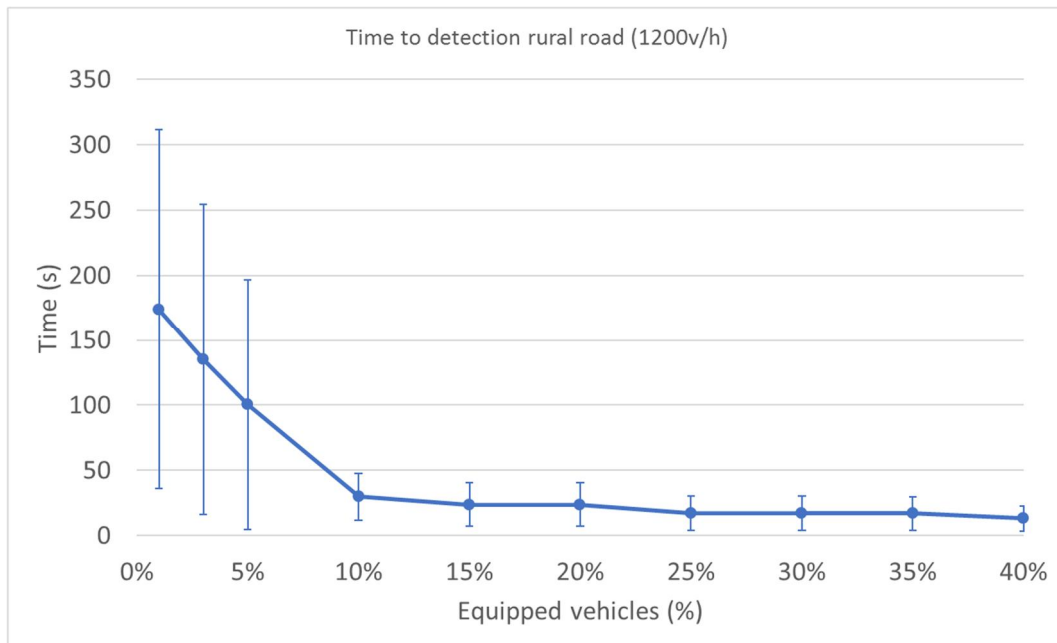
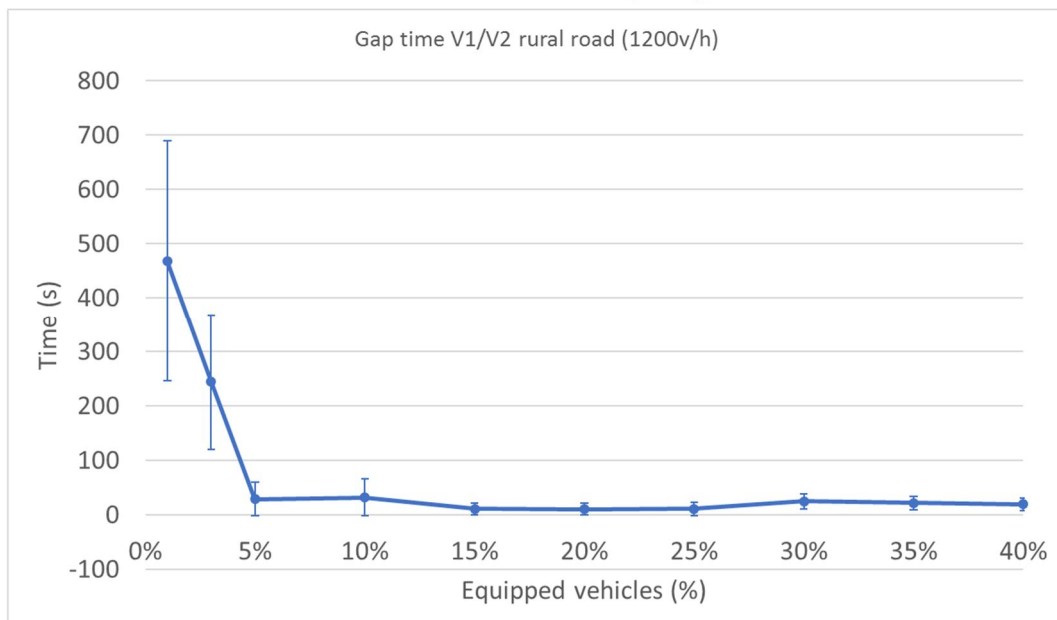**Figure 12 Time to detection on rural road (1200 v/h) for various penetration rates.**

Figure 13 Time from first vehicle detects and reports the hazard until the second vehicle arrives at the hazardous location for rural road (1200 v/h).
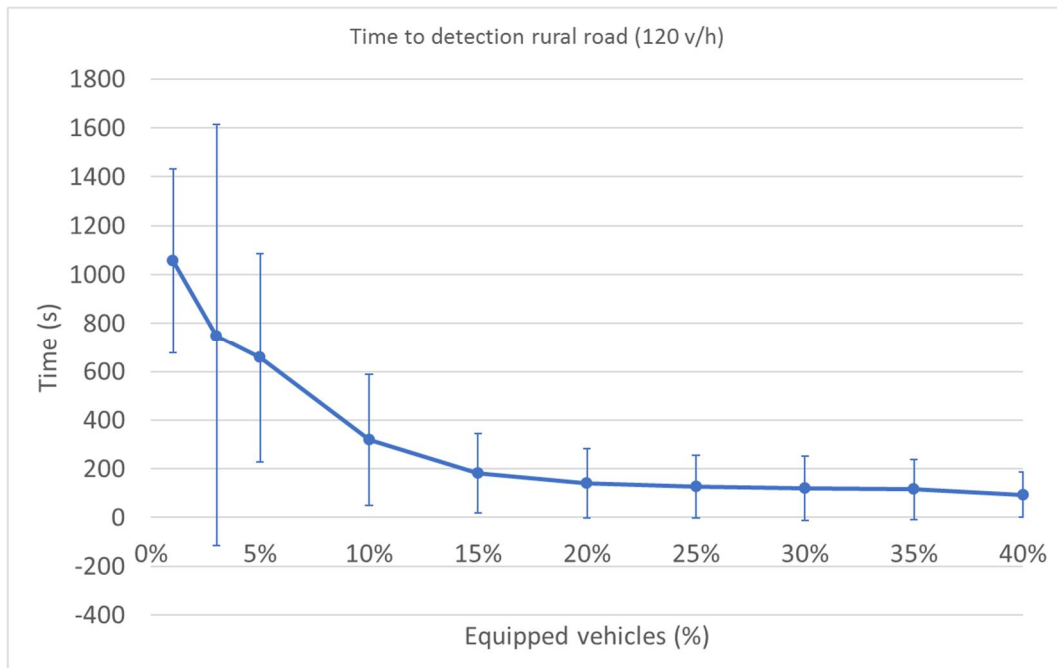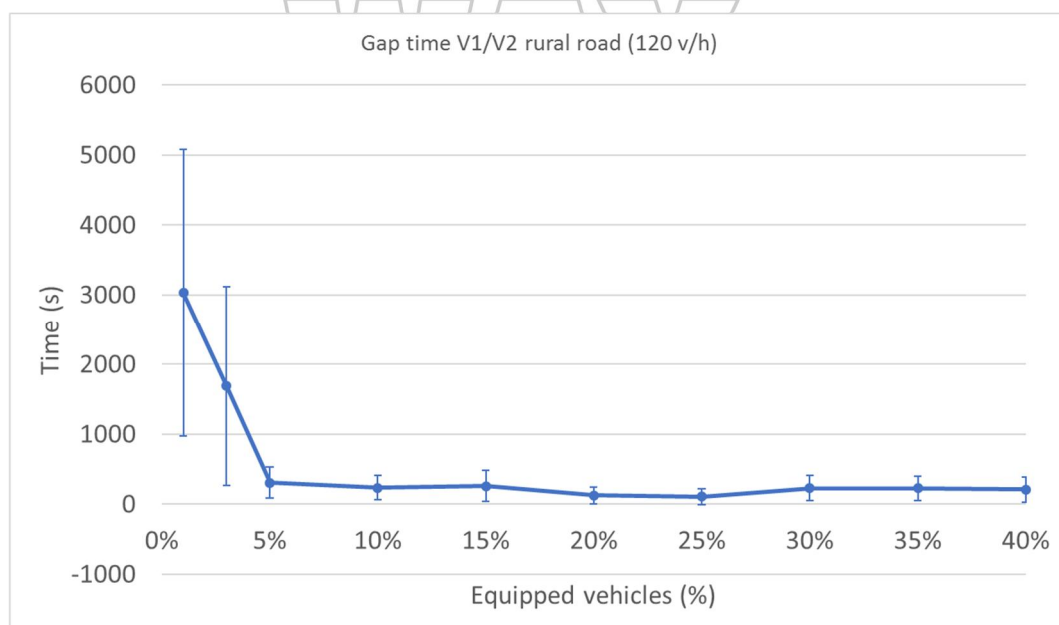
Figure 14 Time to detection on rural road (120 v/h) for various penetration rates.

Figure 15 Time from first vehicle detects and reports the hazard until the second vehicle arrives at the hazardous location for rural road (120 v/h).

For all the three scenarios the pattern was the same, even though the actual times differed. For penetration rates lower than 5% the effect of increased penetration was quite significant, then after 5-10 % the effect of increased penetration rate lessened. This was valid for both Time to detection and Gap time. Similarly the standard deviation of time decreased significantly as penetration rate increased. It should be noted that variability in the graphs is due to the random distribution of vehicles within the Visim simulation model.

The conclusion of the microsimulation is that for a penetration rate less than 5% there is a limited value of having communication between vehicles but the effect increases rapidly for every vehicle and already at 5% and above the effect has saturated to some degree. If that data is compared with the distribution of vehicles per brand it is clear that all brands except the top three would benefit from interoperability between brands and for most it is absolutely crucial (Figure 16). The rate of new registrations of vehicles per year is on average 5,8% for cars which indicates that if the major vehicle manufacturers agreed on sharing data via an interchange node as a standard feature there would be a clear effect already the first year (Figure 17). These findings are in line with the findings from the C2X project where a significant increase in effect was found between low and medium penetration rate.
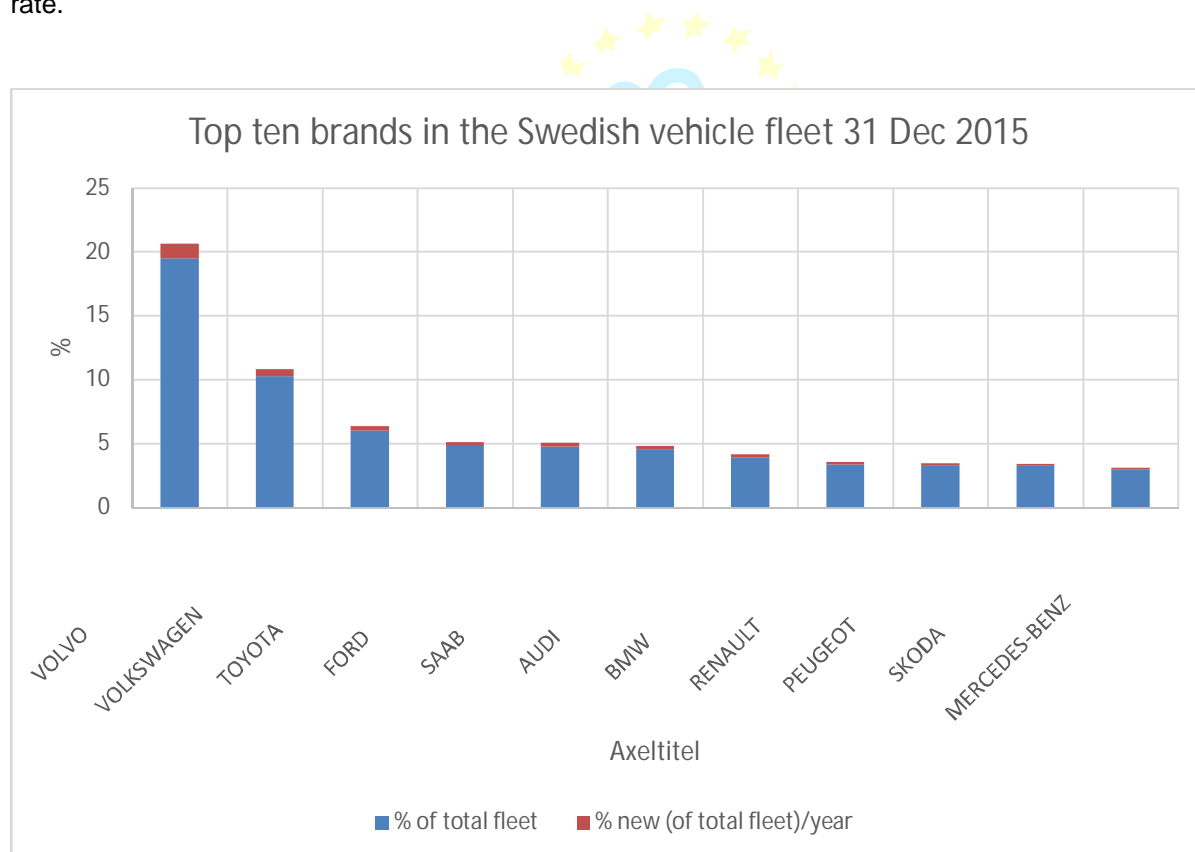

Figure 16 Percent of vehicles per brand in Sweden as of 31st of December 2015 and percentage of new vehicles per year (based on the average of 5.8% new registrations per year)
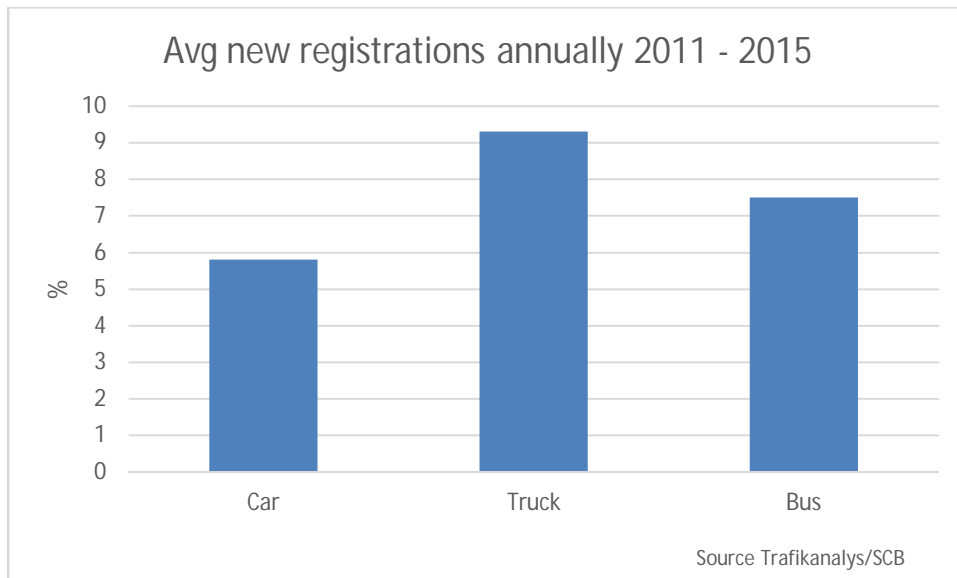
Avg new registrations annually 2011 - 2015

Source Trafikanalys/SCB

Figure 17 Average new registrations for cars, trucks and buses 2011 – 2015.

5. Conclusions

The NordicWay project has shown that fast and reliable data exchange using primarily cellular networks is possible and feasible. The interchange node solves the challenge of keeping track of many different stakeholders and makes integration with new partners and data sources fast and easy.

The Swedish pilot has covered slippery road alert, hazard warning alert and road works warnings where the road works warning was used as an example and was evaluated more thoroughly for this report. These are all examples of safety and efficiency related applications that are interesting for both private and public stakeholders and thus makes them interesting services from a technical perspective as well as a business model perspective.

In the Swedish pilot, messages from the RWWV were sent over ITS-G5 as well as over the cellular network. The evaluation shows that both technologies are viable solutions for transmitting messages. The send/receive latency for messages over the cellular network in the controlled trial ranged from 1.25 to 2.48 seconds from source to vehicle, depending on which scenario that was studied. This is considered sufficient for most services. The latency for messages sent over ITS-G5 is negligible but there are limitations on the communication range. The maximum communication range was in the range 460 to 495 meters (depending on which antenna that was used) with a clear line of sight, but the Swedish evaluation emphasises that the ITS-G5 and cellular have different strengths and weaknesses and that the best solution should be selected depending on the specific requirements for the specific service.

As well as showing the technical feasibility for exchange of data the evaluation has looked into the business model and discussed how the ecosystem of cellular data exchange could look. The conclusion there is that collaboration of private and public stakeholders is needed for a successful implementation and they both see benefits of being a part of the ecosystem. However, it is not clear who should take the responsibility for initiating this and who should take the upfront cost. That doesn't mean that no one is willing to take the lead, On the contrary the involved stakeholders see a good potential in these applications and are willing to continue the cooperation to further integrate the NordicWay interchange into their own systems and vehicles. It does however shows that the business-models of the ecosystem need to be developed further for large scale deployment.

Some success factors for large-scale deployment has been identified during the course of this project:
- Harmonized communication profiles at European level in order to be truly interoperable.
- A reference architecture for the interchange node should be published in order to make it possible for multiple service providers interacting in an interchange network
- Clearly defined business model for the interchange network
- On-boarding of partners, both public and private, outside the Nordic region

- High quality infrastructure data from public partners provided for free. Examples are traffic light information, emergency vehicle, different types of road works warnings etc.

In addition the main barrier for deployment has been identified as the chicken and egg problem, i.e. someone needs to take the upfront cost for establishing the digital infrastructure. Once this is established one could expect the possibility for actors to find profitable business opportunities.

The development of the business models as well as further development and demonstration of the scalability and flexibility of the interchange node by adding more vehicles, more applications/services and exploring the possibility of a network of federated interchange nodes has been highlighted as the most relevant for further development.

6. References

D5.1.1 NordicWay - Road works warning trial - Communication interface specification
D5.1.2 NordicWay - Road works warning trial - Description of system components of the solution

Annex A

NordicWay

Road works warning trial

Description of system components of the solution

Version: 0.6

Date : 21 April 2017

Version	Date	Author	Description
0.1	23.08.2016	Ulrik Janusson	First draft
0.2	4.01.2017	Andreas Höglund	Scania system components
0.3	20.03.2017	Ulrik Janusson	Kapsch system components
0.4	23.03.2017	Anders Olander	Ericsson system components
0.5	03.04.2017	Johny Svedlund	Trafikverkets system components
0.6	13.04.2017	Erik Israelsson	Volvo Cars system components
0.7	11.05.2017	Ulrik Janusson	Updating of all system component overview figures

Table of Content

List of abbreviations

AMQP	Advanced Message Queuing Protocol
ASN.1	Abstract Syntax Notation 1 (defined in ISO-IEC 8824)
DATEXII	Standard developed for information exchange between traffic management centres, traffic information centres and service providers
C-ITS	Cooperative Intelligent Transport System
DENM	Decentralized Environmental Notification Message
GNSS	Global Navigation Satellite System
ITS-G5	Set of protocols and parameters for wireless point to point communication as specified in ETSI ES 202 663 V1.1.0
ITS-S	ITS station, generic designation for a cooperative ITS unit
RWW	Road Works Warning
SP	Service Provider
TMA	Truck Mounted Attenuator

1. Introduction

A high degree of interoperability is a prerequisite for successful introduction of Cooperative Systems or C-ITS. Embedded vehicle systems must work uninterrupted across borders if the potential in terms of vehicle safety, network efficiency and environmental impact should be released and the benefits for society and citizens appear.

Nordic Way is a project under the European CEF programme lead by road authorities in the Nordic countries with the aim to demonstrate cross-border functionality and interoperability.

The Swedish partnership and the Swedish pilot project is managed by the Swedish Transport Administration who has chosen to design the project as a partnership between authorities and private enterprises.

The Nordic Ways primary communicaton technology is cellular networks and so called cloud solutions, but the direct short range communication via ITS-G5 radio link is also tested. Thus Nordic Way is a hybrid project in terms of communication technology.

This document provides a description of system components of the solution for the use case road works warning in the Nordic Way project.

1.1. Objectives and scope

The purpose of this document is to describe the system components provided by the different project partners in the road works warning trials and demonstrations within the NordicWay project. Its focus is both on logical entities, software components and physical components.

1.2. Overview of the Road Works Warning Use Case

A RWW unit on a road works vehicle sends a notification to the road user through the following steps:

1. *The Truck Mounted Attenuator (TMA) on the road works vehicle is activated (to protect workers and equipment from traffic)*

2. *TMA activation triggers a RWW DENM message to be broadcasted over ITS-G5. Vehicles approaching the trailer receive the message.*

3. *The message is also transmitted to the RWW backend via cellular networks.*

4. *The RWW backend tranforms the message into the DATEX II format for RWW and forwards the message to the Nordic Way interchange server*

5. *The Interchange server distributes the RWW message to all subscribing service providers (the information is interesting for the Swedish Transport Administration as well and might be integrated in their systems in future developments).*

6. *The Service Provider sends an alert message to subscribed users in the event area.*

The vehicle mounted RWW units communicate directly with vehicles using ITS-G5 standardised communications. In the Nordic Way use case for roadworks, the DENM (ETSI EN 302 637-3 V1.2.2) is used.

The DATEX II (version 2.3) is used for the communication between Service Providers, and between Service Providers and Traffic Data Providers. Only the Data Model of the DATEX II standard is used, not the Exchange Protocol.

The DATEX II messages are passed through the Interchange Server. In addition the AMQP v1.0 protocol is used for transmitting the data messages to and from the Interchange Server.
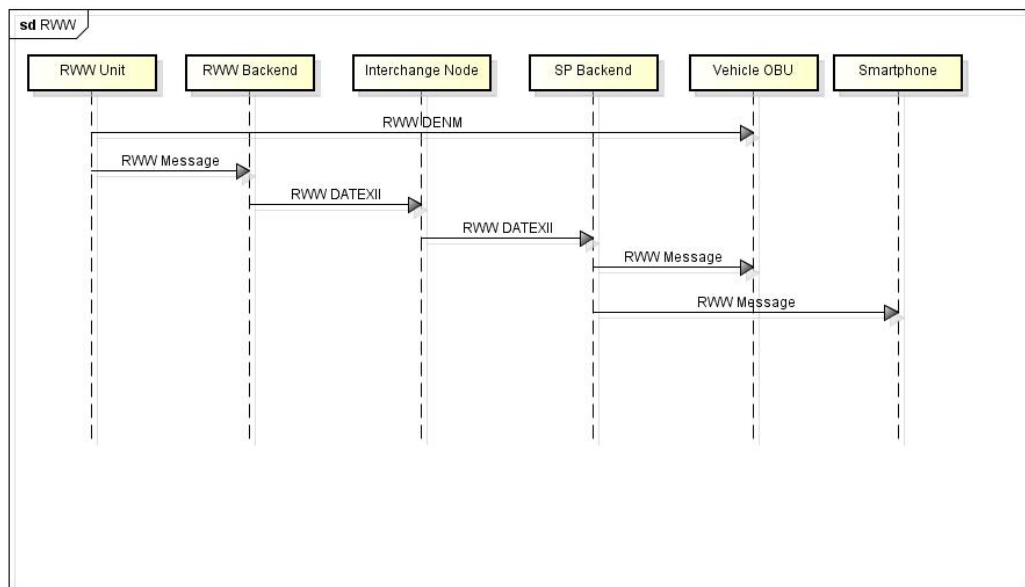
Figure 18 Sequence diagram of the Road Works Warning use case

2. Ericsson system components

2.1. General

The RWW messages are treated as all other messages in the Interchange node and Swedish Traffic Cloud. Reference document is
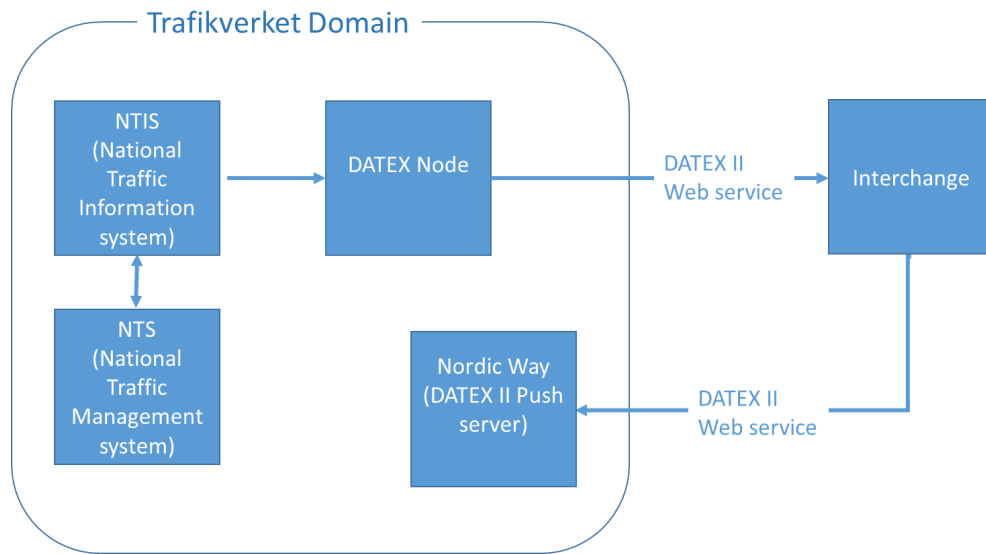·   Architecture, Services and Interoperability[2]

NORDICWAY ARCHITECTURE
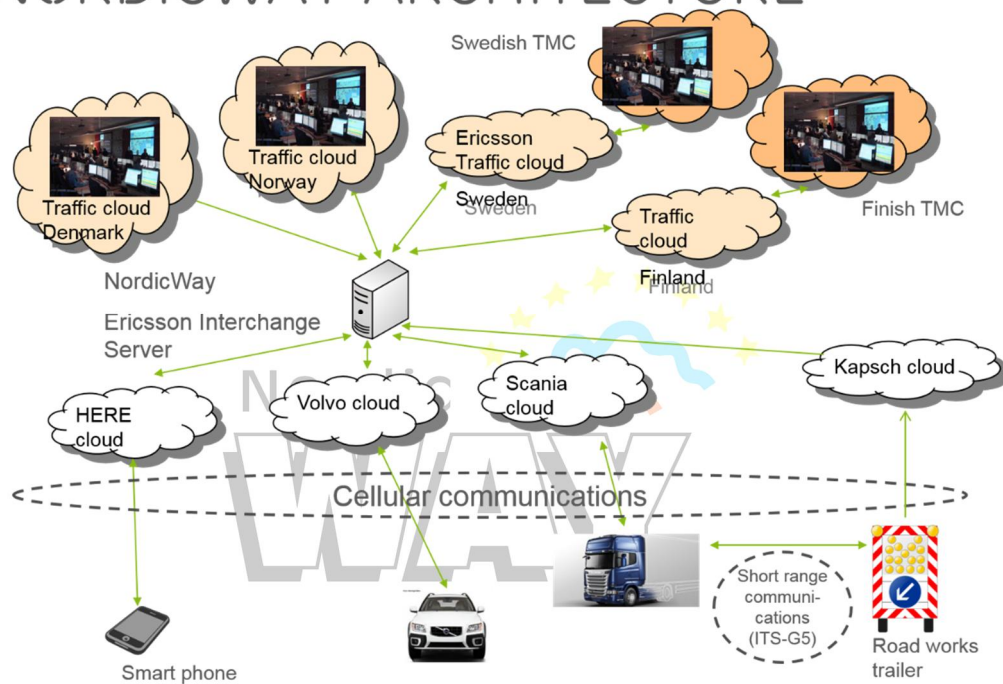
3. Trafikverkets system components

3.1. Component overview

The follwing diagram shows the involved components

3.2. Software components

The main software components in Trafikverkets solution are the following
- NTIS (National Traffic Information System). Which is connected to NTS (National traffic Management System)
- DATEX II Push Server:
  - .Net Web Services based on DATEX II WSDL
- DATEX II Node
  - Pushes information to Traffic cloud in DATEX II 2.3 format. Webservices based on DATEX II 2.3 WSDL is used.
  - Filtering and routing of incoming messages
- Received Nordicway data
  - Incoming data are stored on file

3.3. Physical components

None

4. Kapsch TrafficCom system components

4.1. Component overview

An overview of the components used by Scania for the RWW use case can be found in Figure 19 Kapsch TrafficCom Nordic way RWW component overviewbelow.
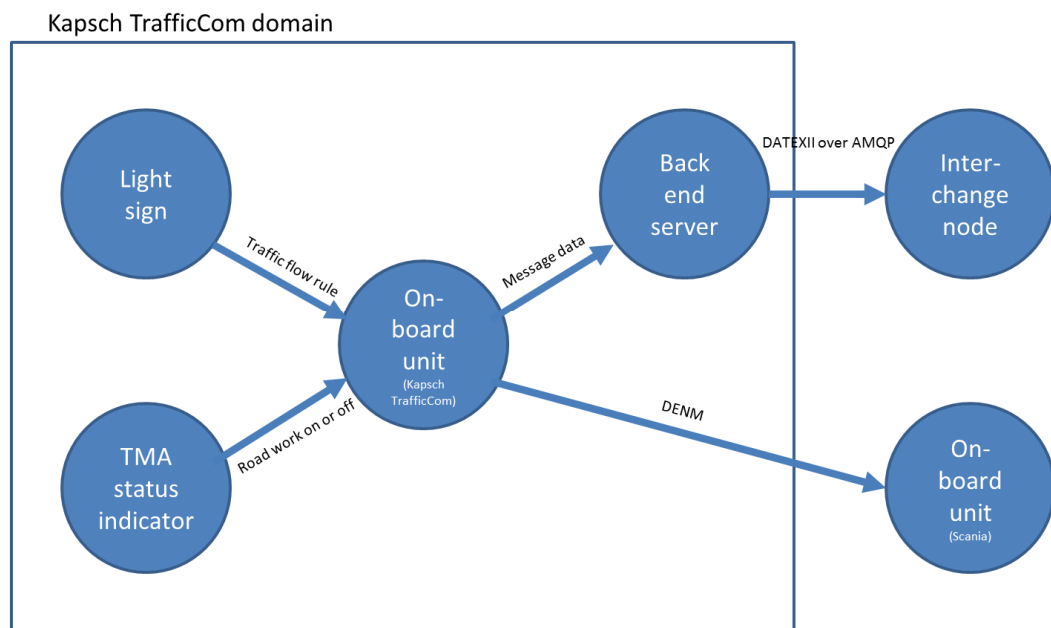
Kapsch TrafficCom domain

Figure 19 Kapsch TrafficCom Nordic way RWW component overview

The central Kapsch TrafficCom component is the ITS-station (ITS-S) that receives signals from an inductive switch mounted to sense the status of the truck mounted attenuator (TMA). The TMA is a device intended to reduce the damage to vehicles, and motorists resulting from a motor vehicle collision (see . The TMA is always lowered when road work is ongoing and can thus be used as an automatic road work indicator. The connection to the the light sign is used for automatic sensing of the traffic flow rule.

Figure 20 Road works vehicle with lowered TMA and light sign

This information information is used to create a road works DENM message that is broadcasted via ITS-G5 to vehicles in the vincinity as well as a DATEXII message that is forwarded to the Kapsch server and from there to the Nordic Way interchange node for dissemination to message subscribers.

4.2. Software components

The main software components in Kapsch TrafficCom's solution are the following

- ITS-S software implementation for road works including:
  - o TMA indicator and light sign sensing
  - o Message encoding and sending via ITS-G5 and to server
  - o Server heartbeat functionality
  - o Software and parameter update functionality
- Linux server implementation including:
  - o AMQP sender for communication with the Interchange node
  - o Logging capability
  - o Heartbeat receiving capability
  - o Client software and parameter update functionality

4.3. Physical components

An overview of the main hardware components in Kapsch TrafficCom's solution can be found in Figure 21.
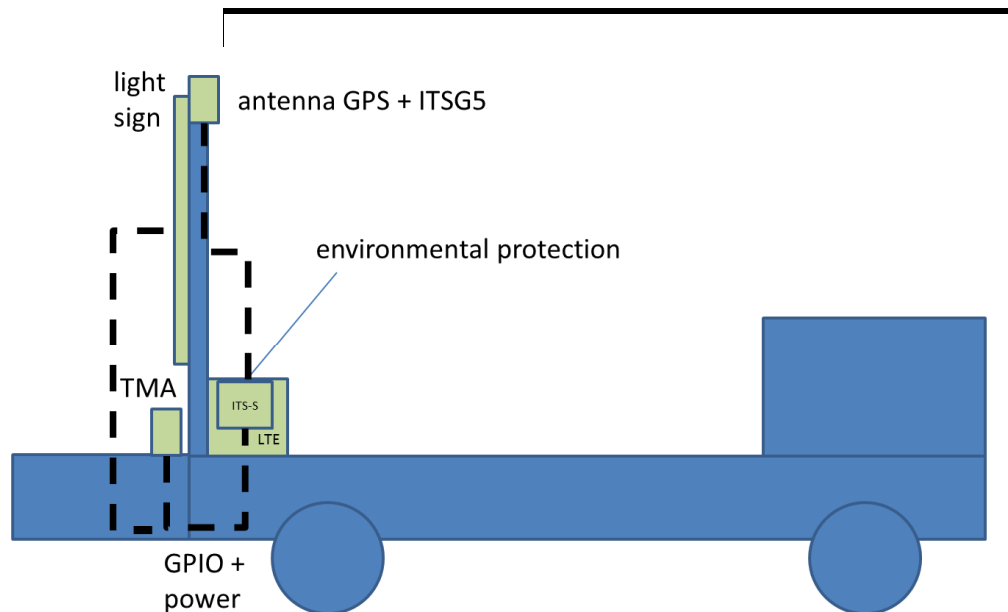
Figure 21 Overview of main hardware components in the Kapsch TrafficCom solution

The ITS-S is pictured in Figure 22 below. The yellow conector to the left provides power to the ITS-S as well as input signals from TMA (see Figure 23) and light sign. The black antenna is a so called stick antenna used for the LTE module in the ITS-S to provide a mobile internet connection. The two other connectors are for the GNSS and ITS-G5 antenna (see Figure 24).

Figure 22 ITS station from Kapsch TrafficCom, the EVK-3300

Figure 23 Mounted inductive switch for sensing of the TMA status

Figure 24 SMG6-5900/1575 Surface Mount Antenna from Mobile Mark for ITS-G5 and GPS/GLONASS

5. Scania system components

5.1. Component overview

An overview of the components used by Scania for the RWW use case can be found in Figure 25 below.
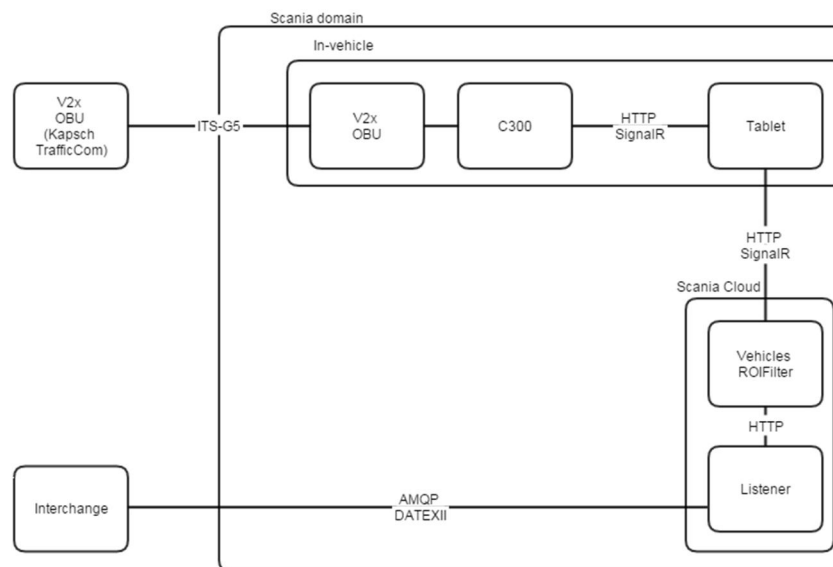

Figure 25 Scania Nordic way RWW component overview

5.2. Software components

The software components in Scania's solution are the following
- Cloud implementation in Microsoft Azure
  - AMQP listener for communication with the Interchange node
  - DatexII decoder for handling incoming RWW messages and transform into JSON objects
  - Vehicle region of interest filtering component – decides which vehicles that should receive a specific message
- HMI implementation in tablet. Communicates with the cloud solution as well as the telematics unit in the vehicle. Shows relevant warnings on a map.
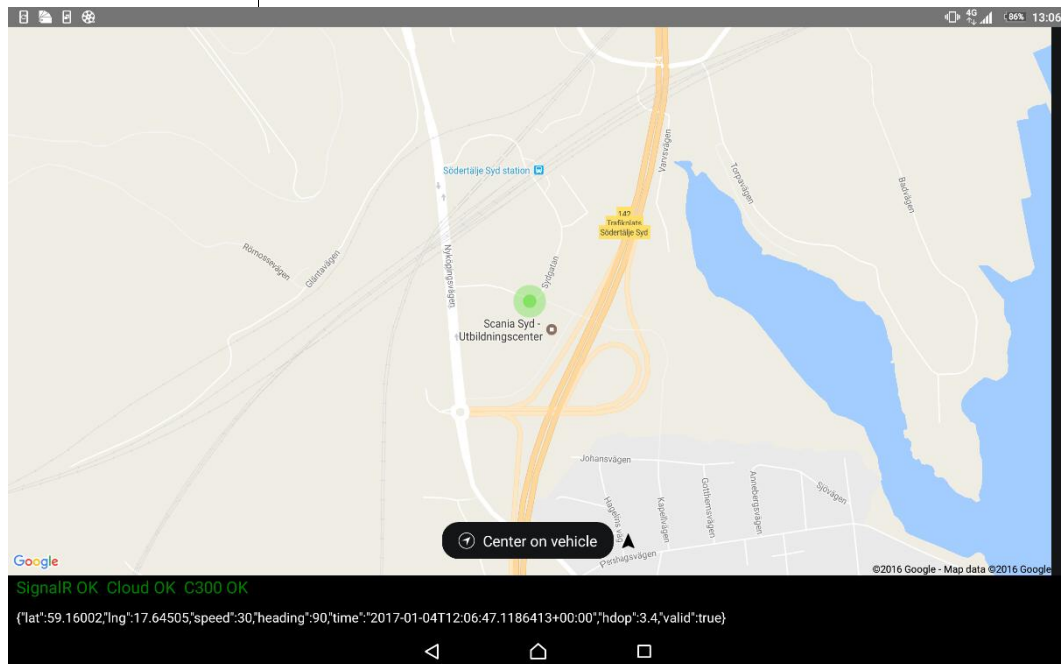- C300 local web application that provides data from the V2x OBU (DENM) and position data.

Figure 26 Scania Nordic way HMI

5.3. Physical components

The physical components in Scania's solution are
- A Sony Android tablet used as a HMI with a SIM card. See Figure 27
- Scania's standard telematics unit C300. See Figure 28
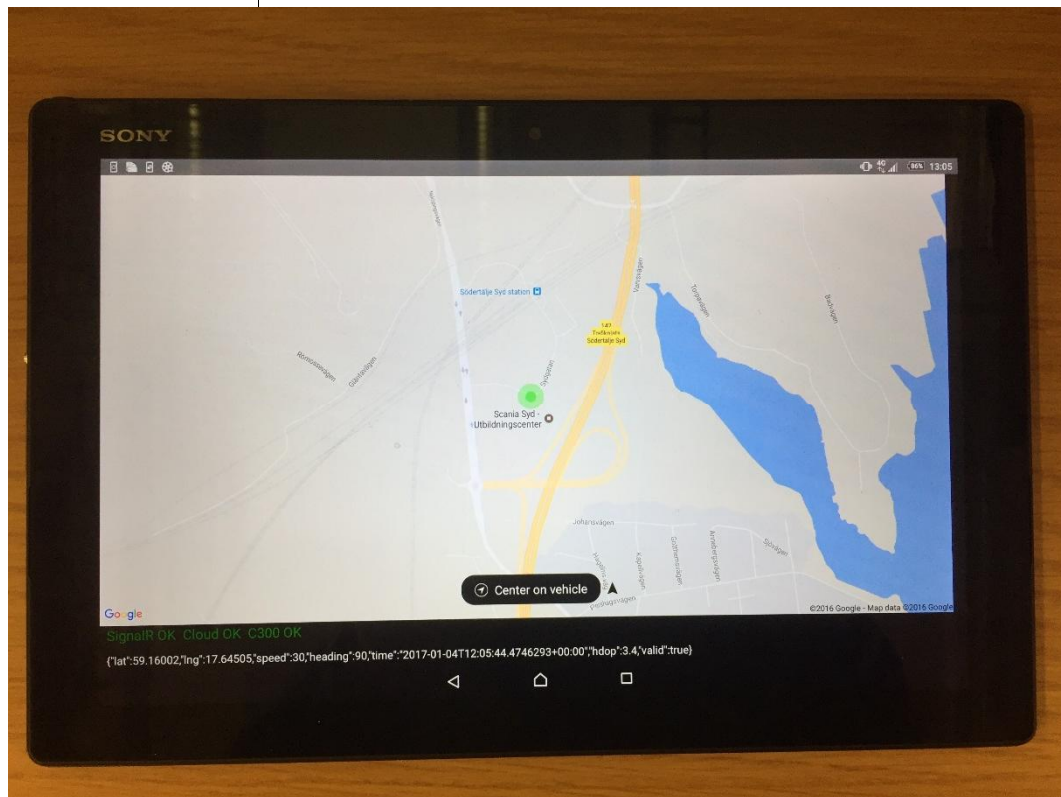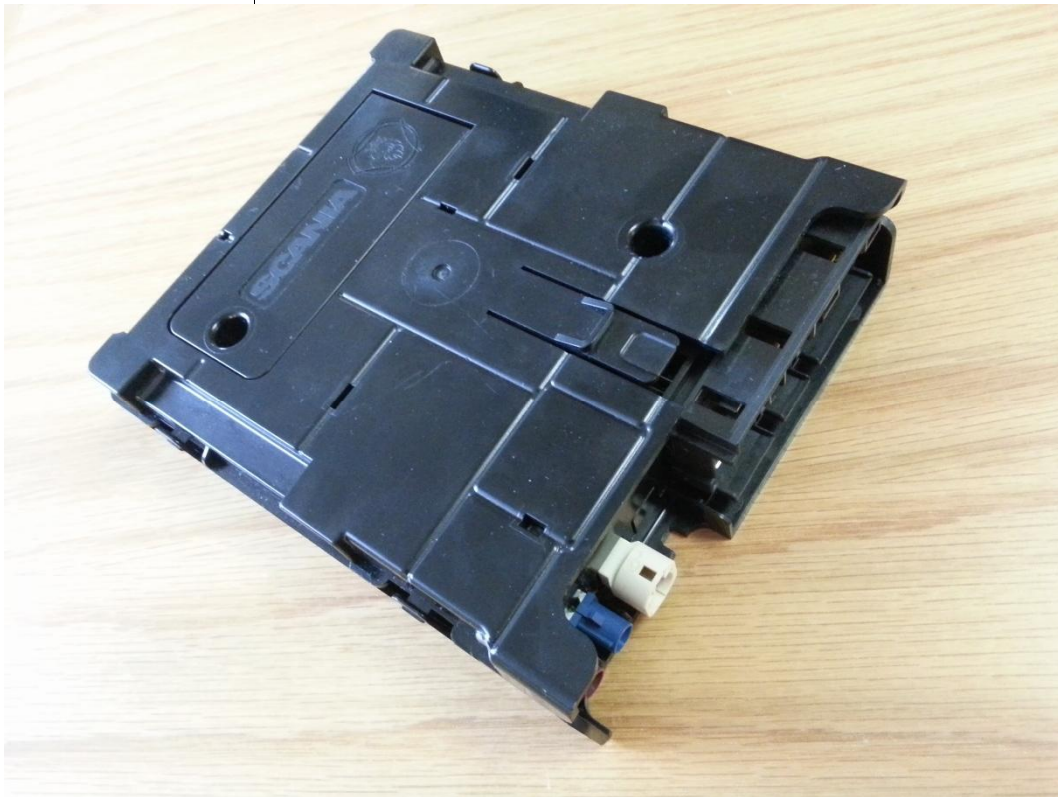- A V2x OBU for ITS G5 communication. See Figure 29

Figure 27 Tablet used as HMI

Figure 28 Scania C300 Telematics ECU

Figure 29 Commsignia V2x OBU

6. Volvo Cars system components

6.1. Component overview

An overview of the components used by Volvo Cars for the RWW use case can be found in X below.
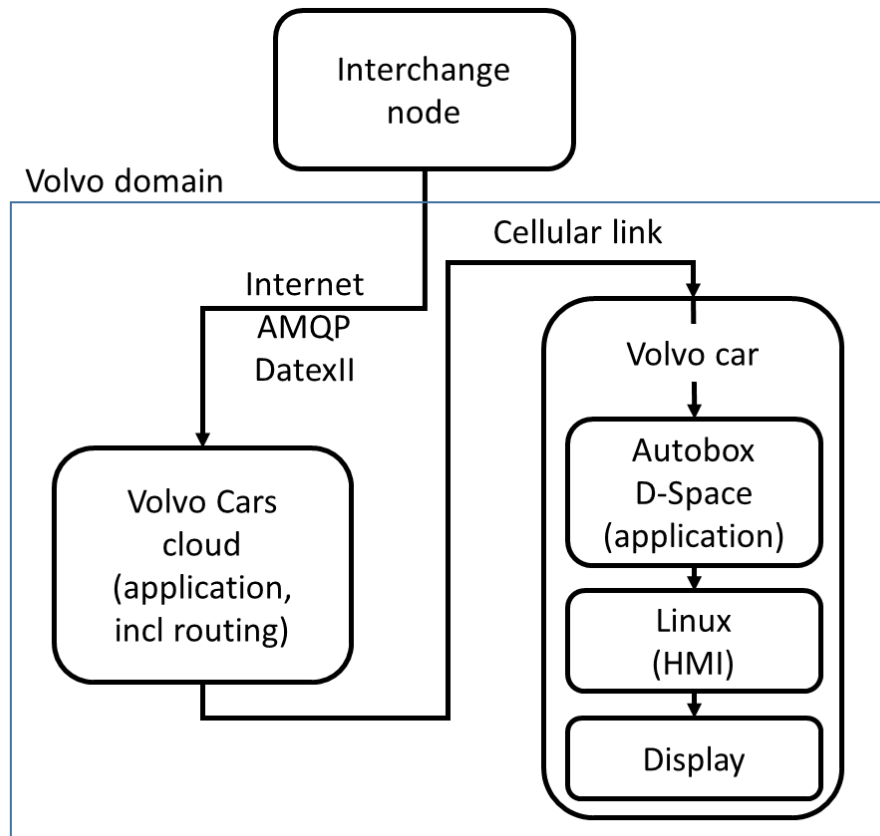

Figure 10 Volvo Cars NordicWay RWW component overview

6.2. Software components

The software components in Volvo Cars solution are the following;
- Cloud application logic, deployed in a development instance of Volvo Cars cloud' Sensus Cloud.
  - o AMQP listener for communication with the Interchange node
  - o DatexII decoder for handling incoming RWW messages
  - o Cloud application logic for routing of received safety related data to relevant vehicles, based on their reported position.
- In-vehicle application logic, running in Autobox D-Space.
  - o Aceesing vehicle data
  - o Receivning messages from cloud

- o Publishing messages to cloud
- o Managing timely activation alert to driver in HMI, dependent on remaining distance to hazard and current speed
- · HMI implementation in Linux computer presented in in-vehicle displayed. HMI graphics is baswerd on Volvo Cars' original HMI with added graphics for new use cases, e.g. RWW. See figure 11.
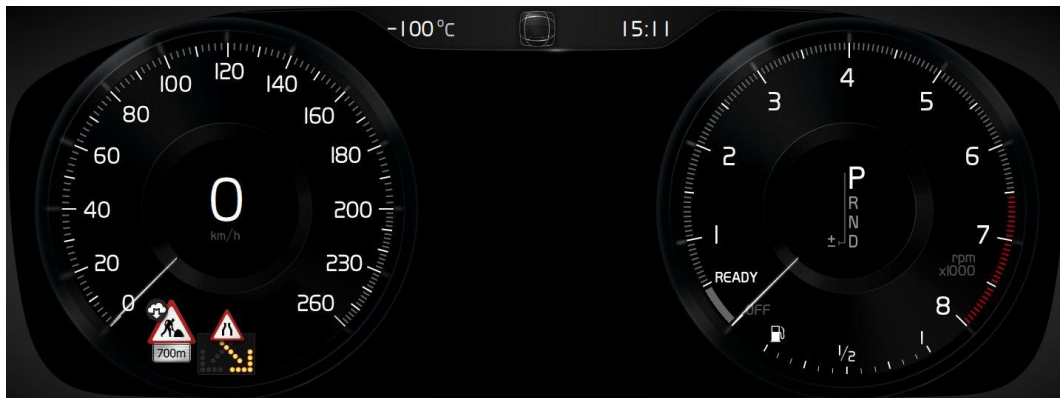

Figure 11 Volvo Cars prototype HMI graphics SW

6.3. Physical components

The physical components in Volvo Cars' solution are

- · Volvo V60 vehicle. See figure 12
- · A full graphical display (from the new 90-series) replacing the original instrument cluster. See figure 13
- · A linux computer running HMI graphics, including. See figure 14
  - o GPS
  - o Cellular modem
- · D-Space Autobox in-vehicle running application logic. See figure 15
  - o Connection to vehicle CAN-network

Figure 12 Volvo Cars development vehicle

Figure 13 Volvo Cars prototype full-graphical display, mounted in development vehicle

Figure 14 Volvo Cars Linux computer, mounted in trunk, hosting prototype HMI SW

Figure 15 Volvo Cars AutoBox dSPACE, mounted in trunk, hosting roadworks warning application logic

References