Combined Final Reports for

Autonomous Driving Aware Traffic Control July 2017

Autonomous Driving Aware Traffic Control – Emergency Vehicle Information December 2018

Report part C: Autonomous Driving Aware Traffic Control Advanced Cooperative Driver Assistance December 2019

With support from:

Report part A: Autonomous Drive Aware Traffic control 2017

Contents

Report part A: Autonomous Drive Aware Traffic control 2017 2
Contents 3
Version History 6
Glossary 8
Executive Summary 8
Project participants 9
Volvo Cars 9
Ericsson 9
Carmenta 9
Trafikverket 9
City of Gothenburg 10
System description 11
Basic principles 11
System architecture 11
OEM AD Traffic Control View 12
Central Traffic Control view 13
System Services 13
Findings 14
Autonomous Traffic Monitoring 15
Better traffic control 15
Increased road safety 16
The transition period involves all connected cars 16
Common terminology is a foundation 16
Whole picture Benefits/Findings 16
Collaborative Road Weather Service 18
Weather Forecast information contributes to better traffic management 19
Weather Forecasts are not yet accurate enough for guiding AD operations 19
Weather Forecasting for AD guidance needs vehicle-collected data 19
The CTC is a good weather information hub 19
Whole picture Benefits/Findings 19
Authority Interfaces 20
Whole picture Benefits/Findings. 20
Risk 20

International liaisons 20
Drive Me in UK and China. 20
EU Cooperative Intelligent Traffic System (C-ITS) platform 20
Plan for commercialisation and growth 20
Future Work 24
More functionality 24
Emergency Vehicle Information 24
More content 24
Another OEM 24
Usage of the platform 24
Drive Me program 24
Automated public transport 24
Appendix A – Deliverables 25
WP 1 Autonomous Traffic Monitoring 25
WP1.1 Central Traffic Control 25
WP1.2 OEM Traffic Control 35
WP1.3 OEM AD Approval 36
WP 2 Collaborative Road Weather Service 37
WP2.1 Road Weather Service 37
WP2.2 Measured weather data provision 39
WP2.3 OEM weather based approval 44
WP2.4 OEM measurement collection 45
WP2.5 Forecast weather data provision 46
WP 3 Pre-study for Authority Interfaces 47
WP3.1 Road Authority Interface 47
WP3.2 City Interface 50
Appendix B - PM: Pre-study for Authority Interfaces 51
Background 51
Scope 51
Method 52
Benefits from increasingly connected and automated vehicles 53
Services to support identified benefits 53
Ranking of attractiveness and actualization of services 54
Findings and recommendations 55

Appendix C – DATEX II schemas 56
Report part B: Autonomous Drive Aware Traffic Control Emergency Vehicle Information December 2018 60
Version History 60
Glossary 60
Executive Summary 61
Project participants 62
Volvo Cars 62
Ericsson 62
Carmenta 62
RISE Viktoria 62
SOS Alarm 63
System description 63
Basic principles 63
System solution 64
SOS Alarm Emergency Situation View 66
Systems part of the end-to-end data flow 67
The Emergency Vehicle (EV) 67
The RAKEL (Tetra) Radio 67
The MSB Network 67
The CoordCom/Zenit System (SOS Alarm) 68
The Central Traffic Cloud/Carmenta TrafficWatch™ 69
The Interchange Node 72
The Volvo Sensus Cloud/Volvo Cars Command Center 73
V2Cloud communication 73
The Autonomous Driving (AD) Vehicle .... **Error! Bookmark not defined.**
Findings 74
Conclusion 1 74
Conclusion 2 .... **Error! Bookmark not defined.**
Carmenta specific findings 74
Finding 1 .... **Error! Bookmark not defined.**
Finding 2 .... **Error! Bookmark not defined.**
International liaisons 76
Future Work 76

Plan for commercialization and growth ... 76
Appendix D – Deliverables ... 78
WP 1 Emergency vehicle information ... 78
WP2 AD advice /central traffic control ... 78
WP3 Improved EV routing ... 79
WP4 OEM traffic control ... 79
WP 5 Study of effects ... 80
Appendix F – DATEX II schemas ... **Error! Bookmark not defined.**

Version History

V1.1 20170814	Updated with comments from Carmenta	Philip King, Volvo Cars
V1 20170714	Final version Known updates to come are the diagrams in Appendix 3 from draft to final	Philip King, Volvo Cars
V.093 20170713	Carmenta corrections	Mikael Gråsjö/Kristian Jaldemark, Carmenta
V0.92 20170712	Final draft	Philip King, Volvo Cars
v0.91 20170710	Carmenta corrections and additions	Mikael Gråsjö, Carmenta
v0.90 20170706	Trafikverket Deliverable 3.2	Peo Svensk, trafikverket
v0.73 20170703	Business Risk	Johan Lindberg, Volvo Cars
v0.72 20170630	Ericsson additions	The Ericsson team
v0.71 20100621	System description added	Anders Fagerholt, Ericsson
v0.70 20170620	Third draft sent out for review	Johan Lindberg, Volvo Cars Mikael Ivari, City of Gothenburg
v0.63	Carmenta additions	Kristian Jaldemark, Carmenta
v0.62	2.2 in appendix added	Ali Bengtsson, Ericsson
v0.61	First Ericsson contribution	Anders Fagerholt, Ericsson.
v0.60 20170609	Second draft sent out for review.	Johan Lindberg, Volvo Cars Kristian Jaldemark, Carmenta Mikael Gråsjö, Carmenta
v0.52 20170608	Updated with comments from *Philip* and *Per-Olof*.	Johan Lindberg, Volvo Cars [editor] Philip King, Volvo Cars Per-Olof Svensk, Trafikverket
v0.51 20170607	Added Appendix B - PM: Pre-study for Authority Interfaces	Johan Lindberg, Volvo Cars [editor] Mikael Ivari, Göteborgs Stad

v0.50 20170605	First draft of the report sent out for review and feed back to the project group.	Johan Lindberg, Volvo Cars Kristian Jaldemark, Carmenta Mikael Gråsjö, Carmenta

Glossary

AD	Autonomous Driving
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
CTC	Central Traffic Control
DATEX II	Standard information model for road traffic and travel information in Europe
Drive Me	Volvo Cars autonomous driving research project
GUI	Graphical User Interface
ITS	Intelligent Traffic System
LTE	Long Term Evolution
OEM	Original Equipment Manufacturer
OGC	Open Geospatial Consortium
OpenLR	Open source location referencing method
RFI	Road Friction Indication
TMA	Truck Mounted Attenuators
TMC	Traffic Monitoring Centre
V2X	Vehicle-to-Everything

Executive Summary

This first part of the report is the concluding document of a joint public private project run over a period of ten months through to the end of June 2017 financed in part by Vinnova. The partnership included Volvo Cars, Ericsson, Carmenta, Trafikverket, and the City of Gothenburg. The goal of the project was to define and propose a traffic control cloud for automated vehicles with interfaces to vehicles, road authorities and city authorities, along with the associated information flows for connected vehicles. In addition the project proposed solutions on required services including traffic control and information sharing.

The main deliverable from this project was a demonstration of the working system held at Lindholmen Science Park in June 2017. This demonstration showed the information flows from the car to the cloud, through to a Central Traffic Control platform and back again, as well as the flow of information to the Central Traffic Control from the road authority. The project utilised and built upon a lot of the already existing cloud infrastructure developed for the Drive Sweden initiative.

This report documents the technical solution implemented, from the architecture envisioned, the technologies implemented and the standards used. Additionally the findings and conclusions of this work have been recorded with where possible desired future steps or recommendations.

Finally the report contains the methodology, results, and recommendations of a large workshop held in April 2017 between the City of Gothenburg, the National Road Administration, Volvo Cars and Carmenta where future services based on the having access to the data from connected cars as well as having actual autonomous cars operating within the traffic environment were discussed.

Project participants

Volvo Cars

Volvo Car Corporation have high ambitions when it comes to sustainable mobility solutions, especially within electrification and autonomous drive. Its leading position within self-driving cars is based on the world first and largest pilot for autonomous driving with real customers on public roads, Drive Me in Gothenburg. Important building blocks to secure its journey to commercial autonomous driving offer includes the joint project with Uber, extensive recruiting in Gothenburg and Zenuity (a new joint venture company with Autoliv) which will develop software for autonomous driving. The work on autonomous driving builds upon 89 years of safety know-how.

Ericsson

Ericsson is a global leader within communication systems and services. 40% of mobile calls are made through Ericsson systems and more than 2 billion people use its networks. Now, Ericsson is leading the development towards a Networked Society, where everything that benefits from being connected - will be connected. The Transport sector will benefit extensively from getting connected, cooperative and automated. Ericsson is now developing and implementing communication services and cloud services to support this development. The next generation of mobile networks, 5G, is now being developed to fully support connected automation and new mobility services. Drive Sweden is a key project, with leading partners and use cases to ensure relevant and innovative input the development of 5G and related services.

Carmenta

Carmenta is a privately held Swedish company, founded in 1985, with offices in Sweden, Germany, France and Spain.

Carmenta has been supplying world-class software for mission-critical systems for more than 30 years – systems in which superior situational awareness is the key to success. Carmenta provide high performance software products, develop client-specific solutions and offer a wide range of services that help some of the world’s most technologically advanced customers optimize their operations using real-time geospatial information. Its technology is designed to meet the highest standards focusing on high performance, high availability, openness and scalability, and ease of use. Carmenta’s customers are found globally with a concentration in Europe.

Carmenta provides command and control technology for connected and autonomous vehicles which helps traffic network operators to improve traffic control and increase road safety. Background maps with integrated sensor data, weather forecasts, video streams and other information provide the type of common operational picture that will be necessary for the command and control systems of the future.

Trafikverket

Trafikverket is responsible for the overall long-term infrastructure planning of road, rail, sea and air transport. Its assignment also includes the construction, operation and maintenance of state roads and railways. They are developers of society and plan for a holistic integration of the entire transport system. In order for society to develop, the country's transportation must work. Increased accessibility is becoming increasingly important. Its task is to develop an efficient and sustainable transport system from a perspective that encompasses all modes of transport. They work with long-term infrastructure planning in close dialogue with regions and municipalities. They are also responsible for building, operating and maintaining state roads and railways. In addition, they are responsible for ensuring that this infrastructure is used effectively and that it promotes safe and environmentally sound transportation.

City of Gothenburg

Gothenburg is a port city with a strategic location in between Oslo and Copenhagen. It has a population of around 550,000 and is Sweden's second largest city.

The city is growing strongly and is preparing to make space for 150,000 more residents by the year 2035. As the city grows, it is also evolving. New residential areas and city districts are emerging on land previously used for industrial purposes. In 2012 the city adopted the River City Vision that sets a firm direction for the future development.

One important strategy for implementing the Vision is to allow areas now under development to become living labs for development of innovative transportation and mobility solutions, always with a strong focus on sustainability. Gothenburg has a long and proud history of developing the transportation system and making it smarter and has many times piloted new advanced ITS features involving cars, buses and trucks.

System description

Basic principles

The Volvo Cars Drive Me project is the foundation for this project. In Drive Me the vehicles are aimed at Level 4 automation = secondary tasks are allowed, if the vehicle cannot manage the situation it will go to a safe stop or make a controlled handover to the driver. AD is allowed on a carefully mapped set of road segments but not under severe weather or traffic conditions. When the vehicle is in AD mode Volvo Cars takes the responsibility.

This means that Volvo Cars must be able to execute that responsibility and allow or revoke AD driving in real time.

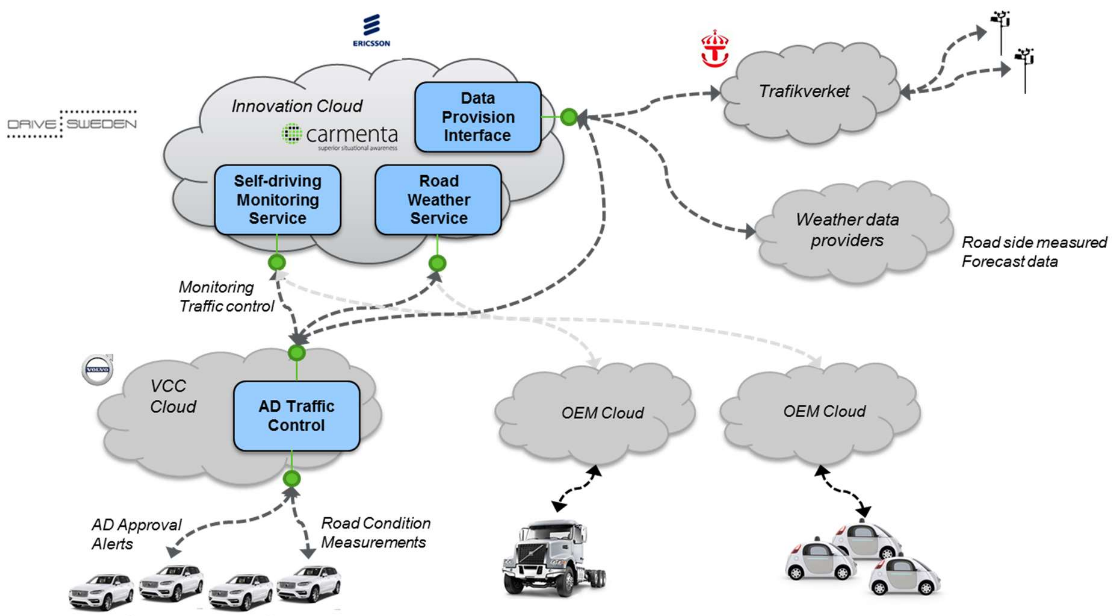
We foresee that other OEM´s and fleet owners will have the same needs in the future.

We foresee that different OEM´s will have different certified roads that will grow over time.

We foresee that different vehicle models will have different capabilities that will grow over time and enable AD driving under more harsh conditions.

Regulation on data protection and privacy must be fulfilled and privacy by design is preferred.

System architecture



The system is composed of a Central Traffic Control (CTC) cloud, a number of OEM-clouds and external data sources.

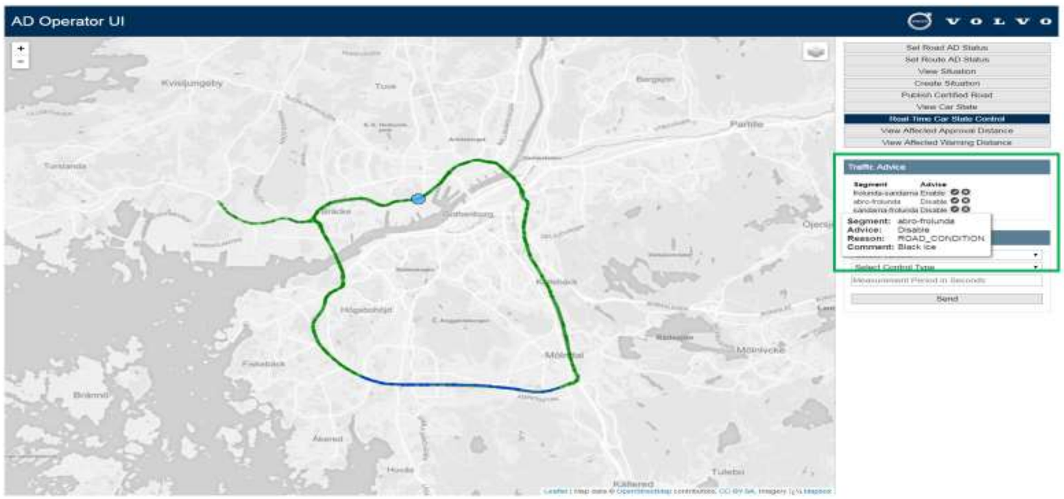
The OEM cloud, in our case an AD enabled instance of the Volvo Sensus Cloud, has the communication to and from the vehicles. The route, position and other data is communicated to the OEM AD traffic control. As the OEM is the only part that should know about the vehicles, know their AD capability, and takes the responsibility in AD mode this control function must reside in the OEM cloud.

With some inspiration from the Nordic Way project and the insight that many OEM´s will have the same need for traffic and weather data we introduced the Central Traffic Control (CTC) Cloud. The CTC Cloud is assumed to be a Public or a Public Private Partnership instance that can serve any number of OEM clouds by aggregating all data of interest.

This cloud has a Publish/subscribe and Request/response mechanism. Also here is a Traffic Controller that monitors the situation (on the different certified roads) and with automation support that can trigger alerts to the OEM clouds if there is an event.

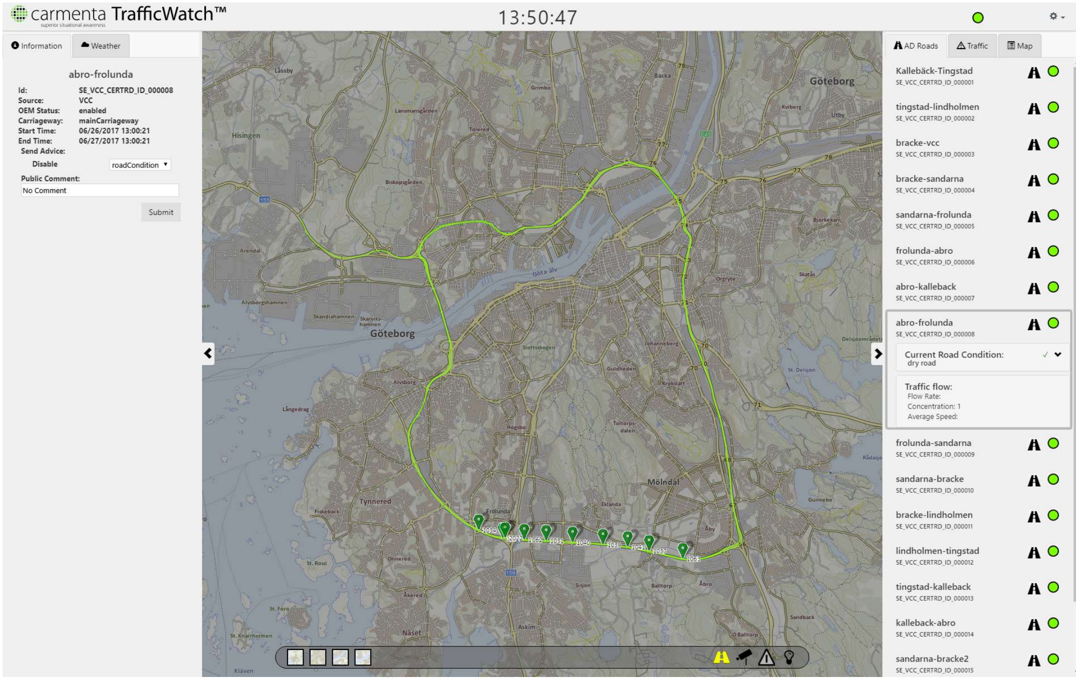
The data exchange between the CTC cloud and OEM clouds use DATEX II with some extensions for AD use cases suggested by the project.

OEM AD Traffic Control View



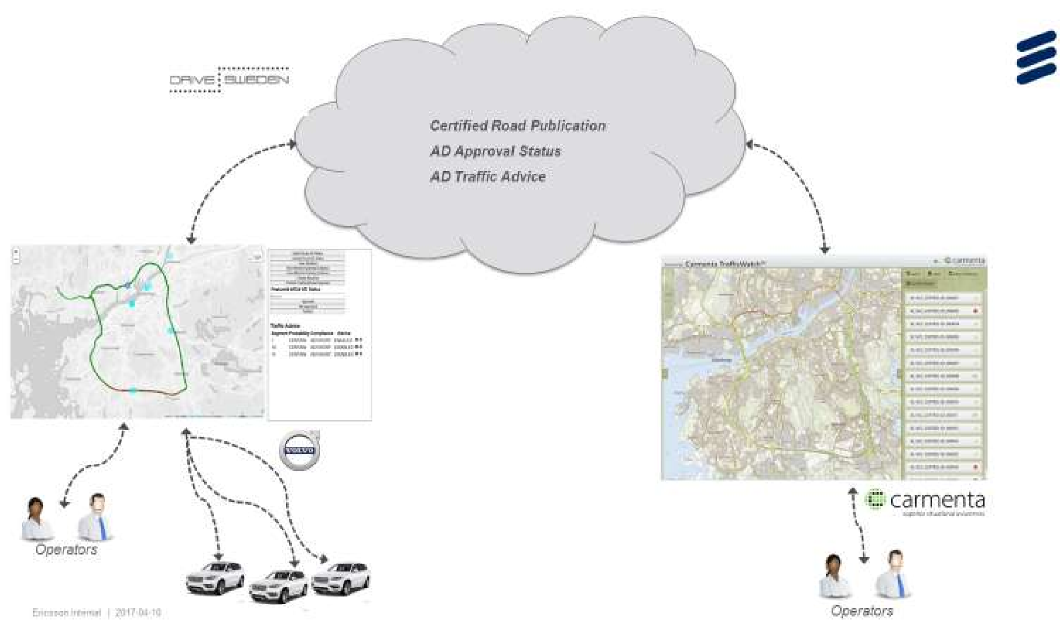
Screen dump showing the Volvo Operator GUI

Central Traffic Control view



Screen dump showing the CTC Operator GUI with the certified AD road segments transferred from OEM VCC.

System Services



The first service is **Transfer of certified road segments map data** from the OEM to the CTC. The OEM mapping of the certified road, in our case the ring motorway around Gothenburg has more than 1000 segments. This has been reduced to 17 segments to reduce complexity. Map data is transferred (DATEX II) to the CTC that makes a map matching to the CTC map and a manual feedback is sent to the OEM to check the validity.

The next service is **Transfer of road segment approval status** from the OEM to the CTC. This allows both traffic controllers to have the same situation awareness.

CTC advice on AD driving based on situation. The CTC reads the DATEX II message stream from Trafikverket (Swedish Road Administrations Safety related traffic information service) and maps out the events. Road conditions like: Lane closures, Road blockage, Construction sites, Faulty Signs on a road segment will trigger an **advice** to the OEM AD traffic control that will then allow them to take a **decision** to allow or revoke AD driving on that segment and send this data to the vehicle. The road segment approval status is sent back to the CTC.

CTC road weather service (situation and forecast). The CTC aggregates weather data and based on thresholds will trigger an **advice** to the OEM AD traffic control that will allow them to take an action as in the case above.

Extreme weather conditions can be:

- Low visibility on a specific section of certified road
- Extreme precipitation on a specific section of certified road
- Snow on a specific section of certified road
- Low lane visibility on a specific section of certified road
- Low object visibility on a specific section of certified road
- Low friction on a specific section of certified road
- Strong winds on a specific section of certified road
- Aquaplaning risk on a specific section of certified road

OEM vehicle sensor data to CTC. Volvo Cars Sensus Cloud can today share (aggregated) road friction information and amber hazard blinker information. In the project today we get this data and road works warning from 12 TMA blocking trucks in Gothenburg from the Nordic Way Interchange Node[1]. This can be developed further with more sensor data from AD vehicles to improve the situation awareness.

OEM query on data on road segments (pre trip). When the driver programs the AD route, this is sent to the OEM AD control that in turn can send a query to the CTC that will return the data to the OEM AD control that allows or revoke AD driving on the road segments. Segment approval status is sent back to the CTC.

In order to protect privacy, the OEM AD control sends the **Density (flow) of AD vehicles in AD mode** on all road segments to the CTC. This can only be simulated now but is regarded as a good function for the future public traffic management of mixed traffic.

In order to protect privacy, the OEM AD control does not expose the position of an individual AD vehicle that made a safe stop. **Safe stop alert to** CTC will be based on aggregated data (like 3 safe stops within 3 km and 3 minutes).

Findings

When we started out this project we had a belief in the usefulness of a platform providing governance for AD vehicles. It was perhaps a sketch to start with, but as the project has progressed the picture

[1] Nordic way film: https://www.youtube.com/watch?v=gTrrl4ymvyc

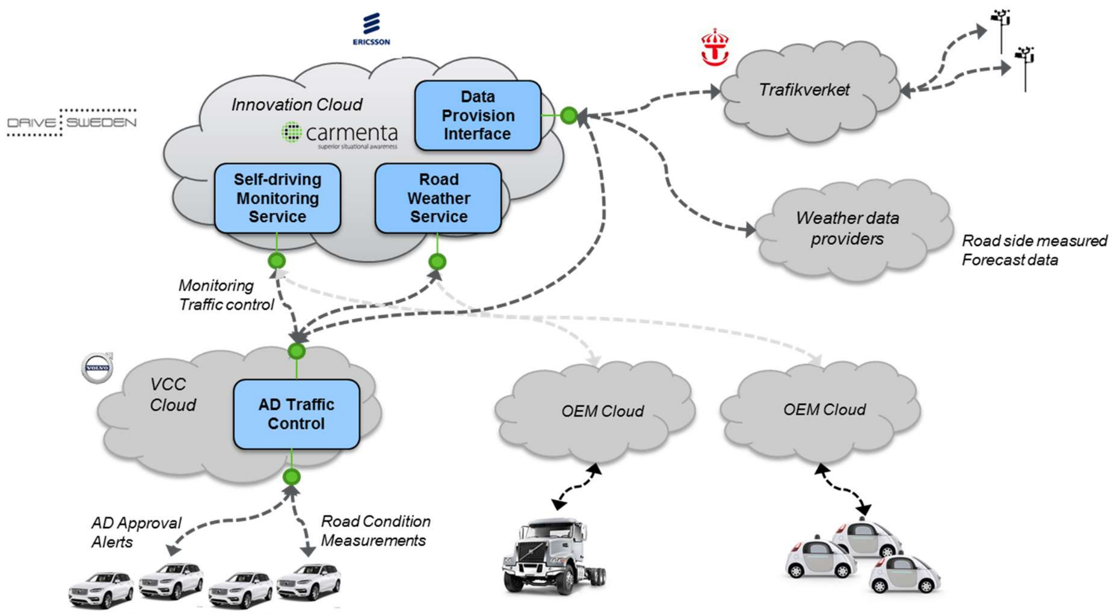
has become clearer. There are still areas that need more research, where we do not fully understand the implications. But it has become clear to all of us participating in the project that this type of platform for the governance of AD vehicles is an important piece of the puzzle in solving the future problems of traffic management in modern cities.

The AD Aware Traffic Control project has been a great way to prepare for the Drive Me pilot that is coming in the end of 2017. It has been an important part of Volvo Cars' preparations and thinking about AD Control, the way it would work and what kind of stakeholders will participate.

There are a number of benefits that we initially assumed and that we still believe are there after further analysis but since the platform hasn't been tested in real production use this is still very much an analysis on paper.

There are also a number of findings that were not part of the initial assumptions coming into the project but that have an impact on how we think going forwards. All of those findings and ideas have come about thanks to the cooperation and the spirit of freely sharing ideas across companies and government agencies.

Benefits and findings are listed under each work package. Since the deliverables in the project plan were mostly about building the platform itself we have summarized them in Appendix A, with a short description and explanation for each deliverable.



Autonomous Traffic Monitoring

Having full traffic situation awareness is a cornerstone to create safer, more efficient and environmental friendly traffic. Real-time traffic situation monitoring on a central level will provide connected entities guidance for a better traffic control including guidance to OEM AD clouds.

Better traffic control

Conclusion

The platform gathers, stores and distributes a lot of relevant data points from various sources, matched to road segments. Data about traffic situations and road conditions are vital for making an informed decision about whether or not to allow AD. Despite being in such an early phase, as we are right now with the Drive Me program, the data available in the platform is also valuable for commercial and public transport providers as they face similar situations.

The fact that more data about road conditions and traffic situations from different sources is shared between OEMs as well as authorities and third parties makes for better decisions. There is however a concern over the diversity of data and lack of sharing. More cooperation and standard data formats and terminology need to be developed.

Increased road safety

Conclusion
The AD Aware Central Traffic Control extends the OEM Traffic Control with data that is shared between OEMs as well as authorities and third parties allowing for better decisions on allowing AD-mode or not. The platform increases the road safety by having monitoring of the conditions that the AD-vehicles are used in. The platform only deals with anonymized data and therefore not violating the privacy of the AD-user.

The project has shown in several demos that the information flow between CTC and the Drive Me AD-vehicle works, but this relies on timely data, open trust between OEM's and government bodies, standard interfaces as well as legislation to ensure commitment.

The transition period involves all connected cars

Conclusion
In order to effectively transition AD-vehicles into full use we will need to have access to more data. There are several ways of achieving this. One is to add more OEMs, another is to connect more types of vehicles. The benefit of having more data is that the probability of an AD vehicle running into an undetected situation, where the driver (without wanting to) exits AD mode and takes control, is minimized. It will of course still happen but the probability is in relation to the number of connected non-AD vehicles in total. The data we are collecting is not only useful to AD cars but could also provide assistance to public transport as well as traffic planning in general.

Common terminology is a foundation

Conclusion
The naming of things might seem a simple task but solving the problems of future traffic management requires a common terminology that is precise, clear and comprehensible. The meaning of what a *certified road segment* is and what role it plays cannot be in doubt in a collaborative ITS setup. As more and more decisions are being automated it's crucial that a common foundation for speaking about traffic management is developed. It will not only reduce time in developing new functionality but will also shorten the time it takes to find and fix problems. Last, but not least, a common language allows for a common foundation for business rules and as such creates an easier way to gain insight and trust in implementations of other stakeholders.

Whole picture Benefits/Findings

Community/Society,

- The CTC creates a Collaborative Situational Awareness that is beneficial for all connected stakeholders, many of which both contributes and use the information in the CTC. By using a collaborative approach to ITS it is possible to collect and fuse information that contributes to a safer traffic situation.

- The need for data privacy (i.e. GDPR) makes it necessary to have several levels of traffic control. Vehicle and personal information are aggregated and filtered when communicated with CTC from OEM Traffic Control to protect the privacy of individuals.
- This project together with Nordic Way point out the way to evolve traffic management by aggregating and sharing sensor data from connected vehicles. The situation awareness will reach new levels of detail. The other important feature is that traffic management now, via the OEM cloud, can reach out to the vehicles. In this project we focus on AD vehicles, but the principles can be used for all connected vehicles.

Environmental,

- Traffic Flow Information – The project has demonstrated the exchange of traffic flow information between autonomous cars and the central traffic cloud. All connected vehicles can contribute with data that enhances the possibility of proactive traffic management that can reduce congestion and also limit the environmental impact of traffic. When the vehicles are autonomous the effect of a proactive traffic management could potentially be even more positive.

Business,

- The CTC could act as a data broker, potentially creating a marketplace for information from autonomous and connected vehicles.
- Public-Private partnership will be the most likely business set up.

Organisational

- A high level goal of the project was to suggest a roles and responsibilities model for relevant actors – i.e. driver, OEM, national/regional traffic authorities, etc. Even though the different actors in the project agree on the benefit from having a CTC that provides collaborative situational awareness, the responsibility for operating the CTC remains to be further investigated.
- Other organisational issues still to be investigated are relations between the CTC and other commercial integration platforms, relations between the CTC and traffic management systems on regional, national and international levels, etc.
- The CTC is a central node but it must be possible to arrange a “federated network” of CTC´s that can interact and cover adjacent areas (cities or nations) or even the same area (public and private roads).

Technical

- The project has shown that on a technical level it is possible to build a cloud based central traffic control for autonomous and connected vehicles using existing and open standards (i.e. DATEX II, Open Geospatial Consortium (OGC), OpenLR, AMQP). However, in order to communicate autonomous driving advice (allowed/not allowed) within DATEX II, the standard needs to be extended. One delivery from this project is the start of a proposal that can be submitted to the DATEX II standardisation board (CEN Technical Committee 278). More details can be found in Appendix C.
- The Drive Sweden Innovation cloud proved to be a good environment to execute the project in.

1. Carmenta specific findings
    a. The integration of the Carmenta products (Carmenta Server, Carmenta TrafficWatch) in the Drive Sweden Innovation Cloud infrastructure has been very smooth and efficient, proving that the products are very well suited to be used in cloud based architectures.
    b. The traffic control operator GUI and AD Aware CTC functionality developed in the project has been demonstrated to traffic management operators at Trafik Göteborg and Trafikverket, showing that CTC fulfil expectations on a future AD Aware traffic management system.
    c. The AD Aware CTC architecture and functionality has been demonstrated and discussed with a group of traffic management systems architects at Trafikverket, showing that the system architecture with a cloud based set of micro services conforms well with the architecture of the future traffic management system planned by Trafikverket.
    d. It is important to have a technical platform flexible enough to handle different use-cases for setting up and maintaining a central road segment database. It should be possible to use both road network data supplied through national or local municipalities (such as NVDB) as well as road data from global suppliers (such as HERE, TomTom etc).

2. Volvo Cars specific findings
    a. AD Approval decisions need to happen on many levels. Ranging from what is technically possible in the vehicle, up to the level of a government authority. This means that the Business Rules surrounding the AD Approval and the terminology, describing it need to be aligned across OEMs, third parties and authorities.
    b. Extending the RFI probe sourced concept to include transmitting data from one car to others based on location/time details means increased safety.

3. Ericsson specific findings
    a. Ericsson has adopted a DevOps approach for AD Aware Traffic Control project. One of the main focuses has been how can Ericsson leverage a fast development, integration and deployment model of interchange servers, across different regions around the world to meet its current and future partner's needs. It has been shown that Ericsson has a cloud ready infrastructure for hosting a container based messaging system solution using standard APIs, which can significantly reduce integration time with partners and OEMs. OEMs and partners are not restricted to us a specific programming language or need to be bound to a particular operating system. It are providing openness, flexibility and a faster method to reach the market.

Collaborative Road Weather Service

Readily available, updated and quality assured information about weather conditions in the road network will improve safety and efficiency.

Weather Forecast information contributes to better traffic management

Conclusion

For CTC purposes weather forecasts provides information that can be used in addition with other data to make more informed decisions for an effective and safe traffic management.

Bad weather conditions can significantly affect the traffic situation with an increased risk for slow or stationary traffic. Suddenly appearing severe weather situations such as icy roads or impaired vision due to heavy snowfall poses an immediate threat to driver safety. The integration of weather information and forecasts in the operational picture will make the traffic operator able to more proactively take actions to avoid or mitigate disturbances or accidents caused by weather phenomena.

Weather Forecasts are not yet accurate enough for guiding AD operations

Conclusion

Currently available on-line sources providing weather forecasts are not yet accurate and precise enough to be useful for operational AD Approval guidance.

Several public and private providers offer weather information services capable of delivering detailed forecasts down to geographical points or road segments. However the spacing and distribution of currently available ground based meteorological observation stations delivering 'start data' for the forecast modelling used in these services are much too sparse. This makes them unable to predict local variations and road-specific conditions on the detailed scale necessary for AD vehicle operation.

Weather Forecasting for AD guidance needs vehicle-collected data

Conclusion

Following on from the previous finding there is a need for more detailed measurements to enhance modelling to deliver accurate enough forecasts for operational AD guidance. Real-time floating car data from connected AD vehicles delivering weather-related sensor information through the OEM TC is potentially a very useful source for enhanced forecasting.

Detailed and accurate measurements of weather-related information through car sensors on AD vehicle fleets provided in real-time could significantly enhance forecast modelling.

The CTC is a good weather information hub

Conclusion

The CTC can effectively act as a weather information 'hub' for collecting, aggregating and analysing meteorological information and making it available to connected parties in a prepared and standardized way.

It makes sense to use a central unit for providing general weather information thus relieving individual OEMs the hassle of dealing with proprietary APIs and 'un-refined' meteorological information. In the project we have successfully made weather forecast data readily available to OEMs both in the form of AD Advices (hazardous road conditions) and through a generic weather 'query' interface.

Whole picture Benefits/Findings

1. There are several potential providers of weather-related data able to supply road-related weather information.
2. Lack of standardized APIs leads to specialized interfaces to external weather information providers. The content and nature of data also varies a great deal between different providers.

3. The data provision interfaces were reasonably easy to implement due to clear specifications from the evaluated offerings. An efficient plugin framework in the Carmenta's products made it also easy tailor-make the interfaces and then integrate the weather information in the CTC data flow.
4. Among the contacted providers, Foreca could offer the most complete road conditions service with best coverage and was used as the primary data source for setting up and testing the meteorological data flow in the project.

Authority Interfaces

Whole picture Benefits/Findings.

Ericsson have reused the interface to Trafikverket DATEX node for Road safety related traffic information that was developed in Nordic Way. Messages can be filtered on both geo-spatial data as well as content.

Risk

The technical challenges to develop self-driving vehicles where the OEM or organisation behind the product take legal responsibility in case of accident requires new processes, methods and solutions. The legal framework doesn't exist today for self-driving cars. For a real commercial implementation (and business opportunities) this has to be solved to secure implementation.

There is also a risk that no one wants to develop and operate a collaborative platform due to the fact that there are unclarified issues in legal frameworks. If that scenario plays out it may seriously hinder the development and implementation of AD. OEMs are more likely to re-invent the wheel and we will fall short on the society benefits.

International liaisons

Drive Me in UK and China.

When the project started there was an intent to also pilot the Drive Me program in UK and China. Along the way it has been decided to suspend those pilots and instead focus on Gothenburg. Therefore, the work of spreading the AD Aware CTC platform via the Drive Me program has been postponed.

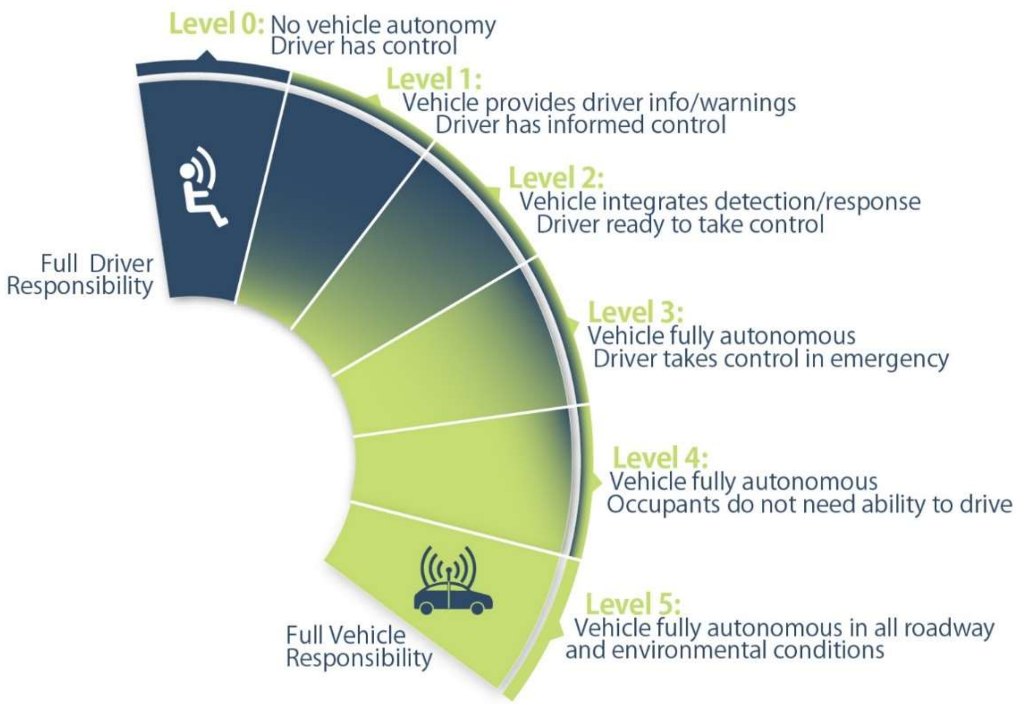
EU Cooperative Intelligent Traffic System (C-ITS) platform

The EU C-ITS-platform is an expert group dealing with connected and automated driving and our project has been presented for the working groups "Enhanced traffic management" and "Physical and digital infrastructure" for AD driving. Our architecture and the concept of OEM-certified roads for AD created a lot of discussion and interest especially among the road operators in many EU countries. Hopefully our project will get a couple of pages in the final report ready in September 2017.

Plan for commercialisation and growth

The project has used AMQP 1.0 for messaging between the clouds and used DATEX II for the data model. Extensions to DATEX II have been made to cater for AD use cases and these can be proposed as extensions to the DATEX standard. Driving the standardization of messages and formats for this type of information and data exchange across OEMs, third parties and governments is a vital part of making the platform ready for growth into other markets and for use with more OEMs. We have chosen to take the more time consuming and difficult route of doing this instead of building our own proprietary message formats. But we all believe that in order for the platform to stand a chance we need to attract more stakeholders in order to grow the platform. Which is necessary for a commercialization and future development that is market driven.

Vehicle automation is classified in 5 levels. For example, Tesla has level 2 = the driver must all the time be prepared to take over the control. Level 5 (that might be utopia) means that the vehicle can drive itself (in all situations that a skilled human could master) and the vision is to take away the steering wheel and controls. Drive Me is aiming at level 4, the vehicle can drive itself on certain roads under certain conditions, and the driver can perform other tasks. The vehicle will bring itself to a safe stop or make a controlled handover to the driver if AD is not possible anymore.

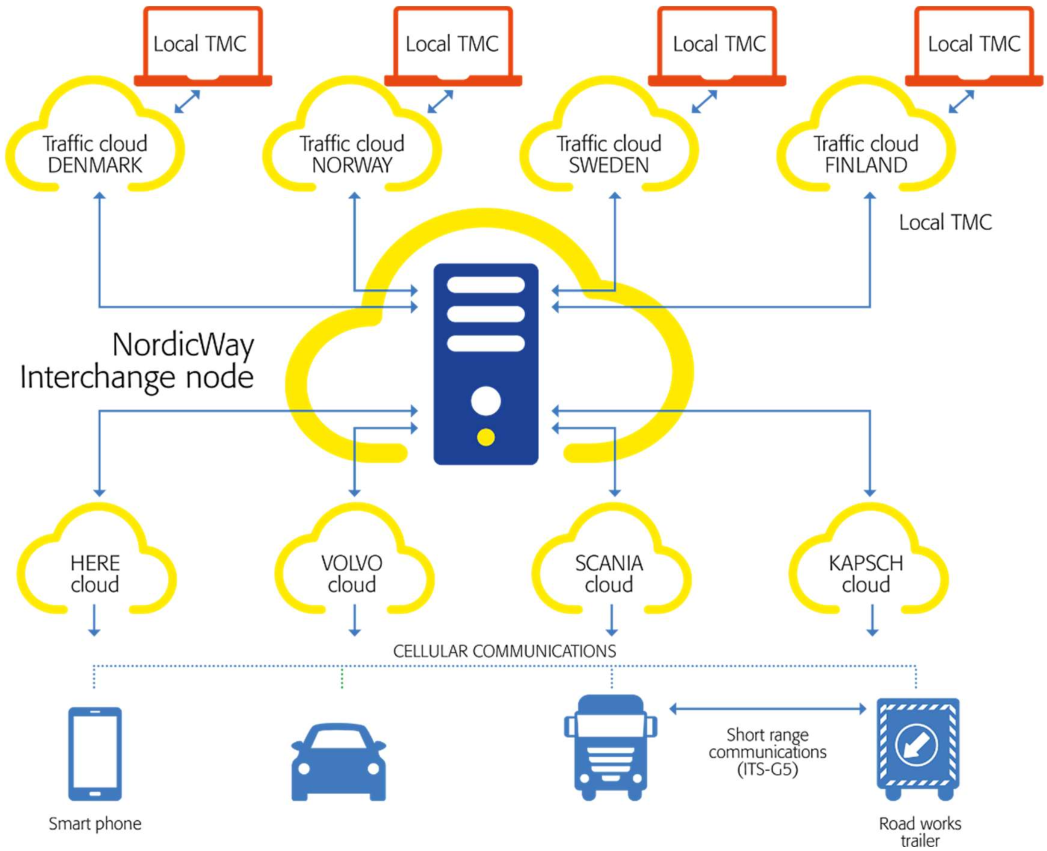


Source: https://www.sae.org/misc/pdfs/automated_driving.pdf

Volvo Cars has stated that they will take the responsibility when in autonomous mode. The logical consequence of this is that Volvo Cars then also must execute that responsibility and must be able to allow and revoke permission for AD drive.

Other OEM´s and fleet owners are coming to the same conclusion according to media.

With inspiration from the Nordic Way project we established a similar system architecture to share data (publish/subscribe and request/response). To expand the Nordic Way C-ITS data sharing concept on a European level there must be a federated network of interchange nodes to avoid vendor lock in and enable flexible governance models.

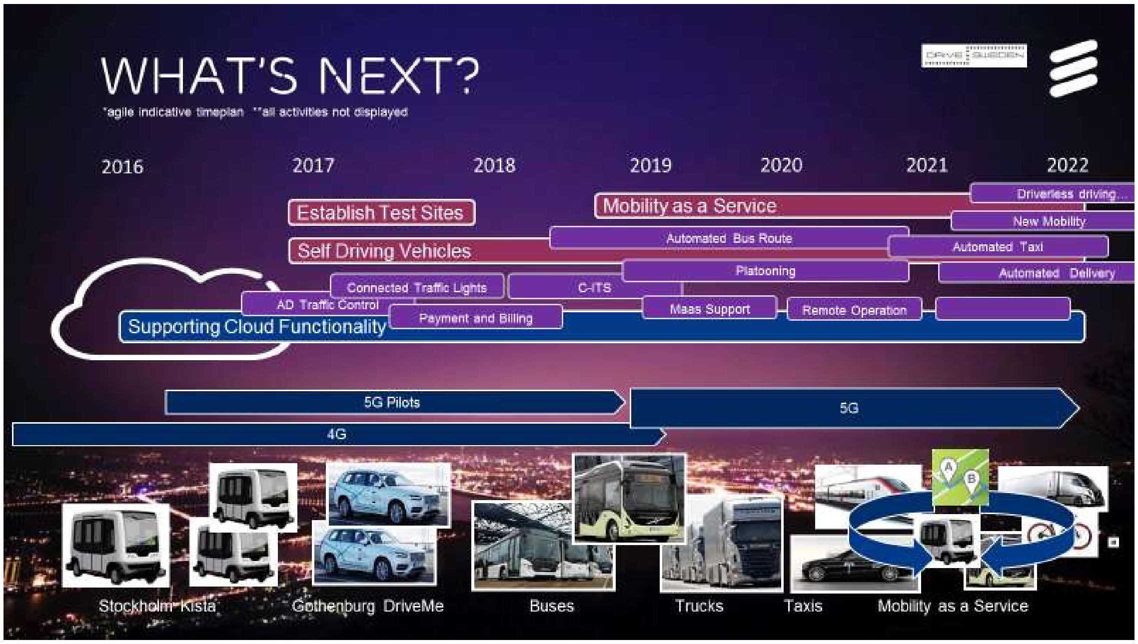


The Nordic Way project[2] has created a lot of interest from road operators in Europe and is more or less becoming a natural part of what in EU is called "the hybrid C-ITS" system. The cloud to cloud communication is based on DATEX II and OpenLR just as in this project.

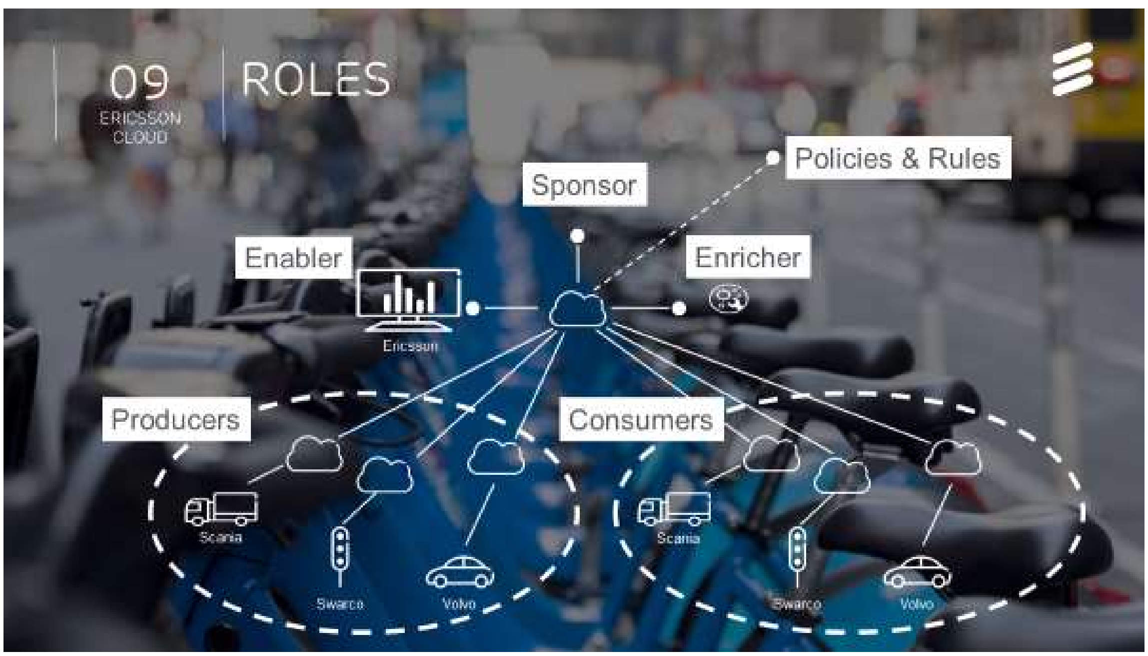
We believe that the results and architecture in the AD Aware Traffic Control project will create the same interest among road operators, OEM's and (public transport) fleet owners aiming for level 4 and taking the responsibility. We will communicate our results of this project and the follow up Emergency Vehicle Information. It is very likely that predicted Drive Sweden projects like Mobility as a service and automated bus routes will use and evolve the platform.

Other OEM's could come to Drive Sweden, join the platform and conduct trials. But it is also easy to set up the system on other trial sites like the German A9 or ASFiNAGs Gratz trial area. The roadmap of Drive Sweden gives us the stability to attract other players and evolve the standardization.

[2] Nordic way film: https://www.youtube.com/watch?v=gTrrl4ymvyc



With inspiration form discussions in Nordic Way and Drive Sweden we see different roles in a commercial setup.



We have elaborated that, as previously stated, it will be a federated network of central control clouds or interchange nodes. One assumption is that Public Private Partnership (PPP) can be an effective set up. Sponsor would be the Public body – Trafikverket. Enabler can be Ericsson. Enricher can be Carmenta and there are many producers of data. Consumers would be OEM clouds and Traffic management. The sponsor will need to trigger the PPP eco system with an initial investment and gradually the internal cloud billing and settlement system will be used to track and monetize all transactions according to the policies and rules and make the system self-supporting.

Future Work

This project has aimed at developing a tool set and a technical platform for AD Aware traffic control. It has put its finger on a number of important issues and highlighted the need for cooperation across companies and regulatory organizations.

We would like to propose three categories for the next steps. To continue to add more functionality, to add more content, and a study into the use of the platform.

More functionality

Emergency Vehicle Information

The project extension to including Emergency Vehicle information has already been submitted and approved. It will provide data about Emergency vehicle's routes and allow us to respond to situations where an AD-vehicle's path intersects that of an emergency vehicle.

More content

Another OEM

By adding another OEM and their AD-vehicles we would primarily test the CTC application and the complexity of handling a many-to-one mapping of, for example, status of certified road segments.

Usage of the platform

Drive Me program

A natural extension is to utilize the platform in the Drive Me program that Volvo Cars is running. It would allow us to refine the information levels, language and other conventions used in the platform.

Automated public transport

In Drive Sweden and in many other places experiments have started with small automated buses and pod´s. This is planned both in Kista and at Lindholmen as part of Drive Sweden. The public transport traffic control would need the same type of information as the OEM cloud in this project and they definitely have a certified route. In addition to this we foresee that the public transport traffic manager not only would allow or revoke autonomous driving but also would like to have the ability to take remote control of the pod and drive the passengers to a safe spot in case of trouble. This will require 5G mobile network technology and Ericsson has this type of remote control with haptic feedback working on the research level[3].

[3] https://www.ericsson.com/en/mobility-report/remote-monitoring-and-control-of-vehicles

Appendix A – Deliverables

WP 1 Autonomous Traffic Monitoring

WP1.1 Central Traffic Control

D1.1. Report with findings, lessons learned and recommendations.

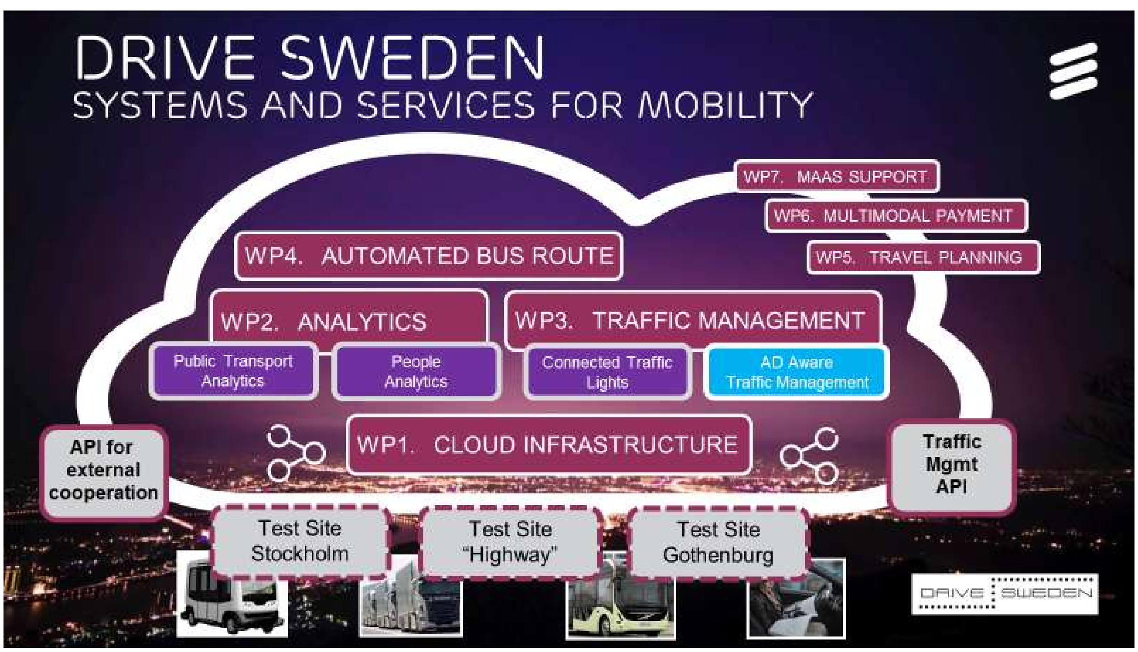
This document.

D1.2. Description of used and proposed interfaces and the flow of information.

We have successfully developed and deployed an up-and-running solution for a Central Traffic Control function. Implemented as a set of services, the solution is smoothly integrated as a demonstrator in the Drive Sweden Innovative Cloud infrastructure. Existing frameworks and tools already part of the Drive Sweden Strategic Project "Systems and services for mobility" have been successfully re-used in this project.

The project has resulted in an efficient operator user interface for an AD vehicle monitoring service that has been used to test and evaluate various interactive operator actions to support OEMs. Valuable insight has been gained on how to operate an AD vehicle monitoring and guidance service as part of the Innovative Cloud solution.

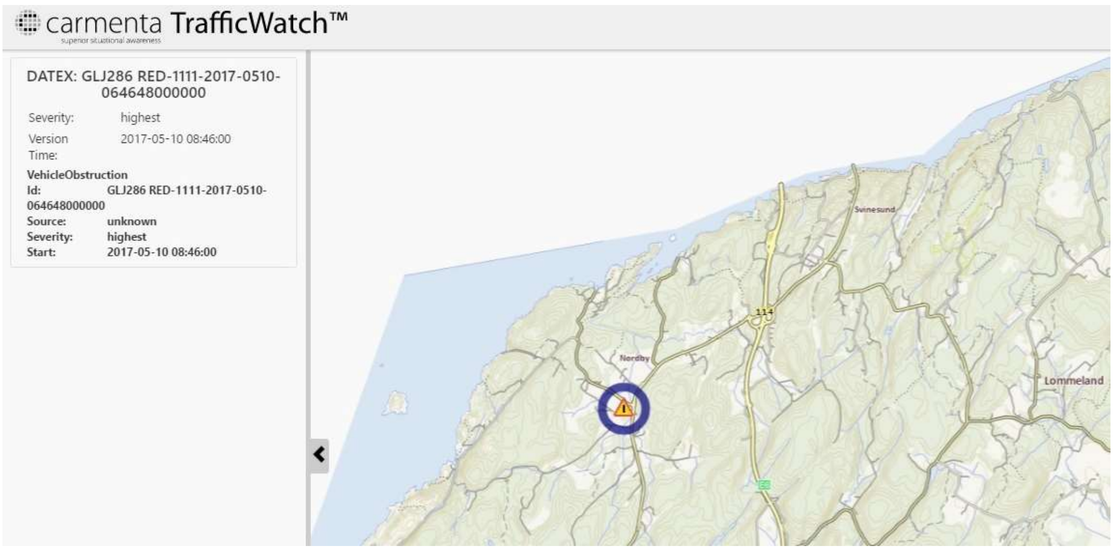
We have established the needed technological foundation for the project SW delivery as well as for further function development including communication, computation and storage capabilities. Based on SW resources made available through parallel projects such as the Drive Sweden Strategic Project "Systems and services for mobility; WP1 – Implementation of cloud infrastructure and base services" (lead Ericsson). Below is a schematic view of existing and planned systems and services in this initiative.



Schematic view of Drive Sweden's overall project structure with the AD Aware Traffic Management sub-project highlighted in blue.

Another fundamental piece that has added value to the project is the Interchange Server solution used in the "Nordic Way" project. We have re-used this (AMQP) solution as the communication back-bone for the message based cloud-to-cloud communication. A specific component/service is developed as part of the CTC system that connects to the Interchange Service, hosted by Ericsson, for further connection to the OEM clouds.

Practical tests have been performed with the Nordic Way service itself and a connection has been established. The figure below shows an example of a 'Vehicle Obstruction' situation registered in that service and transferred to the CTC and displayed for the traffic operator.



Screen dump showing the result of a DATEX 'Vehicle Obstruction' message received from the Nordic Way Interchange Server during tests performed in the Svinesund area near the Norwegian border.

The main capability supported by the AD Aware CTC and implemented in the project is to build and maintain an aggregated traffic situation picture for the traffic operator to interactively dispatch AD messages (example AD driving 'recommendations') to connected OEMs. The traffic situation picture established in the project and used for testing is mainly composed of the following parts:

- **Detailed background map**

In the project we have used Carmenta Sverigekartan[4] as the operational background map. This is a digital map of Sweden optimised for use in command & control systems. The map's layout and colour scheme have been carefully chosen and it has sufficient detail to give the operator a good understanding of the road network and its surroundings also in very 'zoomed-in' views. The map is integrated in the CTC as an external map service and no map data is stored in the CTC itself. One big advantage with using Carmenta Sverigekartan in the CTC is that the road network comes directly from Trafikverkets NVDB (see below). Alternative online map services useful as background maps can be sourced from a large number of suppliers such as HERE, TomTom or OpenStreetMap.

- **Geometry and characteristics of the physical road network**

The road network data used in the CTC is "Nationell VägDataBas" (NVDB) the National Road Database of Sweden. A data processing chain has been established that takes data from Trafikverket's

[4] http://www.carmenta.com/files/4813/9083/1932/Carmenta_Sverigekarta.pdf

'Lastkajen'[5] downloading site and process it for storage in a central road segment database. All AD segments from connected OEMs are map matched (OpenLR) to segments in the central database. Test has also been done using alternative road network data from HERE and OpenStreetMap.

[5] http://www.trafikverket.se/tjanster/Oppna_data/hamta-var-oppna-data/lastkajen---sveriges-vag--och-jarnvagsdata/

- **Real time traffic information**

This data is read from Trafikverket's open dynamic API6 using the DATEX II standard.

- **OEM AD vehicle activity and operations**

Real-time data about AD Certified Roads and their status transferred from connected OEMs. In the project we have integrated AD data from Volvo Car Cloud.

- **Weather data**

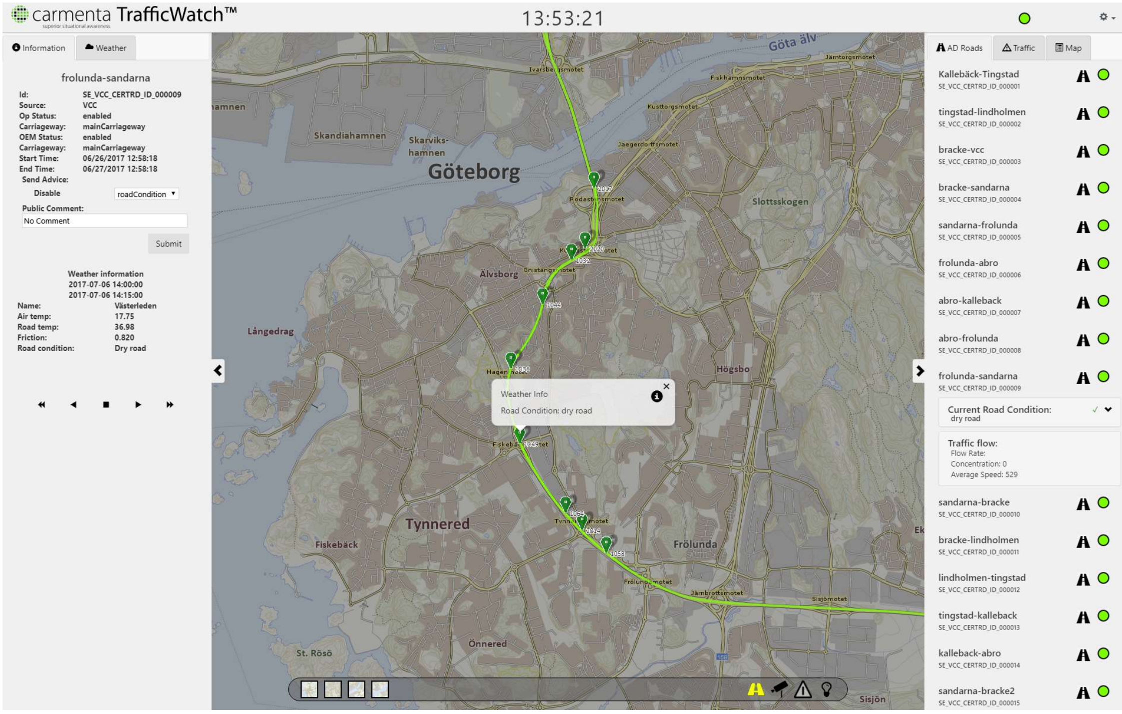
Measured and forecasted weather information including road condition data sourced from four external weather providers have been used and evaluated in the project. These are:

  - Trafikverket (information part of the DATEX II API)
  - SMHI
  - Foreca
  - The RSI demonstrator project

More specific information about the integration tests of weather data in the CTC is found in the Appendix A describing the deliverables from WP2.2.

A custom operator graphical user interface (GUI) has been developed and tested as part of the project. The GUI is map-centric and has been designed based on general principles for command & control operator GUIs but its functions are dressed down and entirely focused to support the monitoring and guidance of connected OEM's AD operations. So far the GUI has been used solely for testing within the project but it has been demonstrated and discussed in meetings with traffic control operators at Trafik Göteborg and Trafikverket, assuring that it fulfil the expectations to be part of any future traffic management system.

[6] http://www.trafikverket.se/tjanster/Oppna_data/hamta-var-oppna-data/datex-trafikinformation-vag-i-realtid/



Screen shot showing the CTC operator GUI with a damped down background map. Map and situation control panels to the right and a general information panel on the left. A status panel on top shows current 'situation' time and if all external connections is running ok (shows the green light). A 'Quick Action Bar' at the bottom makes it easy for the operator to toggle on/off information layers and quickly 'jump' to special interest areas.

The operator GUI shows the overall AD-related traffic situation on top of a detailed and colour-tuned background map. The map can be 'dimmed' darker to allow overlaying objects to be more clearly seen. A map control panel allows the operator to select what is shown in the map window and quickly toggle on/off the presentation of different kinds of information. One control panel is dedicated to show a sorted list of all traffic-related incidents (i.e. DATEX II 'situations') and another panel shows a list of currently monitored OEM AD roads (i.e. OEM VCC 'certified roads'). The operator can easily follow the real-time traffic situation while the lists are continuously updated with data through connected services. The focus can quickly be set on a particular incident or an AD segment by picking a list item. The map centres automatically on the selected object and an information panel opens showing all relevant textual metadata.

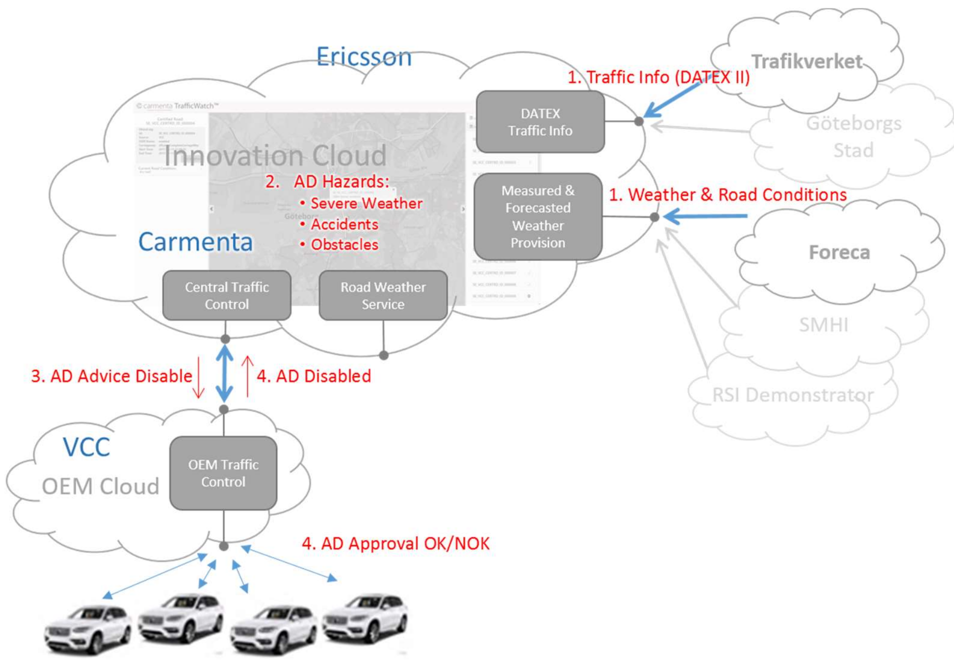
The traffic operator is notified by an automatic warning service when a potentially hazardous situation has occurred on any monitored AD road segment. Current implementation detects when accidents or major obstacles occurs anywhere on the AD road network. This is based on real-time data from Trafikverket's traffic information web service (DATEX II) and analysed on-the-fly by a map matching service in the CTC cloud backend. Also weather data provided from sourcing partners is analysed and warnings triggered whenever a hazardous road condition is detected on the AD road network. All warnings appear in the GUI as a clearly visible notification message on top of the map demanding operator action. Simply by clicking on the message link, the map focuses on the affected AD segment and all connected metadata is displayed for quick action.

Screen dump showing the warning message that notifies the operator that a hazardous road condition has been detected on a monitored AD road segment.

Traffic operator tasks used for building and maintaining the central AD Aware CTC function can be summarized as follows:

- **Establish a common AD situation picture.**
  Connected OEMs publishes all new AD certified road segments with unique ID and version that will be used for AD driving. CTC automatically acknowledges the publication for each road segment and use location referencing functions (OpenLR) to translate it to the CTC internal road database for subsequent use. All changes related to the monitored AD roads will then be related to its unique IDs and stored as situation records in the central database.

- **Guiding OEM vehicle operation through AD Traffic Advices**
  CTC publishes dynamic AD Traffic Advice as defined by each OEM. In the current version of CTC the AD Traffic Advice is published interactively by the traffic operator, who decides when and what to publish. The automatic warning service is a useful tool that notifies the operator when hazardous events occur on the AD road network. The operator can choose to act and then use dedicated functions in the GUI to prepare and publish an AD Traffic Advice with a 'disable' recommendation for the affected road segment also stating the cause etc. It is then up to the OEM Traffic Control if any action is taken based on the advice. If decided to revoke the AD permission on the segment in question, a message is posted back to the CTC which automatically updates the AD status. Below is an overview of the data flow used to collect traffic information and weather data for detecting AD hazards and transferring AD Traffic Advices.



Data and message flow for AD Hazard warnings.

- **Using AD Traffic Information for an improved traffic situation awareness.**
  Large amounts of valuable information is collected by AD vehicle fleets operated by OEM's. In anonymized form this could provide a significant contribution to the traffic situation awareness in a central traffic control. We have implemented and performed preliminary testing of functions to get periodically updated traffic information related to monitored AD road segments. Specific AD Traffic Info messages are published from the OEM containing information regarding AD vehicles such as; Average Vehicle speed (km/h), Vehicle Flow Rate (vehicles per hour) and Vehicle Concentration (vehicles per km).

We have used DATEX II as the basis for the data model used in the central traffic control as well as when modelling the message content in the data exchange solution used in the project. Additional information to support AD vehicle operations have been added to relevant parts of the DATEX II model resulting in a working solution where AD related traffic information is transferred between OEM VCC and the central traffic control. More details about DATEX II and the proposed extensions used in the projects are found in Appendix C.

System Description:

The AD Aware CTC solution is smoothly integrated in the Drive Sweden Innovation Cloud infrastructure. The figure below shows a schematic view of the Central Traffic Cloud part of the Innovation Cloud (hosted by Ericsson) and depicts where the AD Aware SW components supplied by Carmenta and the Volvo Sensus cloud operated by VCC are integrated in the cloud.

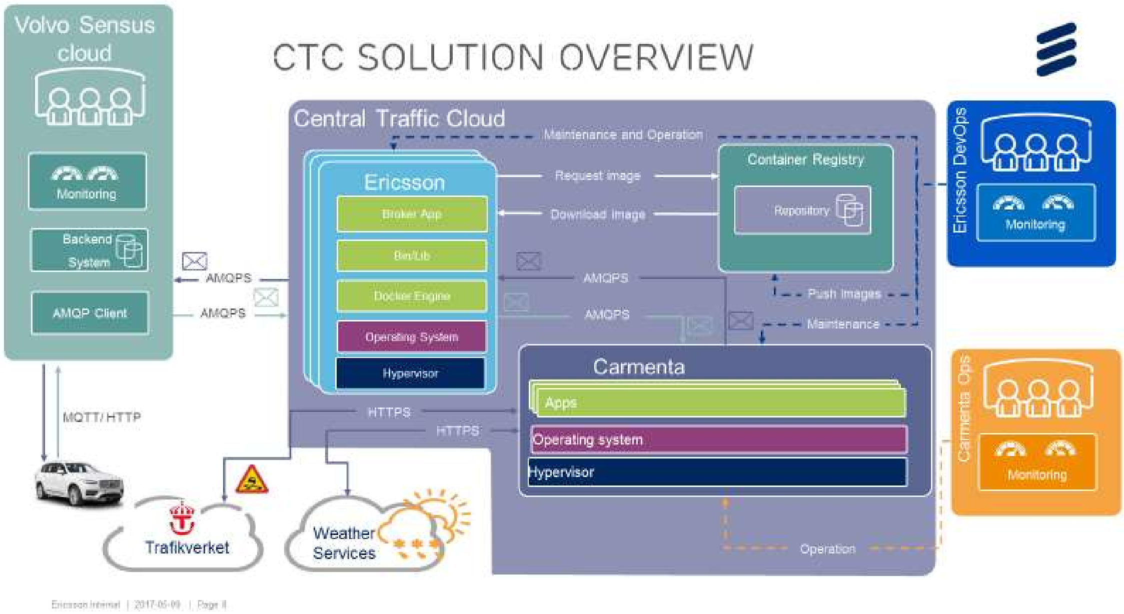


Diagram showing the overall CTC solution.

The Central Traffic Cloud backend installation consist of several components:

Broker App:

The messaging system provided by Ericsson, which provides standard APIs for partners and OEMs to exchange messages over AMQPS (SSL/TLS)[7]

Container Registry:

Ericsson container registry, is a private repository which Ericsson uses to store new container images. Docker engine and container registry are some of the tools Ericsson uses for continuous integration and deployment in the cloud. Ericsson has managed to significantly reduce integration time by applying CI/CD[8] workflow model, Ericsson is now capable of deploying multiple copies of the same instance within seconds, scale out the instance around the world to different regions such as Asia, North America within minutes

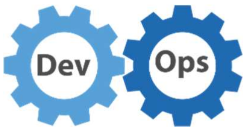
---

[7] AMQP = Advanced Message queuing protocol, SSL = Secure Socket Layer, TLS = Transport Layer Security

[8] CI = continous integration, CD = Continous delivery

Ericsson DevOps:

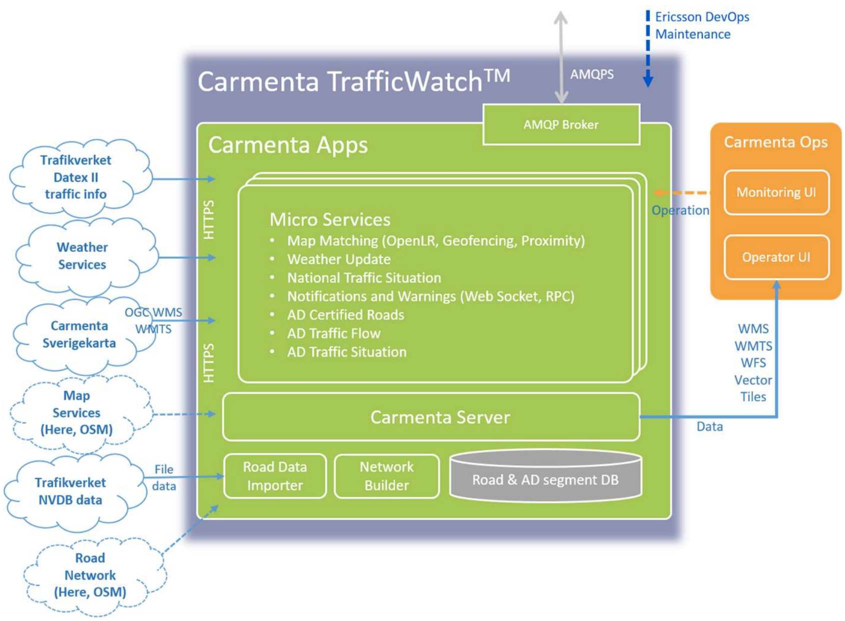
The Ericsson DevOps (=continuous development and operations) manage the monitoring of the system, builds new containers and pushes the images to container registry to make the images ready for deployment. Ericsson DevOps also monitors Carmenta´s virtual infrastructure, ensuring their system is up and running at all times.



Carmenta:

Carmenta's AD Aware CTC application is connecting to the messaging system operated by Ericsson and all communication between Ericsson and Carmenta is over AMQPS.

The figure below shows a more detailed view of the cloud components Carmenta have implemented and customized in the project. The solution is based on Carmenta TrafficWatch™, an adaptable and scalable SW platform for effective decision-making in traffic control centers[9]. Implemented and deployed as a set of services using the latest container technology it is easy to integrate in any cloud platform. Interfaces to external data providers are handled by functions in the Carmenta TrafficWatch platform and can be aggregated for use within the Innovation Cloud. An AMQP Broker component opens the secure cloud-to-cloud message communication to the Volvo Sensus Cloud through Ericsson's Interchange Services.



Detail showing the Carmenta part of the Central Traffic Cloud Solution where the AD Aware functions are implemented.

[9] http://www.carmenta.com/en/products/carmenta-trafficwatch/

Volvo Sensus cloud:

Volvo Sensus cloud connects to the messaging system over AMQPS, in order to exchange information between CTC and Volvo Sensus cloud, the information provided by CTC may be propagated via the AD traffic control to the cars over HTTP/MQTT[10]

The solution implemented in the project has worked very well as a first Proof of Concept for a CTC function and it has been very useful for initial prototyping and testing of the communication of messages and data between different parties. The project has resulted in a working AD Aware traffic control SW platform that will be very useful for further development of the Drive Sweden Innovation Cloud. Suggested future work includes the following:

- More OEMs needs to be added to the platform and integrated in the tests. Current CTC demonstrator platform has VCC as the only connected OEM.
- Tests with larger data volumes has to be performed. Only relatively small data volumes (number of AD segments, road network) has been handled in the current project
- Test in a larger geographical region has to be performed. Only a very small (Göteborg - Drive Me) operation area has been in focus for the project.
- More automated and/or semi-automated functions to dispatch AD advices needs to be added. Focus in the current project has been on interactive GUI operator tools for manual message dispatch.

D1.3. A first version of a live demonstrator with an interactive operator interface showing a dynamic map with the aggregated traffic situation picture, implemented as part of the "Innovative Cloud".

Carmenta has showcased a first version of the functionality as part of the 4 internal demos, held at Volvo Cars on the 21st of January, 28th of March, 24th of April and 8th of May 2017.

D1.4. An updated version of the demonstrator with more functions such as displaying the measured and forecasted weather picture from WP2.2 and WP 2.5, implemented as part of the "Innovative Cloud".

Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D1.5. A summarizing chapter in the final report.

Part of this document. See chapter Autonomous Traffic Monitoring

[10] MQTT=Message Queue Telemetry Transport

WP1.2 OEM Traffic Control

D1.6. Demonstration

Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D1.7. Experience report

So far the Drive Me program has not started so all of our experience from using the platform comes from our own testing. The desired feeling of the Operator GUI was that of a flight control tower. From a project research point of view the following is of interest to monitor:

- The cars real time position (displayed as a dot on the map)
- The cars real time AD-mode status (dot on the map is a different colour)
- A summarized view of the AD-route and individual road segments
- Any traffic situations that have occurred

This information, together with the AD-advice, allows us to take informed decisions about whether or not to allow AD-mode for either an individual car, a road segment or the entire route.

There is a relatively small amount of data in the platform at the moment and getting an overview is therefore a simple task. We're currently looking into how to manage getting an overview with a larger number of AD-vehicles as well as from a larger geographical area with more road segments.

D1.8. A summarizing chapter in the final report.

Part of this document. See chapter Autonomous Traffic Monitoring

WP1.3 OEM AD Approval

D1.9. A demonstration of the system in Q2 2017 showing the system functions and interacting with a limited number of running (Drive Me test) cars on public roads in Gothenburg.

Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D1.10 Part of final report incl. experiences, threat, opportunities and recommendations.

Since the Drive Me program has not started all of our experiences is from our own tests. The AD-approvals that we have granted or revoked have very much been based on the information in the platform. Specifically information about traffic situations. It will be very interesting to see the effects of the platform and the information provided during the piloting of AD-vehicles in the Drive Me program, when “the rubber hits the road” as the saying goes.

We don’t necessarily see any threats at the moment apart from that the information stops or that the platform is taken down. The Volvo Cars Operator GUI has been built with the CTC in mind and is to some extent dependent on information from it in order to function. At least, to function as well as we’d like.

We haven’t been able to test the accuracy of the road conditions based on weather information. We have a concern about whether or not that service will be able to deal with sudden changes during periods of unpredictable weather. The effect of a very local and very heavy shower of rain is something that we’d like to spare our Drive Me participants experiencing. Not necessarily because we believe that the car can’t handle it but simply because it might not be a pleasant experience. There will be a period of adjusting these types of boundary conditions but regardless we will require a very accurate forecast in order to utilize the information in a good way.

Additional sources for weather information can be added in the future. One example is local measurement of rain by monitoring the signals in radio links connecting mobile telephony masts. SMHI collects this information from 3´s network in Gothenburg[11] in collaboration with Ericsson

There are plenty of opportunities for the information in the platform to be used in all connected cars, not only AD-vehicles. This is part of an ongoing discussion internally at Volvo Cars where we can see large benefits for traffic management if more cars share their sensor data. This is however not entirely straight forward since we have the GDPR legislation to take into account. We’re currently investigating if and how we can share data from the Volvo Cars cloud.

Our recommendation is to continue to build on top of the platform, to add both more functionality and more content. We at Volvo Cars will continue to build on our part and will test it in the Drive Me program and we would very much like to continue the cooperation with the other project members.

[11] https://www.smhi.se/om-webbplatsen/om-smhi-se-lab/microweather-livedata/

WP 2 Collaborative Road Weather Service

WP2.1 Road Weather Service

D2.1. Report with findings, lessons learned and recommendations.

This document.

D2.2. Description of used and proposed interfaces and the flow of information.

We have successfully built a flexible and an open message-based infrastructure, based on AMQP 1.0 for the AD Aware CTC platform. The infrastructure provides OEM's and partners an API framework to easily integrate and build robust, cross platform, messaging applications to exchange business messages between the different parties.

Ericsson can be seen as the container of the communication medium, between the different parties, as a result Ericsson has concentrated on providing a reliable broker solution based on QPID C++ in CTC.

Security has been one of the main focus throughout the project, Ericsson has implemented AMQPS (SSL/TLS encryption) in the broker, meaning all business messages traversing the internet between OEMs and CTC are highly encrypted with SSL/TLS. Mutual authentication is also another level of security perimeter which we have implemented in CTC, in order to use the APIs available, mutual authentication is required. Each party will be supplied a username, strong password and a certificate for authentication, this is to prevent attacker from successfully impersonating OEMs. Despite these security perimeters in place, we have also adopted ACLs (Access Control List) this is a level of security within the broker system to protect the OEMs messages from being read by unauthorized parties.

The AD Aware CTC platform has adopted the client-server model, for example one OEM transmits a message on a specific queue which they have permission to publish on, to CTC. CTC will read and internally process the message, in response to the OEMs request, CTC will transmit a reply message on a separate queue which the OEM have only read permission.

Ericsson have defined 9 APIs (queue) for AD Aware CTC, were Weather and VolvoWeather is specifically used for weather services:

- Roads
- VolvoRoads
- Situations
- Situation-Alert
- Prio-Alerts
- Data
- DataReturn
- Weather
- VolvoWeather

The Weather queue, allows Volvo to query CTC for certain weather data for a particular road section, while VolvoWeather is primarily used for CTC to respond with the required data queried by Volvo.

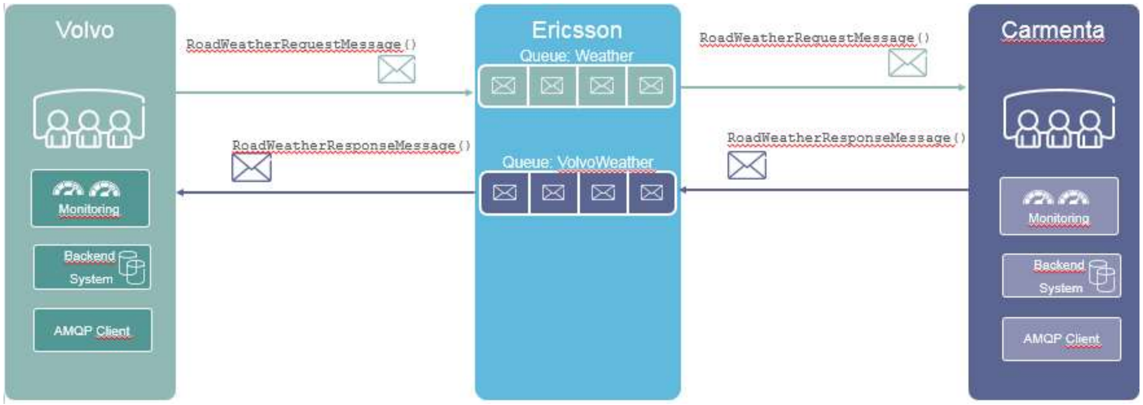


Illustration the broker setup for weather service.

D2.3. A first version of a live demonstrator implemented as part of the "Innovative Cloud".

Showcased as part of the 4 internal demos, held at Volvo Cars on the 21st of January, 28th of March, 24th of April and 8th of May 2017.

D2.4. An updated version of the demonstrator with more functions implemented as part of the "Innovative Cloud".

Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D2.5. A summarizing chapter in the final report.

Part of this report. See chapter Collaborative Road Weather Service

WP2.2 Measured weather data provision

D2.6. Report with findings, lessons learned and recommendations.

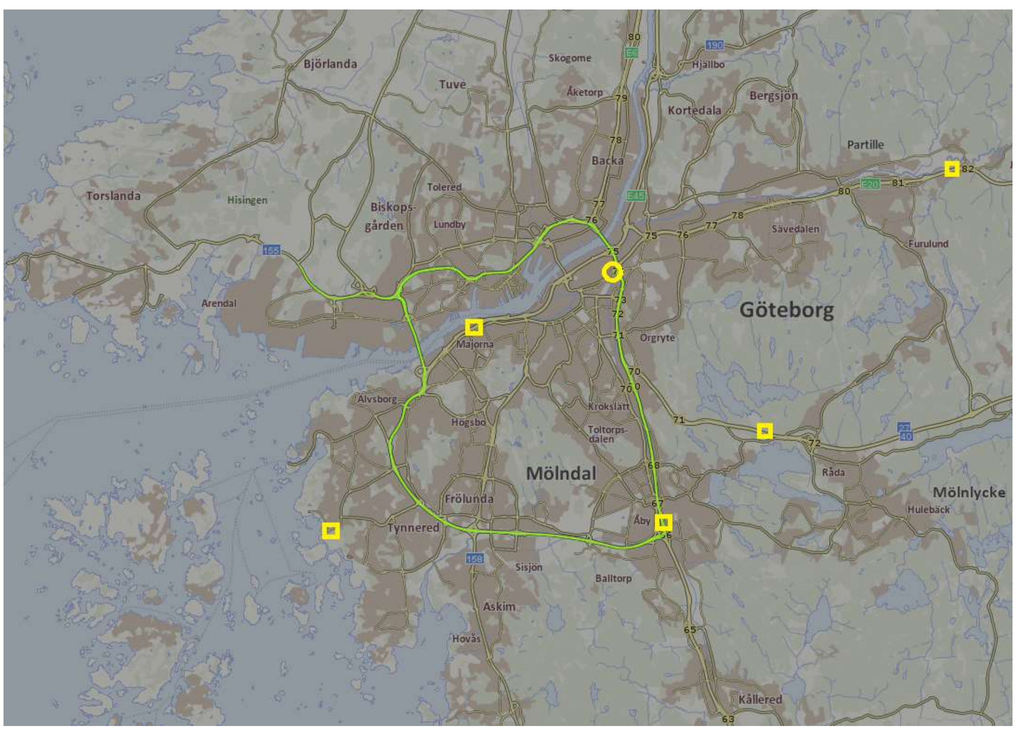
This document.

D2.7. Description of used and proposed interfaces, query API's and the flow of information.

In this section we give a short background and describe how weather data has been integrated and used in the CTC. We have chosen to describe the result from both work package 2.2, the "Measured weather data provision", and work package 2.5, "Forecasted weather data provision" in this section as used interfaces, query API's and flow of information are basically the same for both observed and forecasted weather.

It is important to state that this project has focused entirely on establishing the technical framework for connecting to external weather data providers and integrating the meteorological information in the running data flow as well as in the traffic operators situation picture. The validation of the actual data quality and usefulness for AD vehicle operation is subject to extended trials.

In Sweden measured weather data is collected by two national ground-based systems of observation stations. One is VViS (VägVäderInformationsSystem) run by Trafikverket and dedicated to measure weather conditions on major roads. The VViS stations are placed where extreme weather is likely to occur and isn't representative for the road network in general. The other observation system is run by SMHI and collects general weather information. The total number of stations is relatively few and also unevenly distributed over the country. The figure below shows the distribution of weather observation stations in the Gothenburg area.



Map over the Gothenburg (Drive Me) area showing the location of VViS weather observation stations (squares) and SMHI's observation station (circle).

Between the stations no data is available so interpolation through different meteorological models has to be used to estimate weather values for any given point in an area. The uncertainty of the estimation grows with the distance from the stations and local variations are often missed. Furthermore relatively few stations are located in urban environments, as seen in the figure above, making it even harder to predict the local weather where the traffic intensity is highest.

Detailed knowledge about the current weather situation is also important to make good weather forecasts. Observations from the weather stations are then combined with data collected from satellites, radars, weather balloons, airplanes and ships and loaded as start values for the forecast modelling. Long-term forecasting depends on running sophisticated numerical weather prediction (NWP) models to predict how the weather situation is going to evolve over larger regions and in a longer time perspective. NWP models are not suitable to forecast weather on a very short term period of up to 2 – 4 hours most relevant for AD operations. Nowcasting is a term often used to describe weather forecasting in this short time frame, i.e. more or less an extrapolation in time of measured weather parameters.

Weather agencies and companies compete in applying their own methods to refine the predictions to make more detailed forecasts based on their expertise taking into account things like topographic variations, differences in vegetation, sun exposure and shading etc.

Weather-related effects on AD vehicle operation are obviously connected to the very local road environment and safety issues involve how slippery the road is due to rain, snow and ice. Other safety issues include how visibility is influenced by fog or heavy rain and snowfall. Strong and gusty winds can also affect the safe operation of AD vehicles, especially for larger vehicles. All these weather-related effects are both measured and can be forecasted but the problem is to make them detailed enough in time and space to be useful for a traffic control center when guiding the AD operation or issue warnings to avoid dangerous road paths caused by severe weather.

It is a common understanding, when discussing the issue with the weather data providers that more detailed, de-facto and up-do-date data, preferably sourced from vehicle-mounted sensors is key to make a production-ready weather forecasting service for AD vehicle operation.

We have established an up-and-running technical solution for integrating real-time weather data including weather forecasts in the AD Aware CTC. Several external weather data providers have been screened and evaluated with the aim to find a viable solution for sufficiently detailed and qualitatively relevant weather data supporting AD vehicle operations. A common weather data interface using the message-based infrastructure described above (WP2.1 Road Weather Service) for AD Aware traffic control is delivered as part of the AD Aware CTC platform. Internally this is developed as a micro service, loosely coupled and agnostic to the sourced data.

A technical proof-of-concept implementation of a weather situation picture has been developed based on weather data aggregated from the selected providers, primarily from Foreca who has offered a trial service specifically designed to publish road condition data.

The weather data is potentially an important contribution to the Traffic Operators overall situation perception. Automatic functions have also been added to map the provided weather data to parts of the road network down to individual road segments. The built-in warning service extends this function to detect and trigger notifications when thresholds for "severe weather" are exceeded. This information can then be passed on to OEMs to allow or revoke AD driving in real time for their vehicles.

External query API's in general provides weather predictions and forecast values for a number of parameters connected to geographical points. In the AD Aware CTC these points are automatically map matched to the nearest AD certified road segment and then its values are made representative for that part of the road network. Obviously the amount and distribution of forecast points in relation to the road network have a large effect to which level of detail the roads can be monitored.

Potentially useful on-line sources for building the AD aware weather picture were identified, approached and evaluated in the first phases of the project. The inventory included meteorological data from a number of institutes and companies but the selection for subsequent testing was narrowed down to on-line services made available from the **Swedish Hydrological and Meteorological Institute (SMHI)** and **Foreca**. Furthermore some initial integration tests were also done on road surface condition data provided as part of the **Road Status Information** (RSI) demonstrator project.

Below these providers and their contributions to the project is briefly described.

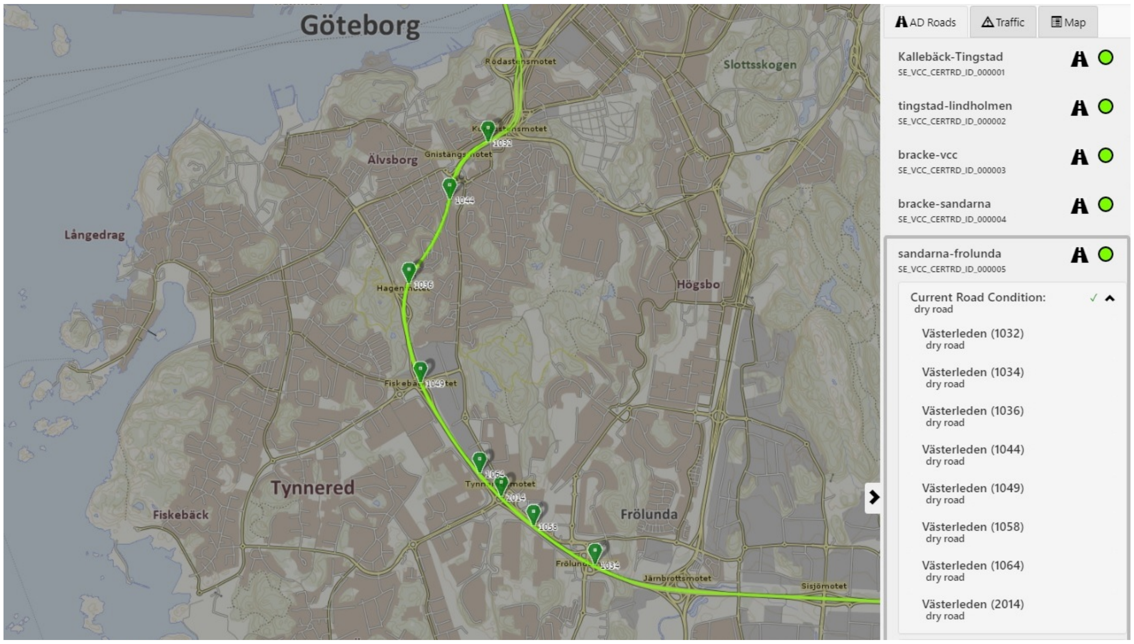
Trafikverket's open dynamic traffic information service provides weather measurement data collected in real time through VVIS and this data has also been integrated in the measured weather provision solution and tested in the project.

Foreca[12] is a provider of digital weather data with a product and service portfolio utilizing the latest technology and the most accurate weather forecast models available. The company can specifically provide road weather data as full-scale digital weather services everywhere in the world. The services can also be custom designed to be used in navigation and automotive applications. Through the combination of atmospheric weather forecasts with radar and 2nd generation satellite data enabled Nowcasting techniques ensures high data accuracy for demanding users. The Foreca road weather services are also prepared to supports incoming 3rd party vehicle sensor data where and when available.

An on-demand weather forecast service was established in the CTC using Foreca's NaviFeed API that delivers quality weather forecasts to every coordinate point or route in the world. The interface can provide hyper-local forecasts and is suitable for integrating weather conditions into a wide range of applications. The forecasts can be asked by coordinate or by location name and in the interface used for trials we used the coordinate API. All commonly used weather parameters are available and road parameters can be added according to Foreca.

A custom road weather data provision interface was tailored by Foreca and was used and integrated in the AD Aware CTC demonstrator. Together with experts from Foreca we defined a set of forecast points to be used to specifically monitor the AD segments part of the Drive Me tests. To cover the area, 77 evenly distributed points along the path were selected and used in the weather hazard warning service. Each forecast point is specified as either "road" or "bridge" and Carmenta's map matching service couples the forecasts into the AD certified road network by choosing the nearest forecast point for each road segment, taking into the account if the segment part is a bridge or a regular road.

[12] http://corporate.foreca.com/se/



Screen dump from the CTC operator GUI showing the forecasting points for a selected AD certified road segment. Symbol color reflects the forecasted road condition for selected time period.

The following forecast values are provided in the service. It is updated every 15 minutes with 15 minutes forecast intervals for the next 2 hours and 1 hour time-steps for 36 hours.

- AIRTEMP: air temperature at 2m height over the surface (Degrees Celsius)
- DEWPOINT: dew point temperature (can also be used to compute relative humidity, if needed)
- ROADTEMP: road surface temperature
- ROADWATER: thickness of water film on road, in mm
- ROADSNOW: thickness of snow cover on road, in cm
- RAINFALL: forecast intensity of liquid rain, in mm/h (instant, not accumulated)
- SNOWFALL: forecast intensity of solid precipitation, expressed as liquid water equivalent (LWE) mm/h (close to cm/h of snow)
- FRICTION: friction coefficient, often values above 0.7 indicate good friction (dry road =~ 0.8) and values below 0.6 indicate bad friction
- RCCODE: road condition code representing a classification of road conditions in some 50+ categories.

Among the tested weather data providers, Foreca could offer the most complete road conditions service with best coverage and was therefore chosen as the primary data source for testing meteorological data flow as well as the hazardous road warning service.

SMHI, the Swedish Meteorological and Hydrological Institute[13], is an expert agency under the Swedish Ministry of the Environment and Energy. The agency's mission is to; "Through expertise in meteorology, hydrology, oceanography and climatology, SMHI contribute towards greater public welfare, increased safety and a sustainable society".

[13] https://www.smhi.se/omsmhi

SMHI makes forecasts, produces decision guidance for the community and follows up climate and environmental development. SMHI's operations run around the clock every day of the year. Warnings in the event of extreme weather events are an important task.

SMHI provides a wide range of forecasting and professional services that can be tailored to the needs of different users. For test and demonstration purposes SMHI allowed the AD Aware Traffic Control project to connect to a custom web service publishing road condition forecasts. This service publish updated forecasts for the 3 weather measurements stations part of the VVIS network closest to the Drive Me test road. SMHI states that too much uncertainty makes it very difficult to make forecasts for any other points in the area and that a contribution of real-time road condition measurements from vehicles such as AD cars would be very useful for improving the ability to provide detailed forecasts.

We have added an up-and-running service using downloaded road condition data for the 3 forecast points where the map matching service choose the closest of these points for each road segment. We have also done some initial testing of road surface data from the RSI demonstrator project and it is integrated in the data flow as a potential source of real-time information about road conditions. More testing is needed to verify the usefulness the SMHI data for AD vehicle operation.

The RSI demonstrator project[14] is an initiative aimed at making winter road maintenance more effective. Representatives for the project describes RSI as follows; *"RSI stands for Road Status Information and is a new type of service where a number of different sources of information work together to make current road maintenance more efficient. In order to assess future road surface conditions and relevant measures Trafikverket and its subcontractors now use weather services with forecast, satellite and radar pictures together with RWIS (Road Weather Information System)"* (http://www.roadstatus.info/about-rsi/).

The RSI project has resulted in a demonstrator where a number of sources of information has been integrated and used, including 'Floating Car Data', i.e. digital car information which has been 'depersonalized' and gives data such as friction, temperature and more. The data are assessed in a climate model and processed in a climate interpreter, which takes into account all accessible information, both in a real-time and in a prognosis mode.

We have done some initial testing of road surface data from the RSI demonstrator project and it is integrated in the data flow as a potential source of real-time information about road conditions. More testing must be done to make any conclusions on the usefulness of the RSI data in a central traffic control situation.

D2.8. Demonstrator of a Weather Data Provision Service answering queries about road weather conditions and implemented as part of the "Innovative Cloud".
Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D2.9. A Weather Data Visualization Service providing an aggregated weather situation picture for integration with the Central Traffic Control user interface in WP1.1.
See D2.7 *Description of used and proposed interfaces, query API's and the flow of information* in WP2.2 *Measured weather data provision*.

[14] http://www.roadstatus.info/about-rsi/

D2.10. A summarizing chapter in the final report.

Part of this report. See chapter Collaborative Road Weather Service

WP2.3 OEM weather based approval

The implementation of this work package has been delayed due to ongoing internal discussions about whether to use an existing weather service that is available for Volvo Cars. Also, since the CTC's AD-advise contains weather information the effects that were sought can be realized anyway.

We are evaluating how to proceed but this discussion is also linked to the deliverables in WP 2.4 OEM Measurement Collection (see below) since they are, at least to some extent, different sides of the same issue.

D2.11. Demonstrate in AD test vehicle on real road.

N/A see above.

D2.12. Experience report.

N/A see above.

D2.13. A summarizing chapter in the final report.

N/A see above.

WP2.4 OEM measurement collection

The implementation of this work package has been delayed due to ongoing internal discussions about how the GDPR legislation affects our possibility to share data with others.

D2.14. Plan and execute a demonstration of the system in Q2 2017 showing system function and interacting with a limited number of running (Drive Me test-) cars on public roads in Gothenburg.
N/A see above.

D2.15.Create a public report at the end of the project documenting experiences, threat, opportunities and recommendations.
N/A see above.

WP2.5 Forecast weather data provision

D2.16. Report with findings, lessons learned and recommendations.

This document.

D2.17. Description of used and proposed interfaces, query API's and the flow of information.

See D2.7 *Description of used and proposed interfaces, query API's and the flow of information* in WP2.2 *Measured weather data provision*.

D2.18. Demonstrator of a Forecast Weather Data Provision Service answering queries about forecasted weather conditions and implemented as part of the "Innovative Cloud".

Part of the public demo at Lindholmen Science Park on the 27th of June 2017.

D2.19. A Forecast Weather Data Visualization Service providing an aggregated weather forecast picture for integration with the Central Traffic Control user interface in WP1.1.

See D2.7 *Description of used and proposed interfaces, query API's and the flow of information* in WP2.2 *Measured weather data provision*.

D2.20. A summarizing chapter in the final report.

Part of this report. See chapter Collaborative Road Weather Service

WP 3 Pre-study for Authority Interfaces

The global trend of digitalization opens new opportunities for road authorities to improve their services and reduce the negative external effects of traffic. In order to prepare for the development and to gain some first insights in future potential roles of road authorities and cities, a workshop was organised to initiate discussions. The setup and the results from the workshop are presented in Appendix B - PM: Pre-study for Authority Interfaces. Key findings and recommendations indicate that need for developing business models related to the exchange of data between different actors is crucial to support the development of new services.

Road authorities can benefit from the exchange of data both as service providers and as managers and operators of infrastructure and from a city perspective the technological development will enable more efficient street designs.

WP3.1 Road Authority Interface

D3.1. Report with findings and recommendation.

See Appendix B - PM: Pre-study for Authority Interfaces.

D3.2. Description of proposed interface and flow of information including list of in- and out signals (information content).

<u>Current situation</u>

As most of the stakeholders in this eco-system, the road authorities will be both producers of data and consumers of data. In the short term the DATEX-interface will be the major real-time channel both for publishing data from the road authorities and for receiving data coming from external actors as Volvo Cars. Although it is important to have in mind that already today Trafikverket and other actors also publish data via their own API's. Trafikverket also receives data from external actors using their API's.

Static data like road attributes and traffic regulations, is currently available via a public interface called "Lastkajen". Updates of static data are also available via an interface based on a European cooperation called TN-ITS.

<u>Data published from Trafikverket</u>

DATEX (push and pull):

- Travel times (Stockholm, Göteborg, Malmö)
- Accident
- EmergencyInfo
- Ferries
- RestAreas
- TrafficMessages,
- RoadWorks
- RoadCondition
- RoadConditionStatus
- FrostDamage
- TruckParking
- RestAreaStatus

- Weather

Also TrafficFlowCameras and RoadConditionCameras are available via DATEX.

Extensions with current speed per minute and current number of vehicles per minute will be available in September. Also extensions with the information available on Variable Message Signs (e.g. temporary speed limits per lane, closed lane, etc.) will be available. Traffic Management Plans via DATEX has been tested in other countries and is of great interest to provide in the future. Road attributes and traffic regulations from Lastkajen and the TN-ITS interface.

Data that could be of interest to receive from Volvo Cars in the Drive Me pilot trial:

- Safe stops – when and where
- Number of vehicles per road segment driving in AD-mode / not driving in AD-mode
- Road-segments currently allowed for AD
- Accident- and incident reports
- Queue-reports

General data elements of interest include:

- Position (along the road and lateral)
- Speed
- Heading
- Acceleration
- Emissions
- Distance/Time gap to vehicle in front and behind
- ABS/ESC status
- Road surface status
- Wiper on/off
- Headlight on/off
- Ambient temperature
- Visibility
- Hazard alert on
- Destination
- Route choice
- Broken vehicle warning
- Traffic jam warning

Possible future scenario for data exchange and traffic management

Potentially all data sourced by Trafikverket, which is not classified, could be published and available for external actors, static data, real time data and statistical data. Trafikverket will also promote the exchange of open data in Sweden. The EU-commission urges the member states to establish National Access Points for data, an access point can potentially be further developed towards a more advanced data exchange platform for open data.

Future traffic management will need a strong cooperation between public and private actors. Several initiatives like TM2.0, C-ITS platform and Socrates2 are working in this direction. What can be called as a Common Operational Picture is needed to inform vehicles and travellers in a harmonized and coordinated way. Also policies and agreements on how to manage traffic should be transparent and available for all actors. The Central Traffic Control established in this project enables a common operational picture and is a promising way to implement the needed cooperation between public and private actors. However, how to operate and finance a Central Traffic Control remains to be investigated.

D3.3. Chapter in final report.

Part of this report. See chapter Authority Interfaces

WP3.2 City Interface

D3.4. Description of proposed interface and flow of information including list of in- and out signals (information content).

See D3.2

D3.5. Chapter in final report, incl. findings and recommendation.

Part of this report. See chapter Authority Interfaces

Appendix B - PM: Pre-study for Authority Interfaces

This PM is a deliverable within work package 3, Road Authority Interface, a part of the strategic innovation project “AD Aware Traffic Control”, funded by the Swedish innovation agency Vinnova. The aim with the activities in this work package is to increase knowledge on the potential benefits, the needs and the requirements for information flow between a traffic cloud and a road authority. This will result in first insights of what potential roles cities and other road authorities can and should take in relation to external actors when it comes to information flows and control in a future with connected and increasingly automated vehicles.

Background

Modern vehicles are increasingly becoming connected to OEM-cloud solutions and the onboard sensors and the sensor fusion becomes more and more advanced. At the same time, there is a global trend of digitalization that eventually will enable new mobility services to emerge. Through the exchange of information between different actors, there will be a multitude of progress for society, industry and individuals to benefit from.

For the development of new services, there will be a need for existing and new mobility actors to find new ways of co-operation. This will allow for the take up of new business models.

To start discussing what the future will hold, key actors including representatives from City of Gothenburg, National Road Administration, Volvo Cars and Carmenta, were invited to a workshop on the 20th of April 2017. The focus of the workshop was to identify benefits resulting from increasingly connected and automated vehicles and what services that will be needed to achieve them. In total, there were about 15 participants at the workshop.

Scope

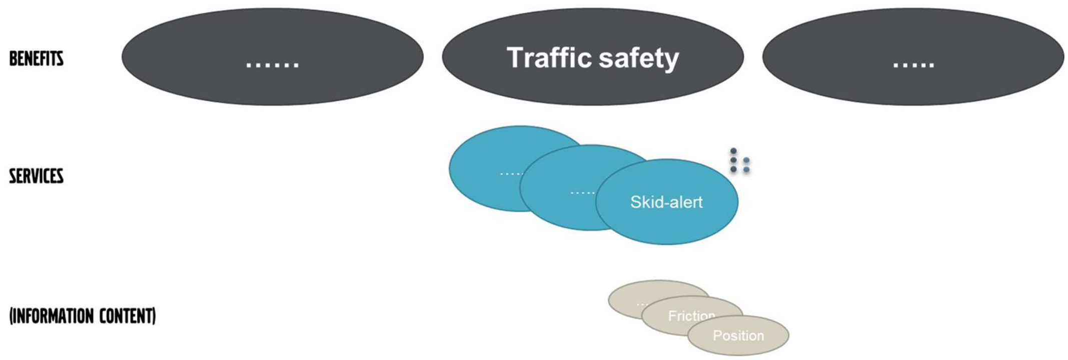
The development of self-driving technologies is currently running at a fast pace. It is highly likely that in five years there will be vehicles on the market with limited level 4 functionality (level of automation per SAE standards). At the same time many experts believe that it will take a long time before fully automated vehicles, that will be able to operate almost everywhere under almost any weather conditions, will be introduced (level 5).

Running in parallel with the development of autonomous vehicles is the development of LTE and 5G mobile communication technology also with short range AD-hoc modes as well as ITS G5 5.9 GHz V2X short range communication. Already today many vehicles sold are connected to an OEM cloud solution. This means that there are already many vehicles in the market that can be used to exchange information between OEM’s and road authorities.

Taking this into account the workshop focused on identifying solutions based on an increased number of connected vehicles as well as the development of autonomous vehicles (level 4 and up).

Method

Services and benefits were identified using a conceptual framework as shown in figure 1.



Conceptual framework used for discussion

The discussions followed a top-down structure starting with identifying benefits before going on with services. Identifying information content was left out due to restrictions in time and format of the workshop. Finally, the identified services were ranked based on attractiveness and actualization, thus resulting in a list of desirable future project ideas.

The workshop was split in three parts; identifying benefits, identifying services and ranking of services.

For the first part, a combination of brainstorming and clustering techniques resulted in a set of benefits, including societal, individual and other benefits. In total, there were 73 ideas generated that were clustered in to 12 segments.

For the second part, the participants chose five segments to continue work with. Different supporting services were discussed in a “fish-bowl format”. This format means that the group was split in two halves. One half started with an open group discussion focusing on one segment and the other half sat silent and listened. Then the groups changed roles, and the discussion took up where the first group left it. Finally, the whole group joined the discussion. In total 39 services were identified.

For the third part, each participant was given three votes to vote for the attractiveness of the identified services and another three votes to vote for the actualization of the services. There was no limit in how many votes a participant could use on one service. Even though there were 39 services to choose from there were some services that were more attractive and easily actuated than others.

Benefits from increasingly connected and automated vehicles

The first part of the workshop, brainstorming benefits, generated 73 ideas which were clustered in to 12 segments as shown below.

Segment	No of ideas
Improved Traffic performance	13
Enhanced data collections	10
Improved Traffic safety	7
Prioritized accessibility	7
Increased accessibility	7
Enhanced traffic information	6
Reduced local emissions	6
Enhanced traffic optimization	5
Improved mobility services	4
Energy efficiency	3
New traffic planning prerequisites	3
Increased individual needs	2

Identified benefits from the workshop

As the table shows most ideas generated were clustered into the segments of traffic performance and data collection. Ideas within traffic performance were often coupled to intelligent connected traffic signals in combination with connected cars. Also, some ideas about optimized traffic flows through optimal routing were discussed. When it comes to data collection the discussions were about big data opportunities, using cars as probes and new types of real time information that could be possible, for instance air quality.

Using geofencing as a tool was a use case discussed that would fit into several segments. The ability to control speed and powertrain would probably benefit several different segments, e.g. traffic safety, local emission and traffic performance.

From a road authority perspective, using vehicles as probe to enhance maintenance and operations are of great interest. Discussions ranged from the use of static data, to update geometry, to the use of dynamic data to manage traffic.

Services to support identified benefits

Five segments out of twelve were chosen by the participants to continue working with. For each of the chosen segments supporting services were derived using the “fish-bowl” method.

In total, 39 services were derived as shown below.

Segment	No of services
Enhanced Traffic Information	9
Improved Traffic Performance	9
Energy efficiency	9
Improved Traffic Safety	8
Increased accessibility	4

Services supporting the ideated benefits.

As was the case with ideating benefits, several services are applicable in many segments.

Many services discussed were coupled to Traffic control and dynamic road usage. One conclusion was that the use of dynamic information is the key to produce more advanced services that will provide new benefits.

There was also an interesting discussion about how data should be enabled and distributed. Suggested services include digital market place for data and the use of raw-data. There is clearly a need for developing business models that facilitate the interchange of data between involved actors.

A more dynamic use of streets is of great interest to cities due to space scarcity. This is not only limited to traffic efficiency through dynamic routing but also allowing for mixed use of city streets depending on demand. Today cities offer different kinds of services except for just providing the infrastructure. Parking is one such example where connected vehicles open up new opportunities.

Ranking of attractiveness and actualization of services

The final part of the workshop was to identify which services were seen as attractive to develop and which are easy to actuate, a.k.a. "low-hanging fruits". The top ten results from the voting procedure, ranked by ease of actualization, are shown below.

Service	Ease of Actualization	Attractiveness
Steady speed by AD	6	1
Traffic signal control	4	0
Digital marketplace for data	3	0
Electronic signage	3	0
Gamification of driving behaviour	2	3
Convoys	2	1
Topography	2	0
Real time information	1	3
Virtual speed bumps	1	2
Accident information	1	1

Top ten services ranked by ease of actualization.

Many people believe that the increasing share of autonomous vehicles will make it easy to pace the traffic flow in the future. Pacing of the traffic flow is expected to bring several benefits, including increase traffic safety, less local emissions, better throughput etc.

Developing traffic signal controls is also considered as a "low-hanging fruit". This can be achieved with an increasing number of connected vehicles and is also seen as a must-do to promote the development of autonomous vehicles.

Obviously, a digital marketplace for data is almost a prerequisite for developing new services and it is also considered as easy to actuate.

When the result is ranked by attractiveness the result is a bit different as shown below.

Service	Attractiveness	Ease of Actualization
Gamification of driving behaviour	3	2
Real time information	3	1
Virtual speed bumps	2	1
Route/congestion information	2	0
More dynamic traffic control	2	0
Traffic management controling traffic	2	0
Level of service	2	0
AD vehicles enables dynamic PT	2	0
Steady speed by AD	1	6
Convoys	1	2

Top ten services ranked by attractiveness.

Gamification of driving behaviour was voted most popular and it is also thought as rather easy to implement. Various types of real time information applications is also popular.

Findings and recommendations

The exchange of data between different actors is key to almost all development of new services. This is not just a technical question but relates very much to business models, roles and responsibilities. This is not an easy task but it is essential that actors take initiatives to push the development forward since there are so many potential benefits to gain. If data is related to personal information there is obviously also need to find efficient solutions that respects the privacy of individuals.

Road authorities can benefit from both services provided to the public and the way the infrastructure is managed and operated. There are numerous services ranging from static/slow data, like geodata, to highly dynamic data that are of value. For instance, geofencing technologies can be used to limit the negative external effects of traffic, e.g. noise, emissions and accidents.

For city planning, the technological development makes it possible to come up with more space efficient designs. The use of a more dynamic data exchange will allow for more mixed use of city streets, both in time and space. In the future, it will also be possible to implement dynamic regulations of traffic. This means that a typical city street can be used for different purposes during the day or depending on the circumstances.

Appendix C – DATEX II schemas

This appendix shows some of the resulting UML schemas for the messages modelled from DATEX II and used in the project.

DATEX II (TS 16157 1-3)[15] is the acknowledged European technical specification for modelling and exchanging ITS-related information between different parties and it provides a standardized way of communicating and exchanging traffic information. It has a huge but well-structured data model, currently mapped to XML schema as the exchange message syntax.

DATEX II has built-in flexibility and a well-defined set of rules for users to extend the model to suit local application needs. It is also possible to select only those elements for schema creation that are actually used in specific services.

DATEX II is developed and maintained under the umbrella of the EasyWay[16] project and is supported by the European Commission.

In the schemas below standard DATEX II objects are pictured as gray boxes and AD extensions is shown as white and light green boxes.

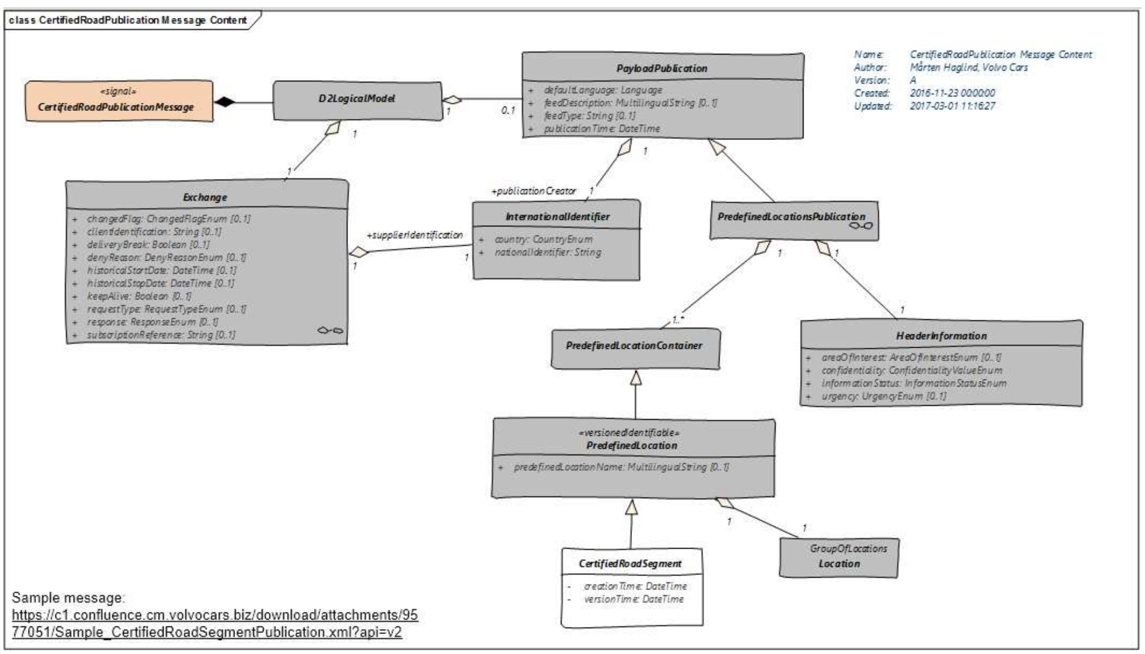


Diagram showing the data model for the CertifiedRoadPublication message.

[15] http://www.datex2.eu/sites/www.datex2.eu/files/Datex_Brochure_2011.pdf

[16] https://www.its-platform.eu/highlights/easyway-programme-2007-2020-and-its-projects

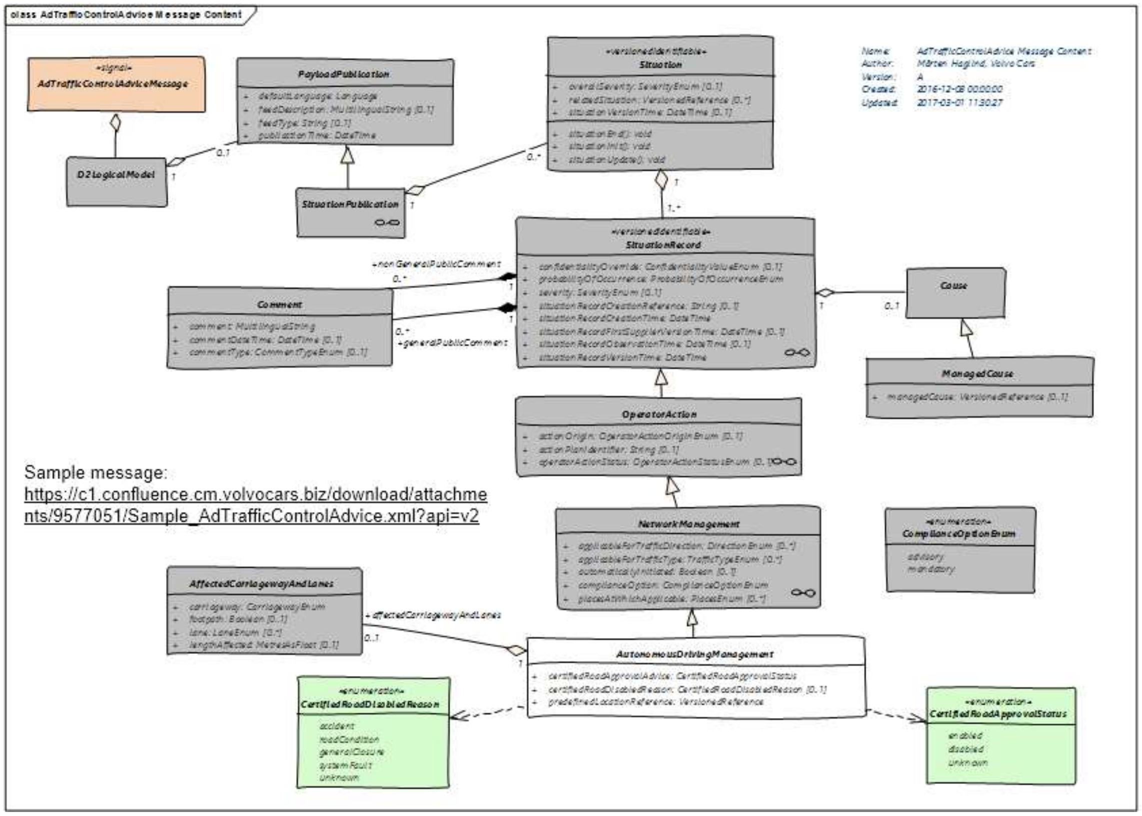


Diagram showing the data model for the AdTrafficControlAdvice message.

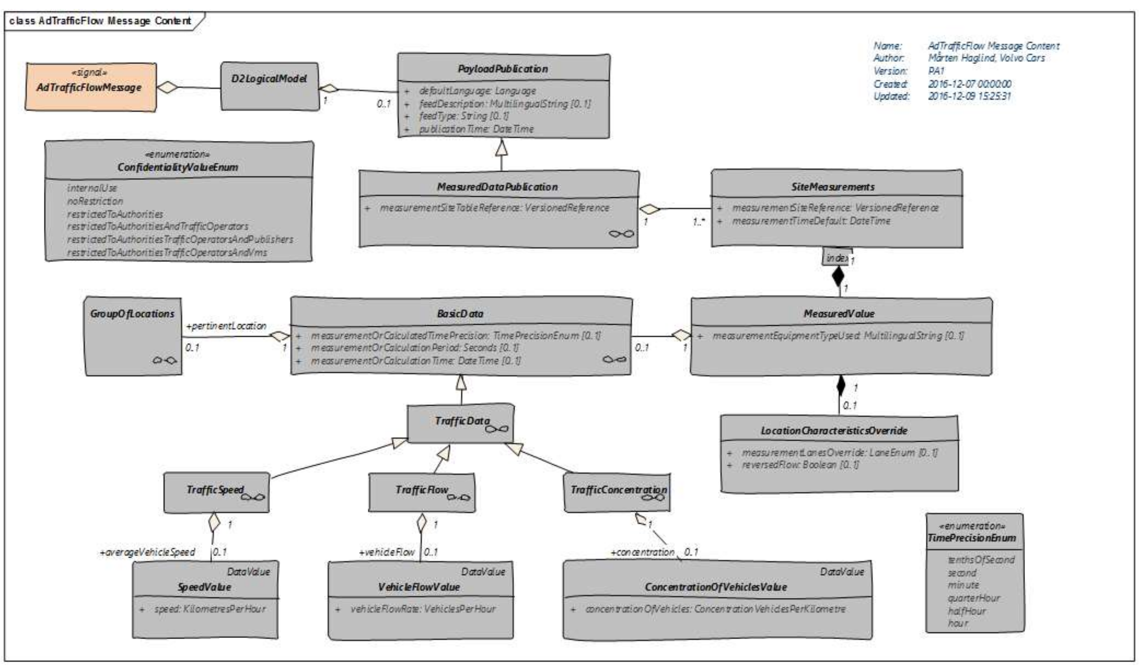


Diagram showing the data model for the AdTrafficFLow message.

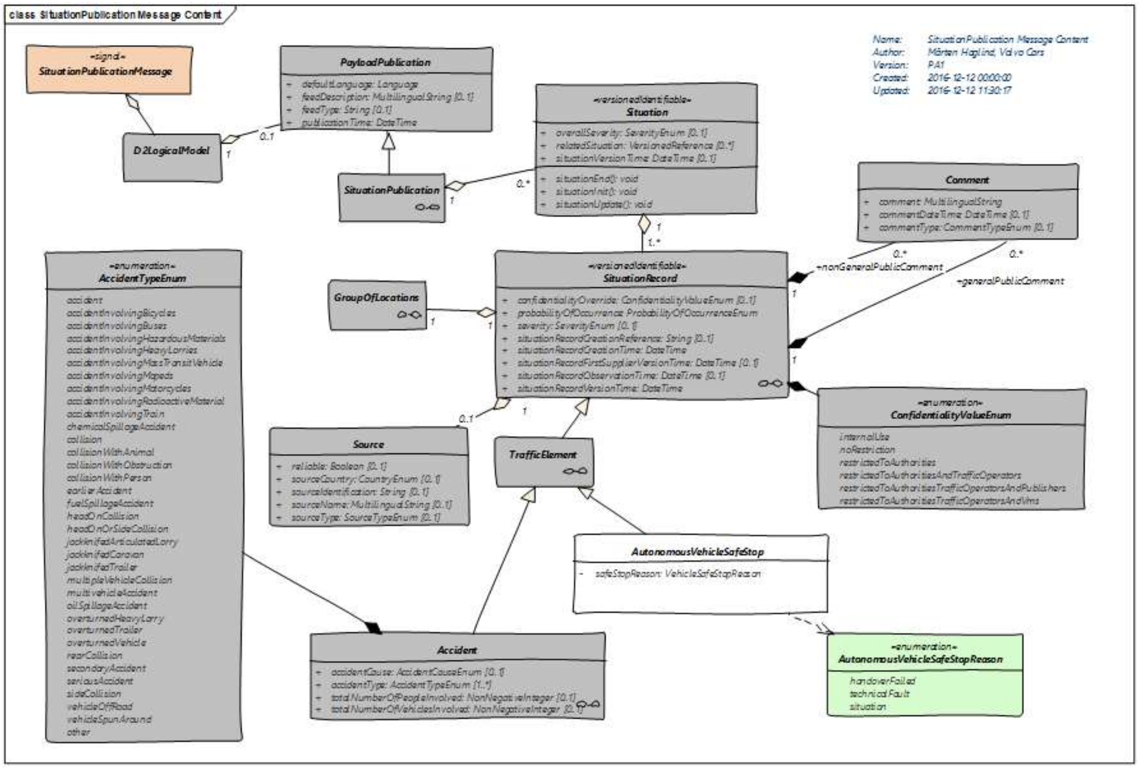


Diagram showing the data model for the SituationPublication message used to exchange AD safe stop information.

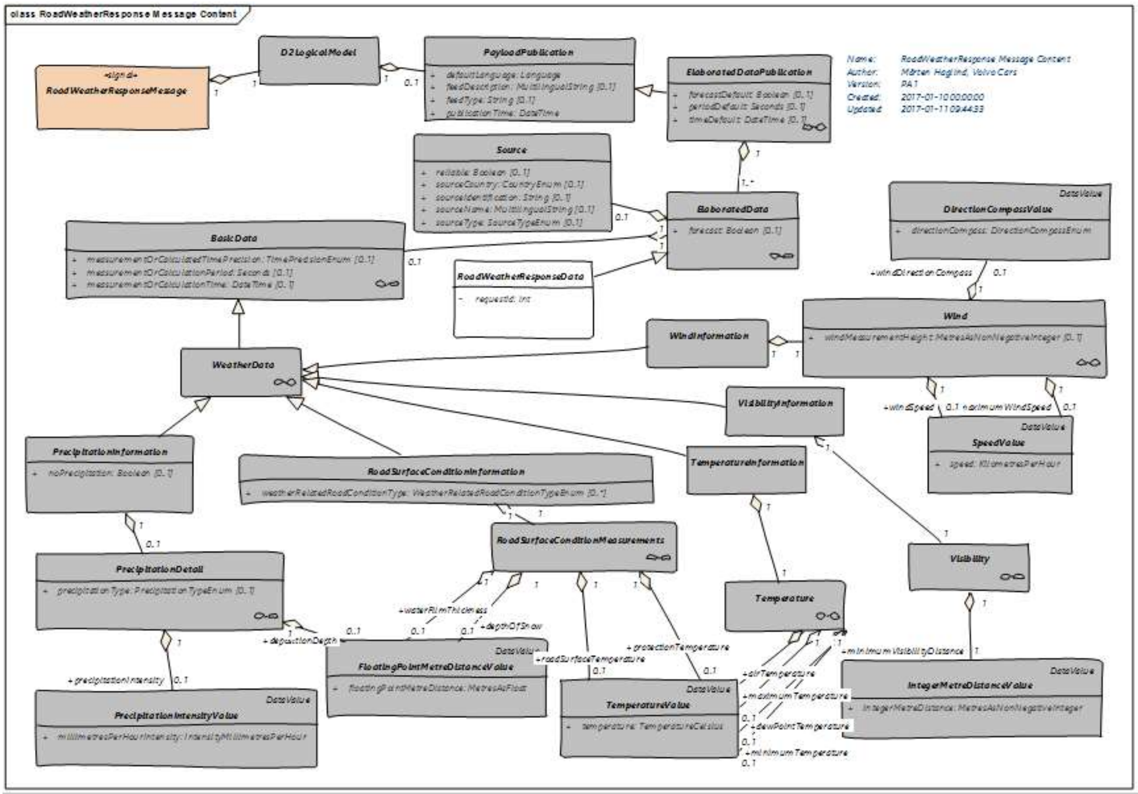


Diagram showing the data model for the RoadWeatherResponse message used to exchange road weather information.

Report part B: Autonomous Drive Aware Traffic Control Emergency Vehicle Information December 2018

Version History

V0.1 20181026	First skeleton	Anders Fagerholt, Ericsson
V0.2 20181101	Added general descriptions	Anders Fagerholt, Ericsson
V0.3 20181127	Added Volvo Cars parts	Mattias Bernson, Volvo Cars
V0.3 20181128	Added SOS-alarm parts	Louise Brask, SOS-Alarm
V0.4 20181129	Added Carmenta parts	Mikael Gråsjö, Carmenta
V0.5 20181203	Added draft of RISE parts	Azra Habibovic, RISE
V0.6 20181213	Updated Ericsson parts	Anders Fagerholt, Vijay Lyengar Ericsson
V0.7 20181214	Polished Carmeta parts Polished the document	Mikael Gråsjö, Carmenta Anders Fagerholt, Ericsson
V0.71 20181218	Clean version	Anders Fagerholt, Ericsson
V 0.8 20181218	Polished Volvo Cars parts	Mattias Bernson, Volvo Cars
V 1.0 181218	Polished by RISE	Azra Habibovic, RISE

Glossary

ACEA	European Automotive OEM association
AD	Autonomous driving
AMQP	Advanced Message Queuing Protocol
C-ITS	Cooperative Intelligent Traffic System
C-Roads	EU project to harmonize and cross boarder test C-ITS
CAM	ETSI Cooperative awareness message
CEVT	China Euro Vehicle Technology (Geely / Volvo Cars owned OEM)
CoordCom	Carmenta´s emergency control room and communication product
CTC	Central traffic cloud (Drive Sweden Innovation Cloud)
DATEX II	EU standard for communication between traffic management centers
EATA	European Automotive and Telecom Alliance

EV	Emergency vehicle
EU CEF	EU project type, Connecting Europe Facility
DENM	ETSI Decentralized Environmental Notification Message
DriveMe	Volvo Cars family of autonomous drive projects
GPS	Global Positioning system
ITS-G5	ETSI standard for short range ad-hoc communication, 5.9 GHz
MPP	Most probable path (of the emergency mission)
MSB	Swedish Civil Contingencies Agency
MQTT	Message Queuing Telemetry Transport
OEM	Original Equipment Manufacturer (Car manufacturer)
PSAP	Public safety answering point
Rakel	Tetra radio network for public safety agencies
TETRA	Trans-European Trunked Radio Access
TLS	Transport Layer Security
VTI	Swedish Road and Transport Research Institute
Zenit	The System of SOS alarm

Executive Summary

This second part of this report is the concluding document of a joint public private project run over a period of sixteen months through to the end of December 2018 financed in part by Vinnova. The partnership included Volvo Cars, Carmenta, Ericsson, SOS-Alarm and RISE Viktoria. The goal of this "add on" project was to connect to SOS-Alarm to get access to position and target area of ambulance and fire truck rescue missions and automatically force AD vehicles to return to manual drive when the EV mission approaches. This can look like a simple task, but it took deep understanding and some novel thinking to get a smooth working system.

The main deliverable from this project was a demonstration of the working system held at Lindholmen Science Park in August 2017. This demonstration showed the information flows from SOS-Alarm through to a Central Traffic Control platform and the data processing to the Volvo Car Traffic Control and to the AD vehicle and back again, as well as resetting the alert and actions. The project utilized and built upon a lot of the already existing cloud infrastructure developed for the Drive Sweden initiative. The project also produced a film showcasing the functions Film AD aware https://youtu.be/HUW6YNROgnI .

This report documents the technical solution implemented, from the architecture envisioned, the technologies implemented and the standards used. Additionally the findings and conclusions of this work have been recorded with where possible desired future steps or recommendations.

Project participants

Volvo Cars

Volvo Car Corporation have high ambitions when it comes to sustainable mobility solutions, especially within electrification and autonomous drive. Its leading position within self-driving cars is based on the world first and largest pilot for autonomous driving with real customers on public roads, Drive Me in Gothenburg. Important building blocks to secure its journey to commercial autonomous driving offer includes the joint project with Uber, extensive recruiting in Gothenburg and Zenuity (a new joint venture company with Autoliv) which will develop software for autonomous driving. The work on autonomous driving builds upon 89 years of safety know-how.

Ericsson

Ericsson is a global leader within communication systems and services. 40% of mobile calls are made through Ericsson systems and more than 2 billion people use its networks. Now, Ericsson is leading the development towards a Networked Society, where everything that benefits from being connected will be connected. The Transport sector will benefit extensively from getting connected, cooperative and automated. Ericsson is now developing and implementing communication services and cloud services to support this development. The next generation of mobile networks, 5G, is now being developed to fully support connected automation and new mobility services. Drive Sweden is a key project, with leading partners and use cases to ensure relevant and innovative input the development of 5G and related services.

Carmenta

Carmenta is a privately held Swedish company, founded in 1985, with offices in Sweden, Germany, France and Spain. Carmenta has been supplying world-class software for mission-critical systems for more than 30 years – systems in which superior situational awareness is the key to success. Carmenta provide high performance software products, develop client-specific solutions and offer a wide range of services that help some of the world's most technologically advanced customers optimize their operations using real-time geospatial information. Its technology is designed to meet the highest standards focusing on high performance, high availability, openness and scalability, and ease of use. Carmenta's customers are found globally with a concentration in Europe.

Carmenta provides command and control technology for connected and autonomous vehicles which helps traffic network operators to improve traffic control and increase road safety. Background maps with integrated sensor data, weather forecasts, video streams and other information provide the type of common operational picture that will be necessary for the command and control systems of the future.

RISE Viktoria

RISE Viktoria is a non-profit research institute dedicated to enable sustainable mobility by use of information and communication technology (ICT). The overall aim is to contribute to a worldwide development that takes care of the great challenges for the automotive and transport sector: Oil dependency, accidents, and impact on climate and environment.

Our research is mainly directed towards five application areas close to the automotive and transport, energy and communication industries: Cooperative Systems, Digital Innovation, Electromobility, Sustainable Business and Sustainable Transport.

We are a fast-growing organization that presently includes about 70 researchers with competences and experiences from areas like informatics, systems engineering, communication, automotive and transportation business. Our projects are performed in close cooperation with users and we can thus develop innovative services that from the start are prepared for commercial use.

RISE Viktoria is located at Lindholmen in Gothenburg, Sweden, and is part of RISE Research Institutes of Sweden.

SOS Alarm

SOS Alarm Sweden is a dedicated contributor to a safe and secure society for anyone within our nation's borders, by dispatching emergency services 24/7. When calling the emergency number 112 anyone may request emergency assistance, whoever you are, wherever you are. SOS Alarm Sweden is also responsible for the information number 113 13, used to obtain or contribute with information during major accidents or societal crises. SOS Alarm is a pivotal player in the Swedish society's emergency preparedness alongside alarm dispatching, security and on call services. With the benefits of unique competence, long experience and by constant development of services, SOS Alarm is the hub that creates safety and security.

System description

The DriveMe AD vehicles can go in AD mode on the "certified" ring motorway around Gothenburg under certain conditions (AD level 4). This road is a dual carriageway. AD vehicles "always follow the traffic rules", in this case lane keeping. But when an emergency mission approaches from behind manual vehicles turn to the hard shoulder or form an "emergency lane" in the middle of the road. Somehow Volvo Cars need to handle such an event and, in this project, we decided to revoke allowance for AD mode and force the vehicle to manual mode and have the driver to resume control.

In this project we have implemented, tested and evaluated a solution for handling these situations. Through the sharing of real-time data among systems we have managed to build a systems-of-systems solution that uses already available data in one usage domain (rescue operations) to the benefit of another (AD driving). The system is built on the architecture and functions developed in a previous AD aware project and we have for this project added a connection to the Swedish alarm and rescue operations center (PSAP) run by SOS Alarm for the region of Western Sweden.

Basic principles

Emergency drivers are highly motivated and experienced. They have good knowledge about the traffic situation and how it varies over time of the day, day of the week, month of year and other conditions. It is an important part of their professional skill to select the fastest route to their target. This includes using one-way streets and bicycle lanes, avoiding traffic jams etc.

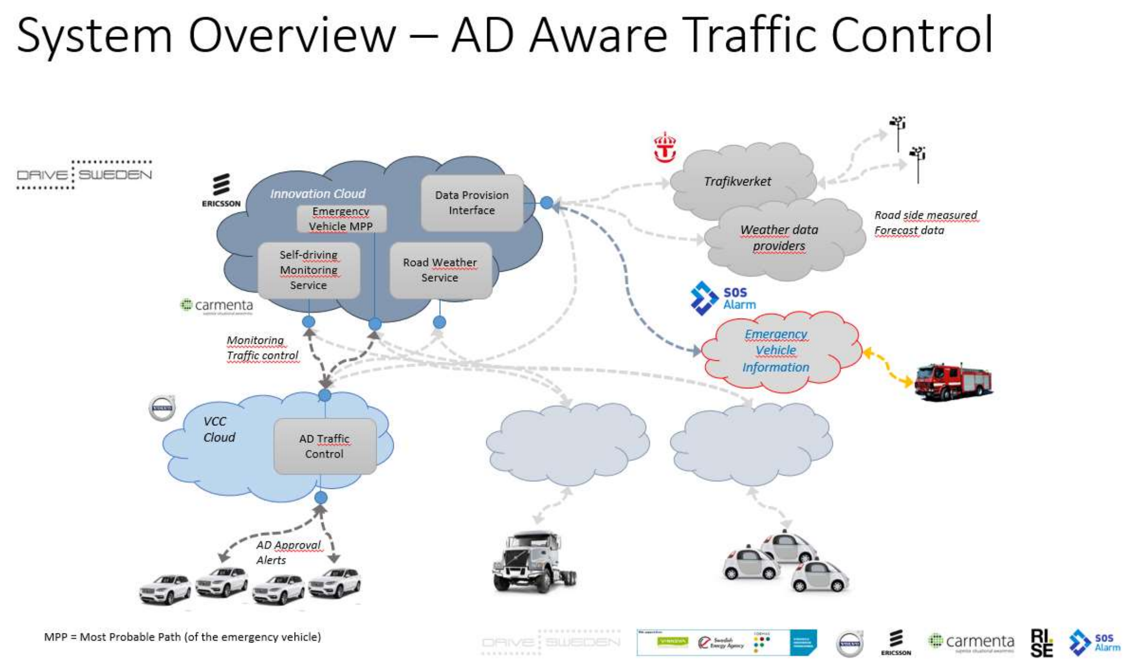
All rescue operations are centrally coordinated from dedicated command centers. In Sweden, SOS Alarm runs most of these command centers and have the overall responsibility to act as Sweden's national PSAP (Public Safety Answering Point), collecting all calls to the emergency number – 112. SOS Alarm also dispatch resources (ambulances, fire trucks etc.) to handle the rescue operations in the regions under their control. All Emergency Vehicles (EV´s) are connected to receive orders from the central command center and report back the current status as well as its measured GPS position. Therefore, the PSAP system have full control and overview of the rescue situation, constantly monitoring the connected fleet of EV´s. When an emergency situation occurs EV´s are allocated to participate in the rescue mission and receives orders with instructions from the command center including the estimated position of the emergency situation. Which route to take is then decided by the driver and in serious cases the EV runs with sirens and flashing blue-lights with the mandate to break traffic rules if necessary.

We have added a software component to the SOS Alarm system that collects EV positions and their destinations in runtime and sends that information as “EV Mission” messages to the Central Traffic Cloud. As it is not always the shortest route that is deemed the fastest by the driver, we have introduced the concept of the **Most Probable Path** (MPP) the EV driver will choose to drive as fast as possible. The MPP is then continuously calculated in the Central Traffic Control by functions in Carmenta Traffic Watch™. Every time a new position update is received the MPP is recalculated and compared to the previous and when the MPP includes a segment of an OEM AD Certified Road an “Incident” is registered by the system. Depending on if certain criteria are met the Incident automatically triggers the CTC to send AD Advices to connected OEMs. This mechanism has been tested and evaluated in the project together with the OEM Volvo Cars Traffic Control. When receiving an AD Advice for “EV on Road” over a certain probability level for a specific AD Certified Road segment, Volvo Cars have implemented functions that automatically send an AD revocation to any AD vehicle on that segment for the driver to take manual control.

When the EV mission has left the road segment the CTC alert signal is terminated and a message is sent to Volvo Car traffic control that in turn allow AD mode on the vehicles again and the driver can disengage.

System solution

Following on the work done in the previous AD Aware Traffic Control project, the system solution has been extended by adding a communication channel to CoordCom/Zenit, the command center system operated by SOS Alarms .New software components have been implemented so that when a rescue mission is started in the SOS Alarm system, the position of the emergency vehicle(s) together with the destination area (not exact position to protect privacy) is sent as an “EV Mission” message from SOS-alarm to the CTC.



The CTC Cloud can then serve any number of OEM clouds by aggregating data of interest, now including information about ongoing rescue missions. This CTC Cloud implements a Publish/subscribe and Request/response mechanism and a central function is to monitor the situation (on the OEM´s certified roads) and with automation support trigger alerts to the OEM clouds if there is an event such as an approaching EV.

The data exchange between the CTC cloud and OEM clouds use DATEX II with some extensions for AD use cases suggested by the previous project.

The figure below shows an updated overview of the CTC solution. The SOS Alarm CoordCom/Zenit system is connected through a standard AMQP message broker.

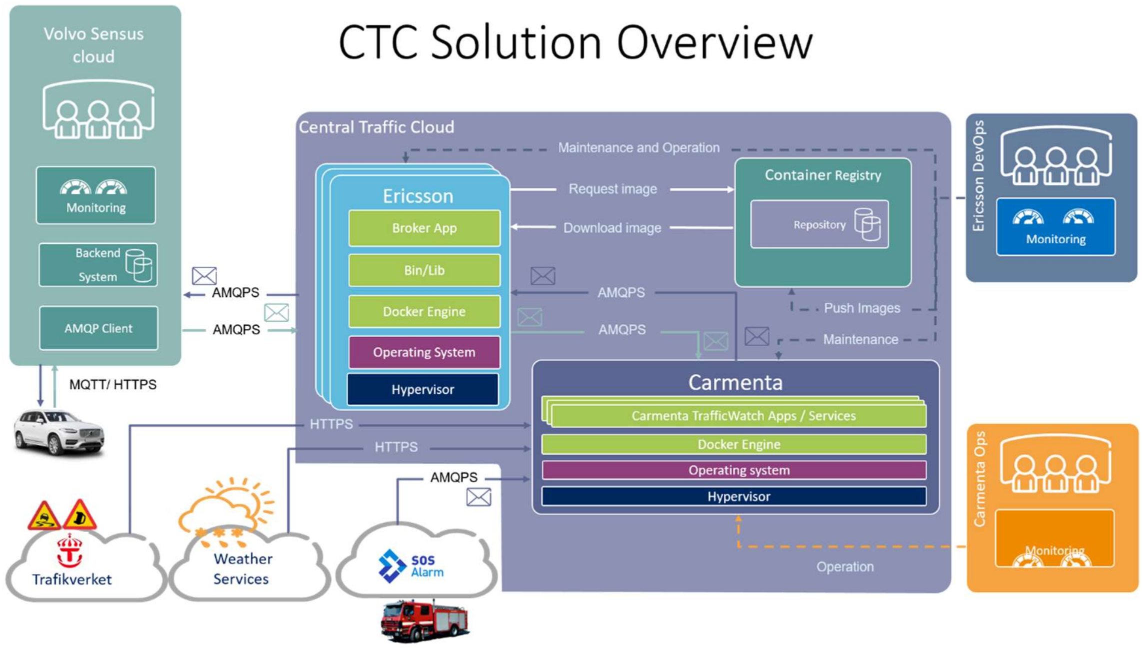


Figure 1 Diagram showing an overview of the CTC Solution after adding the SOS Alarm command center system.

SOS Alarm Emergency Situation View

The SOS Alarm system adds another view to the overall situational awareness of the AD Aware Traffic Control System, thus complementing the "OEM AD Traffic Control View" and the "Central Traffic Control view", previously described in the main report. Below figure shows the Operator UI for the rescue operator at SOS Alarm.

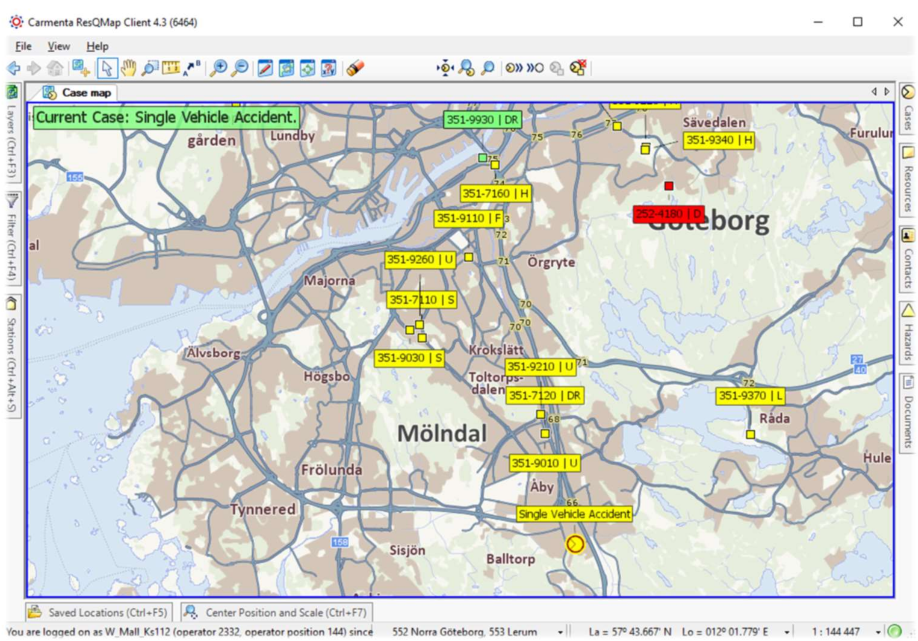


Figure 2 Screen dump showing the Operator UI in the SOS Alarm CoordCom/Zenit system. Available emergency vehicles are tracked and displayed on the situation map. An accident is registered and shown as a yellow circle symbol near Balltorp on the map.

Systems part of the end-to-end data flow

The information exchange between the different systems constitutes an end-to-end flow of messages starting from the Emergency Vehicle sending its position and status to the AD vehicle receiving an AD Advice that the EV is approaching. The figure below illustrates the data flow and the systems it passes. Following in this chapter are more detailed descriptions on how each system contributes to the overall functionality.

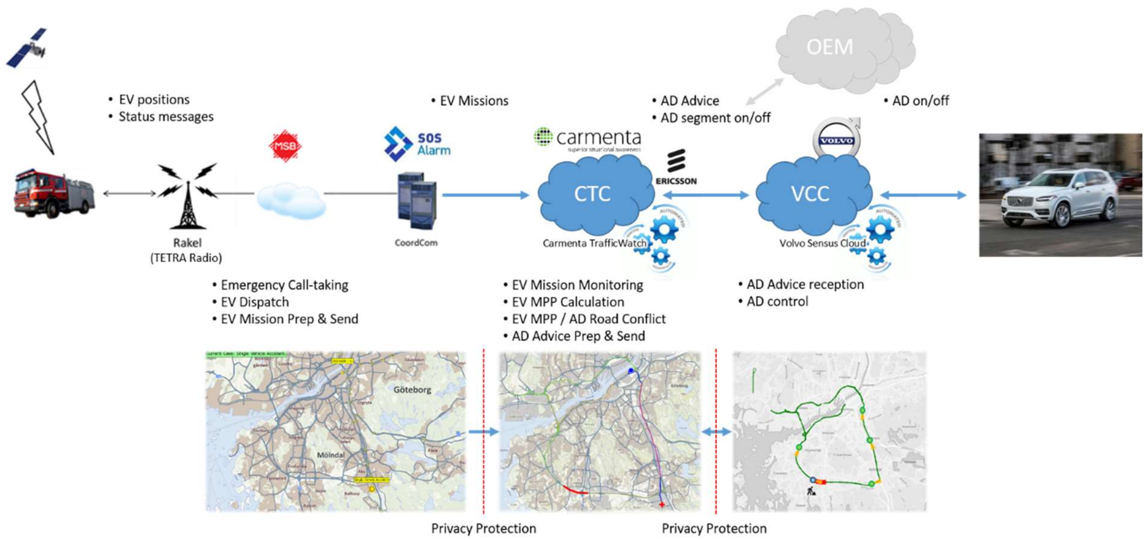


Figure 3 Picture showing the end-to-end data flow also summarizing what actions are performed in each system along the data message chain.

The Emergency Vehicle (EV)

The Emergency Vehicle (EV) has an in-vehicle system to receive and sign orders and calls from the SOS Alarm command central. In Sweden the rescue services use the RAKEL system for secure communication (see below) between the EV and the command central. The vehicle registers and sends its positions using the GPS functionality also part of the onboard RAKEL system. The equipment in itself can come from any certified RAKEL supplier, but it implements a common set of basic functions including the GPS positioning. Due to limitations in the radio-based communication solution the GPS positions can only be updated and transmitted every 15 to 25 second.

The RAKEL (Tetra) Radio

RAKEL (RAdioKommunikation för Effektiv Ledning) is the system for radio communication used by Swedish security organizations and rescue services, mainly the police, the military police, ambulance services, SOS Alarm etc. RAKEL uses the TETRA standard (Trans-European Trunked Radio Access) which is developed by ETSI (the European Telecommunications Standards Institute) for secure radio communication.

The MSB Network

MSB (Myndigheten för samhällsskydd och beredskap) is the Swedish Civil Contingencies Agency which is responsible for operating the Swedish RAKEL network. SOS Alarm uses this network for communicating with the EV´s so the positions and status are transmitted through this solution.

The CoordCom/Zenit System (SOS Alarm)

Summary about adding Emergency Vehicle Info:

- All rescue vehicles and ambulances (EV´s) on call sends their positions to SOS Alarm
- EV positions are updated every 15 to 25 second
- EV´s with Prio 1 (i.e. blue light ON) are filtered out.
- Case positions (destination) are obfuscated for privacy reasons
- Only the EV identity and positions are exported from SOS Alarms system
- The EV:s position and its obfuscated destination are sent as an ”EV Mission” message
- The EV Messages are sent to CTC via an AMQP message broker
- A software module has been added to SOS Alarm by the project to create and send EV Mission Messages

Zenit is the technology platform developed and used by SOS Alarm to handle its role as Sweden’s national PSAP (Public Safety Answering Point), collecting all calls to the emergency number – 112. The platform is also used to dispatch resources (ambulances, fire trucks etc.) for handling rescue operations in the regions under SOS Alarms control.

Zenit is built against extremely high requirements on redundancy and safety in order to handle SOS Alarms public safety services to the Swedish society in a reliable and secure way. The system is delivered by Carmenta who is also responsible for its design and continued development. Zenit is based on two Carmenta products as its major parts; Carmenta CoordCom™, that is the incident management and communications system and Carmenta ResQMap™ that adds an integrated multi-user map display designed for mission critical applications.

Zenit is very much based on standard Commercial of the Shelf (COTS) products and it uses advanced network technology to connect all physical command centers in a common technical solution. This adds a high level of redundancy and makes it possible to have local centers assist other regions in situations with exceptionally high load as can be the case in disastrous situations.

All rescue vehicles and ambulances (EV´s) on call sends their positions to SOS Alarms Zenit system and gets dispatched through the system if needed to participate in a rescue operation.

Connecting to the CTC cloud

A new SW component named *ResQMapConnectionService* was developed and added to the SOS system backend for this project with the function to retrieve information in runtime about ongoing emergency missions. This service connects to two already existing SW services in the SOS Alarms system. The newly developed service receives information about current status, position etc. for all existing ‘resources’ (EV´s etc.) from one of the existing services and information about ‘cases’ (accidents etc.) from the other. A case that the *ResQMapConnectionService* receives from the system contains information about where an incident has happened and which resources are assigned to that case. The SW component then creates an “EV Mission” message for each resource that is assigned to a case with the following information:

- Id of the mission

- Id of the resource
- Position of the resource
- Time for when the resource was at the given position
- Status of the resource
- Position of the incident (this position is obfuscated within a radius of 100 m for privacy reasons)
- Priority (1-4)

Missions are written to a queue on an AMQP Message Broker every time a new mission is created or any of the data in an existing mission is updated. The data can also be filtered based on a number of parameters:

- Type of case i.e. “Ambulance” or “Rescue”
- Priority
- Which Station the resource is belonging to

The tests that has been performed in the project was with “Rescue” vehicles (i.e. Fire Trucks) only from a limited/selected number of stations in Gothenburg which was assigned to a case with priority 1 or 2.

The Central Traffic Cloud/Carmenta TrafficWatch™

The main capability implemented and tested in the previous AD Aware CTC project was to build and maintain an aggregated traffic situation picture for a traffic operator to interactively dispatch AD messages (example AD driving ‘recommendations’) to connected OEMs. The traffic situation picture established in this project and used for testing was mainly composed of the following parts:

- A detailed background map
- The geometry and characteristics of the physical road network
- Real time traffic information
- OEM AD vehicle activity and operations
- Weather data including road conditions

The current project adds another very important part to the overall situation picture; the **Emergency Vehicle Operations.** Real-time data about ongoing EV missions are transferred from the connected SOS Alarm command center. The data is collected and initially used for calculating the Most Probable Path for each EV mission. The current EV Operation Picture can then be shown as a dynamic layer on the Operator UI map where a CTC operator can visually follow all ongoing rescue missions.

To handle the EV data, a new component; the *EmergencyVehicleRouteService* was developed and added to the Carmenta TrafficWatch™ backend as a micro-service. The component connects to the AMQP broker and listens for EV Mission updates on the AMQP message queue.

Most Probable Path calculation

When a new EV Mission is received by the CTC the *EmergencyVehicleRouteService* calculates the Most Probable Path (MPP) from the position of the resource to the incident position (see figure below). The MPP is recalculated every time an EV position update is received. The actual route calculation is delegated to a SW component running as separate micro service. This design allows for easy changing or updating the way the MPP is calculated without affecting the overall data flow. In the project a basic algorithm was used as the focus was on setting up a working technical solution for the end-to-end data flow and not to optimize the precision on how to predict the MPP in itself.

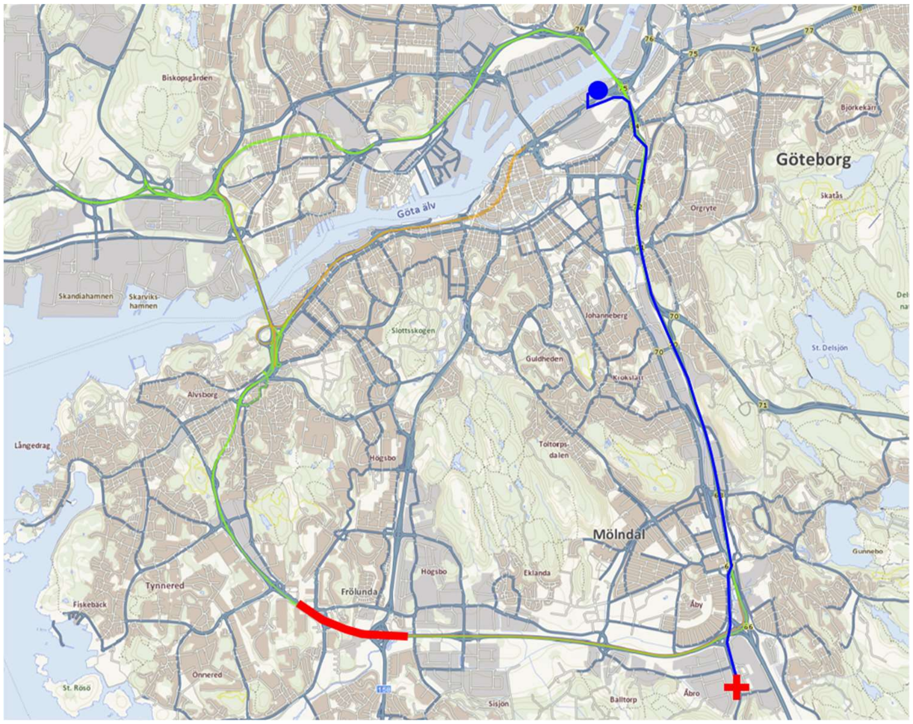


Figure 4 An EV Mission shown in the Operator UI where the blue dot is the EV position and the red cross is the obfuscated position of the emergency situation. The blue line is the calculated MPP.

When an MPP coincides with one or more segments of a monitored OEM AD Certified Road an "Incident" is registered by the system (see figure below).

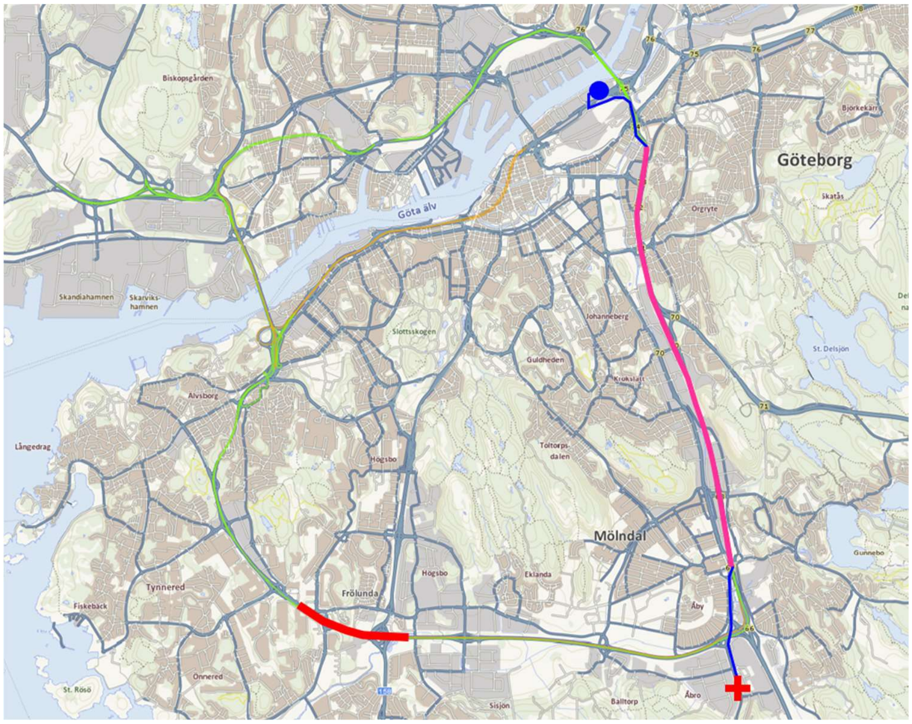


Figure 5 An "Incident" is detected where the MPP coincides with several of OEM VCC:s AD certified road segments part of the DriveMe "slinga". The Incident is shown as a pink line in the Operator UI.

AD Advice for "EV_on_Road"

In the project we have re-used the AD Advice message mechanism from the previous project for sending guidance instructions about approaching EV´s. This was done by adding a new AD Advice type; "EV_on_Road", where we also used the "Probability of Occurance" simple type from the DATEX II data exchange standard for classifying the probability of the EV to actually turn up on the AD Certified Road segment. The "Probability_of_Occurance" type has three enumerations which we used as follows:

- Risk_Of – is sent as the first version of an AD Advice immediately when an MPP/AD Road intersection is detected
- Probable – is sent as an updated version of the AD Advice when an EV has 60 seconds to reach the AD road segment
- Certain – is sent as an updated version of the AD Advice when an EV is on, or very close, to an AD road segment

The AD Advice function in CTC was also extended to allow **automatic** sending of AD Advices, a function that is part of the Carmenta TrafficWatch™ platform. This is a configurable way to set up rules for executing automatic commands when certain criteria are met. This mechanism was tested and evaluated in the project together with the OEM Volvo Cars Traffic Control.

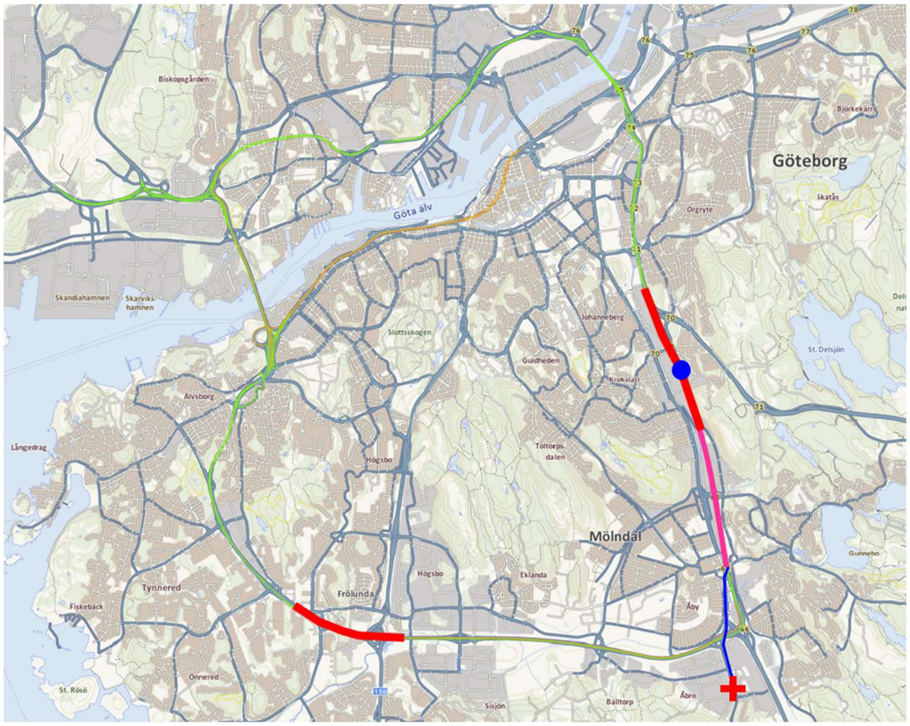


Figure 6 An AD Advice; "EV_on_Road" has been sent to the VCC control who has revoked AD for any AD vehicle on the segment where the EV is driving (blue dot). The CTC Operator UI has been updated to reflect the AD off status (red line)

When the EV mission has left the road segment the CTC alert signal is terminated and a message is sent to Volvo Car traffic control that in turn allow AD mode on the vehicles again and the driver can disengage.

The Interchange Node

The Interchange Node is a high-performance low-latency AMQP Broker based on Apache QPID.

AMQP 1.0 with TLS is used.

The deployment consists of queues:

- Carmenta Traffic Watch™ to consume data published by OEMs as well as publish data for consumption by OEMs.
- OEMs to consume data published by Carmenta Traffic Watch™ as well as publish data for consumption by Carmenta Traffic Watch™

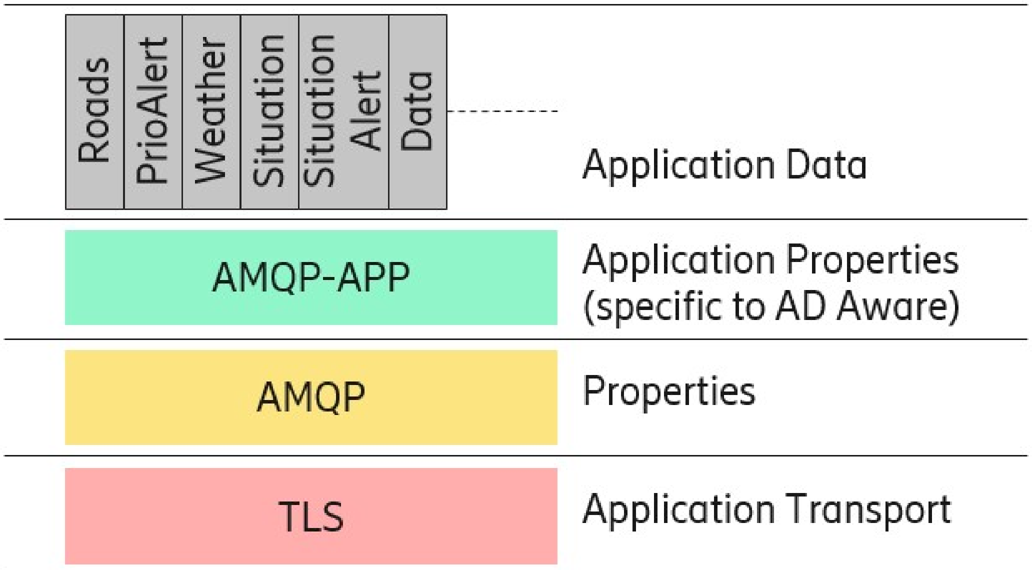


Figure 7 An overview of the Protocol Stack based on AMQP used for communication through the Interchange

The Volvo Sensus Cloud/Volvo Cars Command Center

The command center is a secure mechanism to visualize and administer the location and status of all the elements needed to be understood to support autonomous driving, such as:

- The location and drive status of AD cars
- The ability to define and administer AD road segments
- The ability to see all received situations
- The ability to see EV vehicles and the predicated route
- The ability to create AD Advice

V2Cloud communication

- Ericsson's Connected Vehicle Platform is used for the Vehicle-Cloud Communication. The Platform also provides an Application Development Environment for developing applications to support both vehicle communication as well backend integration.
- The Platform consists of a high performance MQTT broker along with advanced authorization mechanism for the MQTT Topics based on the vehicle identifiers. The MQTT broker components provides inbuilt support for anonymization.

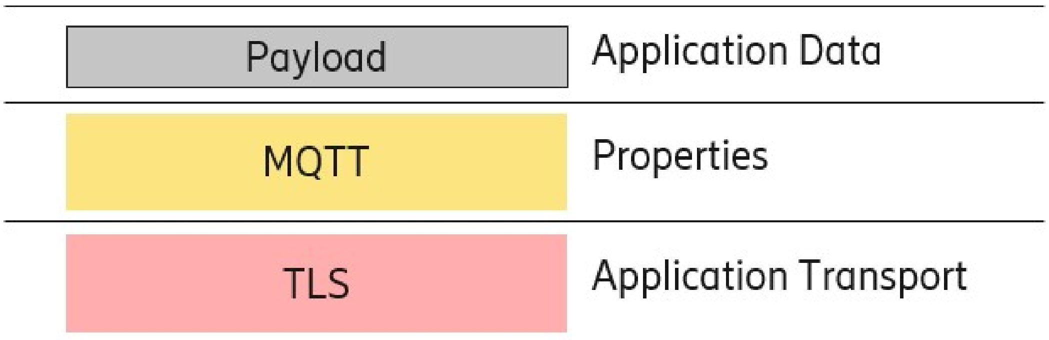


Figure 8 An overview of the Protocol Stack based on MQTT used for vehicle communication

Findings

Conclusions

The good cooperation and efficient way of working from the previous project was carried over to this project and included the new partners. The different skills and knowledge of the partners made it possible to work out a solution for the problem we set out to solve.

Some of the project findings and conclusions are:

- The cooperation in Drive Sweden works very well and the Innovation Cloud platform proved its usefulness when adding and handling Emergency Vehicle Information.
- Real-time traffic situation monitoring on a central level that includes information about ongoing emergency operations provides a better overall traffic control as well as creating a safer and more efficient operation of connected emergency vehicles.
- Monitoring emergency operations in a central traffic control system can provide connected entities better guidance to avoid conflicts that hamper the execution of emergency missions.
- The ability to send specific guidance messages about approaching EV´s results in a more proactive guidance of OEM AD vehicle fleets.
- The sharing of information about emergency vehicles MPP´s and AD vehicle positions among connected entities greatly improve the overall safety and efficiency for both Emergency Response operations and guidance of AD vehicles.
- The use of standardized formats and services in the cloud-based environment makes it easy for other systems to connect
- A high degree of automation is mandatory to send AD Advices with the frequency needed to support the OEM AD operation. This was successfully tested in the project.
- The timing of when to dispatch AD Advices with different probability levels from the CTC to the OEM clouds has to be calibrated.

Carmenta specific findings

Based on work done in the previous AD Aware project we could re-use s lot of technology and quickly set up a successful integration of the SOS Alarm system. The established AD Aware CTC cloud architecture then proved its versatility and extendibility in a good way. Our Carmenta TrafficWatch™ product also was used very efficiently to handle and analyze data about Emergency Operations and we successfully implemented and tested a completely automated mechanism for sending AD Advices about Emergency Vehicles approaching and possibly affecting an OEM´s (Volvo Cars) connected AD vehicles. A solution designed in a way that can be easily extended to involve also other OEM´s.

The solution was also tested live and "in the field" where we could run the entire end-to-end data flow through all involved systems and vehicles. These tests were very valuable learning sessions that contributed a lot to the overall project result.

Volvo Cars specific findings

This proves that we can use a flow of external and internal information to enable more intelligent decision making based on real time data. The next step is to add more OEM's for further evaluation.

Ericsson specific findings

Ericsson played a minor part in this project, but that is because the Drive Sweden Innovation cloud has been built up in the projects Systems and services 2016 and 2017 and the basic configuration for AD aware was set up in the previous project. We are happy to conclude that the Innovation cloud works very well to support this and other projects.

Rise Viktoria specific findings

To create a better understanding of technical requirements that AD Aware Traffic Control needs to fulfil, and how it could add value to the society and accelerate acceptance of automated vehicles, a proof-of-concept evaluation was carried out. Building upon our extensive experience in evaluation methodologies, both societal impact and system functionality evaluation have been performed.

Based on extensive interviews with different stakeholders within the emergency response system, we have identified the Swedish practices on emergency response, different stakeholders' responsibilities and restrictions, attitudes towards new technologies, key challenges, support needs, as well as opinions on future traffic systems with autonomous vehicles. The current system under development has received positive feedback and it has addressed some of the key challenges including stakeholder collaboration, cloud systems for EV information distribution, etc. In the meanwhile, RISE Viktoria has also identified significant challenges and future works that stakeholders suggested and that remain to be addressed in future projects.

Based on the observations of multiple demonstrations and analysis of the collected data, RISE Viktoria has evaluated the functionalities of the system, and some of the key performance metrics. It has been observed that all functionalities specified by the involved stakeholders have been achieved and an end-to-end system demonstration has been done during the project. As for the key performance metrics, single trip time from SOS Alarm to CTC is shown to be in average 253 ms, while round-trip time from CTC to VCC is shown to be in average 203 ms. EV location update interval is decided by the SOS Alarm and the current interval is in average 23 seconds. It is acknowledged that current performance is preliminary and further investigation can be done with further collection of data.

With those results, RISE Viktoria can conclude that the current system provides a good technical and collaboration foundation for emergency response in future connected and automated traffic systems. RISE Viktoria takes with the knowledge created and further investigate future emergency response system from a system-of-system perspective on how such a socio-technical system can be implemented by fully integrating multiple stakeholder needs and emerging technologies. This will go hand-in-hand with the on-going implementation of C-ITS and other initiatives of future emergency response systems.

SOS Alarm specific findings

In an emergency situation every second counts. SOS Alarm aims to continuously develop and shorten the help chain in order to save more life. This is done by continuous improvements in SOS Alarms own operation and also by developing and be part of collaborations like the AD Aware Emergency Vehicle initiative. The function developed in the AD Aware Emergency Vehicle project has been proved to save seconds, even minutes for the ambulance and fire brigades on their way to the help seeker. This will be of great benefit foremost for the person in need but also for the society overall.

International liaisons

We have had an information exchange with the “Data Task Force” (initiated by EATA and ACEA and now a subgroup of the C-Roads project) about Emergency Vehicle Warning. P-O Svensk from Trafikverket is the Swedish delegate.

Future Work

The EU CEF project *Nordic Way 2* that is developing more C-ITS functions over the cellular connection has in the Swedish pilot a task about emergency vehicle warning and this project is up to speed at the time of writing. The task is to warn “all vehicles on all roads”. The project reuses most of the knowledge, results and software of this project. The messages to the vehicles will be DATEX and ETSI CAM and DEMN to alert the drivers. In Nordic Way 2 the AMQP deployment as well as the client profile are standardized to support and ease the onboarding of new partners on to a C-ITS data interchange. The interchange deployed for AD Aware will be upgraded to the Nordic Way interchange profile. This will also provide a base for cross-border testing. Project partners are Carmenta, Volvo Cars, Volvo AB, Zenuity, Ericsson, VTI, MSB and Trafikverket.

A new Drive Sweden project has been approved: *Autonomous aware traffic control – Advanced Coopertive Driver Assistance*. The project will use the architecture and functions and we will add a new OEM – CEVT (with the brand Lynk&Co). Alerts and warnings generated from the cars sensors and systems will be shared between Volvo Cars, CEVT and the central traffic cloud. Project partners are Carmenta, Volvo Cars, CEVT, Ericsson and RISE Viktoria.

Plan for commercialization and growth

As stated above the results of this project is carried over to Nordic Way 2. The traffic / road administrations in Sweden, Denmark, Norway and Finland are leading this project. The EU CEF project C-Roads is an umbrella project over “all” EU C-ITS projects. Focus has first been on C-ITS using short range direct AD-Hoc communication (ITS-G5 on 5.9 GHz) and the task of C-Roads is to profile and harmonize the ETSI standard messages and facilitate EU cross boarder interoperability testing. The Nordic Way 2 partners have taken lead in C-Roads TF 4 “Hybrid Communication” with the task of profile and harmonize C-ITS using cellular communication for distributing messages. This will also apply to Emergency Vehicle Warning and we have good hope that the concept we have developed will be accepted as a European “standard”. A good starting point for commercialization.

Appendix D – Deliverables

WP 1 Emergency vehicle information

In the project we have established a fully functional technical solution for integrating real-time information about ongoing Emergency Vehicles' missions in the AD Aware Traffic Control platform. A communication solution between the SOS Alarm CoordCom/Zenit system and the AD Aware Traffic Control Cloud was developed and successfully tested and evaluated in the project. The result is a working solution where information about a filtered set of Emergency Vehicle "missions", in a designated area, are constantly transmitted to the Central Traffic Cloud. The EV mission data, consisting of the current EV position, status and destination is then used to calculate the Most Probable Path (MPP) the EV will use to navigate the road network to reach the emergency situation as quickly as possible. As the EV positions are updated only every 15 - 25 second the MPP has to be recalculated several times for each EV mission. Using analytical functions developed in the project, the Central Traffic Cloud detects when a MPP interferes with any of the monitored OEM AD Certified Roads. The Estimated Time to Arrival (ETA) for the EV to reach each AD Certified Road segment is then calculated together with an estimated probability of occurrence. Following a set of criteria (rules) the CTC then automatically dispatches AD Advice messages to connected OEMs (see WP2 description).

The end-to-end dataflow with the interfaces used in the project are described in more detail in the previous chapters.

WP2 AD advice /central traffic control

D2.1. Report with findings, lessons learned and recommendations

This document.

D2.2. Description of used and proposed interfaces and the flow of information.

We have successfully extended the previously developed AD Advice mechanism to include handling of approaching EV´s driving on monitored OEM AD Certified Road. AD Advices are used to transmit AD driving 'recommendations' (AD allowed/not allowed) from a Central Traffic Control to OEM Traffic Controls. The AD Advice message structure and content is based on the DATEX II standard with the extensions added in the previous project.

The interactive operator interface in the AD Aware Traffic Control was extended with tools to monitor and handle MPP´s on the situation map and control the updated AD Advice function. A model for automatic dispatching of AD Advices, when defined criteria was met, was also developed and successfully tested in the project. This has resulted in a fully automated AD Advice function for sending guidance information about approaching EV´s.

The work has closely followed other activities and projects in the Drive Sweden program and the resulting demonstrator platform has added substantial and important capabilities to the AD Aware Traffic Cloud which is now an integrated part of the Innovation Cloud infrastructure.

The initial goal for to add services for sharing information about AD Vehicle positions from connected OEMs with EV Coordinators was not met in this project. This is due to several reasons:

- Privacy and safety aspects of sharing AD vehicle positions are not fully clarified and needs to be handled further which is out-of-scope for the project.
- For safety reasons only a one-way communication solution was set up between the SOS Alarm Zenit system and the Central Traffic Cloud, limited to sending only a controlled amount of EV mission data.
- The scope of adding functions in the SOS Alarm Zenit system to handle AD Vehicle data was deemed too large for the current project. Certainly, an interesting topic for further research and development.

The end-to-end dataflow with the interfaces used in the project are described in more detail in the previous chapters.

D2.3. A demonstrator within the AD Aware Traffic Cloud.

This was held August 29:th 2018 at Lindholmen Science Park.

D2.4. A summarizing chapter in the final report

Part of this report.

WP3 Improved EV routing

In the project application we mentioned a work item WP3:*"In a report, summarize a study of the opportunity to use the AD Aware Traffic Control platform to suggest a quicker and safer route for Emergency Vehicles. What amount and type of traffic information is required and what other data (i.e. traffic density, roadworks, slippery roads etc.) could be added."*

We found that we in the project did not get access to people with the right domain knowledge to perform this study (Experienced emergency drivers and rescue mission operators). RISE Viktoria/Högskolan in Halmstad has made a master thesis on MPP prediction (http://hh.diva-portal.org/smash/get/diva2:1221964/FULLTEXT02.pdf).

The questions on how to use traffic information and how to get the optimum driving behavior from vehicles/drivers that receive an emergency vehicle waring has been carried over to the Nordic Way 2 (EU-CEF project). Building on the results of this project the application is extended to emergency vehicle warning to "all vehicles on all roads" using DATEX II and ETSI DEMN and CAM messages. In Activity 9, task 3 "Blue light driving simulator studies and demos" VTI will use their driving simulator to study the behavior of both emergency vehicle drivers and ordinary drivers. This will deliver the wanted insights and suggestions for the future. (The budget for this task 2018-2020 is 4.150 MSEK)

WP4 OEM traffic control

Deliverables

The functionality to automatically turn AD mode OFF on certified road segments when a specific situation is received. In this case when an Emergency Vehicle (EV) is certain to intersect with an AD certified road segment the OEM traffic control will send a message to the Central Traffic Control system that the effected segment is closed for AD driving. If the EV only is probable to intersect the OEM traffic control will not automatically turn the AD mode OFF.

The functionality to automatically turn AD mode ON, for AD driving, when a specific criterion has occurred. In this case when an EV has left an AD certified road segment that was previously turned OFF for AD driving. The OEM traffic control will then turn ON the AD mode and send a message to the Central Traffic Control system that the segment is now open for AD driving.

The functionality to log all received and sent messages for both evaluation of latency between the different systems and validation of functionality.

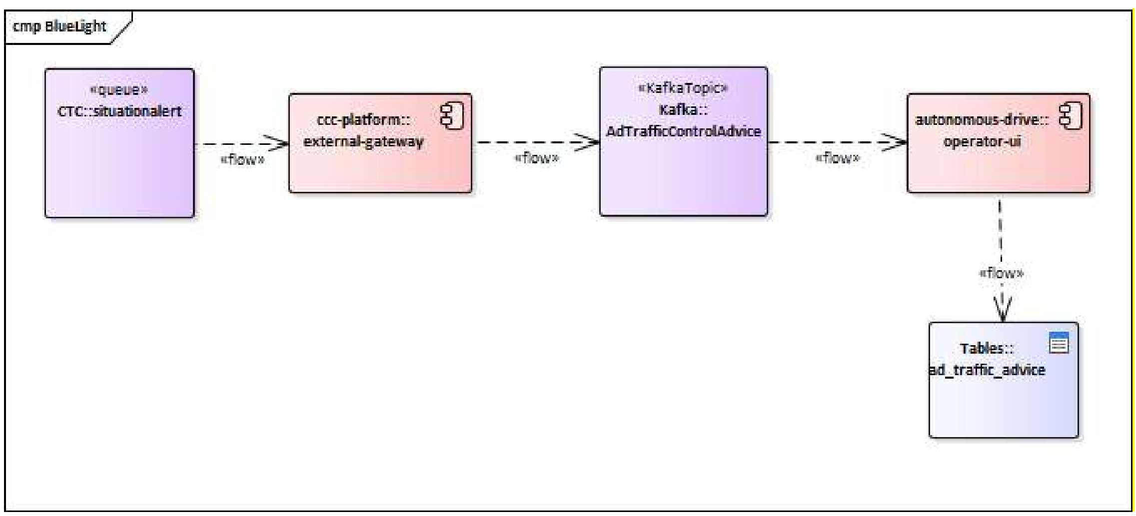
D4.1. Report with findings, lessons learned and recommendations.

This proof of concept was developed to prove that we could use a flow of external and internal information (via the external data exchange) to enable more intelligent decision making based on real time data. When we receive external messages from the Central Traffic Cloud/Innovation Cloud informing us that there is an emergency vehicle intersecting one of our AD certified road, we can automatically shut down the AD-mode for the affected cars on that segment

As this has now been proved we would like to make these decisions better by adding data from one or additional OEM's.

D4.2. Description of used and proposed interfaces and the flow of information.

Functionality



D4.3. A demonstrator within the AD Aware Traffic Cloud.

Volvo Cars was part of the demonstration held at Lindholmen on the 29th of August and also at the FLISA conference in Örebro on the 3rd of October.

WP 5 Study of effects

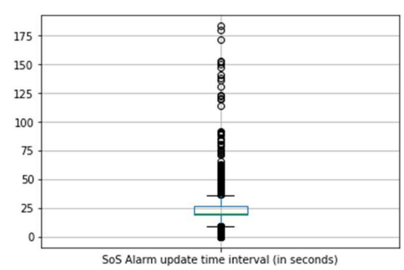
Platform functionality assessment

This section describes the verification of the functionalities of each industrial stakeholder in the project through six internal demonstrations and the final demonstration at DriveSweden event within which a public demonstration with AD vehicles and a realistic fire truck. Functionalities are mostly verified through observations together with all partners.

In addition, data have been collected at the central traffic cloud (CTC) and Volvo Cars cloud and analyzed for the period between 2018-11-13 10:31 to 2018-11-27 10:50. In total, there were 31400 records of messages at CTC including SOS Alarm mission (EV location) update, mission registration at CTC, MPP calculation, incident detection, AD advisory, as well as AD advisory responses from VCC cloud. Those data correspond to in total 251 situations (rescue missions). We give a preliminary analysis on the mission update frequency from SOS Alarm, latency between SOS Alarm and CTC and round-trip time between CTC and VCC cloud.

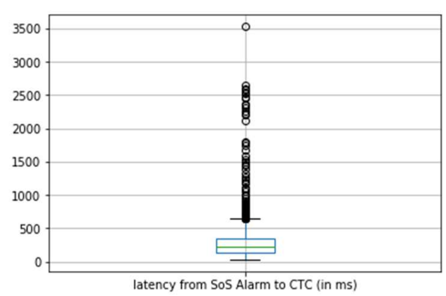
SOS-Alarm

In this project, SOS alarm provides information through the mission control system Zenit, the functionalities and the assessment of them are listed as below.

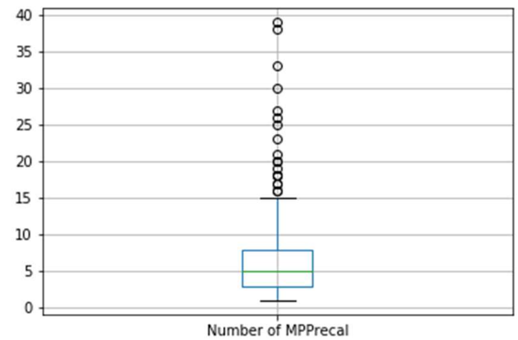
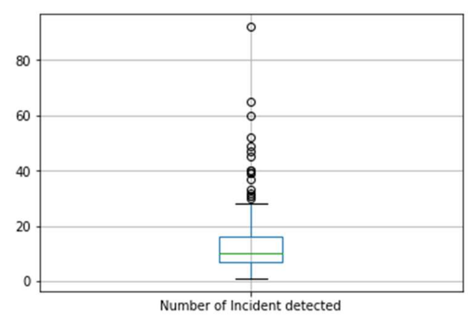
Functionality	The SOS Alarm operating platform Zenit is able to update ambulance mission together with real-time position information with CTC.
Assessment	We have observed that EV information is updated with CTC and EV is shown on the map at the control center. Mission information including situation identifier and EV position update timestamps are logged.
Performance - mission update	Zenit updates EV position with a certain time interval during each mission. This time interval is mostly decided by SOS Alarm system.
Assessment	In total, there are 6567 valid data counts, however, there are data with large time intervals. We filter and remove data counts with time interval larger than 200 s, leaving 6550 data counts. Average mission update delay is 23.33 seconds and statistical summary is shown below.
Statistical summary	**SoS Alarm update time interval (in seconds)** **count** 6550.000000 **mean** 23.332615 **std** 10.692718 **min** 0.046875 **25%** 19.742356 **50%** 20.668616 **75%** 26.586105 **max** 183.405209 

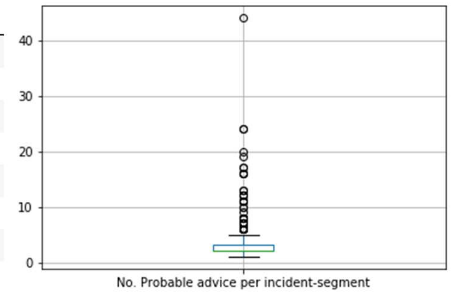
Center Traffic Cloud (CTC)

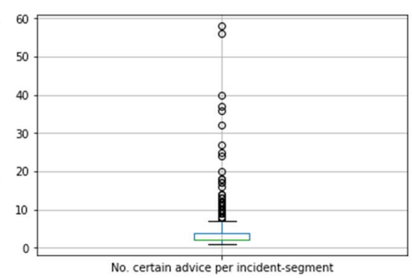
CTC is the decision point that takes in EV information from SOS Alarm, calculates the most probable path (MPP), detects if there is overlap with the AD route segment and sends warning messages to Volvo Cars. The major functionalities and assessments are listed as follows:

<table>
<tr><td>Functionality</td><td>CTC is able to receive EV mission information with live EV position as an additional information source to the AD aware traffic control system.</td></tr>
<tr><td>Assessment</td><td>We have observed that EV information is updated with CTC and EV is shown on the map at the control center. EV update messages are also recorded with timestamps.</td></tr>
<tr><td>Performance - latency from SOS Alarm to CTC</td><td>The latency of mission update from SOS Alarm to mission registration at CTC.</td></tr>
<tr><td>Assessment</td><td>Based on 5584 valid records, and average latency from SOS Alarm to CTC is 253.3 ms.</td></tr>
<tr><td>Statistical summary</td><td>
<table>
<tr><th></th><th>latency from SoS Alarm to CTC (in ms)</th></tr>
<tr><td>count</td><td>5584.000000</td></tr>
<tr><td>mean</td><td>253.269399</td></tr>
<tr><td>std</td><td>188.749807</td></tr>
<tr><td>min</td><td>31.782866</td></tr>
<tr><td>25%</td><td>134.908557</td></tr>
<tr><td>50%</td><td>229.516029</td></tr>
<tr><td>75%</td><td>341.633737</td></tr>
<tr><td>max</td><td>3531.204700</td></tr>
</table>


</td></tr>
<tr><td>Functionality</td><td>CTC is able to calculate the MPP for the EV mission and update MPP accordingly.</td></tr>
<tr><td>Assessment</td><td>We have observed that MPP is calculated and visualized on the map and is dynamically updated based on the position of the EV. Each time when an MPP is recalculated, a record is logged.</td></tr>
<tr><td>MPP recalculation frequency</td><td>The number of MPP recalculations for each rescue mission.</td></tr>
<tr><td>Assessment</td><td>Based on MPP recalculation over 241 rescue missions. Average MPP recalculation is about 6.57 per mission.</td></tr>
</table>

Statistical summary	**Number of MPPrecal** **count** 241.000000 **mean** 6.568465 **std** 6.152615 **min** 1.000000 **25%** 3.000000 **50%** 5.000000 **75%** 8.000000 **max** 39.000000 
Functionality	CTC is able to detect the potential intersect of MPP and AD route segment, and generate warning messages including the related AD segment, occurrence time periods and the confidence level.
Assessment	We have observed the generation of such a message and logged at CTC. All detected incidents are logged.
No. of incident detection	The number of detected incidents for each mission.
Assessment	Based on all 251 missions. There are in average 13 detected incident per mission.
Statistical summary	**Number of Incident detected** **count** 251.000000 **mean** 13.270916 **std** 11.199567 **min** 1.000000 **25%** 7.000000 **50%** 10.000000 **75%** 16.000000 **max** 92.000000 
Functionality	CTC is able to send AD advisory containing relevant information to Volvo Cars for warning AD vehicles of approaching EV.
Assessment	We have observed that AD advices are sent and logged at CTC and Volvo Cars
No. probable ad advices	The number of 'probable' ad advices for each detected incident and for each affect road segment. After a certain number of ad advices with 'probable' status, an ad advice with 'certain' will be issued.

<table>
<tr><td>Assessment</td><td>Based on 2184 probable ad advices for 712 incident-segment pairs. Average number per incident per road segment is 3.06.</td></tr>
<tr><td>Statistical summary</td><td>
<table>
<tr><th></th><th>No. Probable advice per incident-segment</th></tr>
<tr><td>count</td><td>712.000000</td></tr>
<tr><td>mean</td><td>3.067416</td></tr>
<tr><td>std</td><td>3.019571</td></tr>
<tr><td>min</td><td>1.000000</td></tr>
<tr><td>25%</td><td>2.000000</td></tr>
<tr><td>50%</td><td>2.000000</td></tr>
<tr><td>75%</td><td>3.250000</td></tr>
<tr><td>max</td><td>44.000000</td></tr>
</table>


</td></tr>
<tr><td>No. advices with certain statuses</td><td>The number of ‘certain’ advices for each detected incident and for each affected road segment. A certain ad advice means an EV is on the segment. The message may repeat with several versions.</td></tr>
<tr><td>Assessment</td><td>Based on 2625 ad advices with certain statuses for 698 incident-segments. Average number of certain messages per incident per segment is 3.76.</td></tr>
<tr><td>Statistical summary</td><td>
<table>
<tr><th></th><th>No. certain advice per incident-segment</th></tr>
<tr><td>count</td><td>698.000000</td></tr>
<tr><td>mean</td><td>3.760745</td></tr>
<tr><td>std</td><td>4.870938</td></tr>
<tr><td>min</td><td>1.000000</td></tr>
<tr><td>25%</td><td>2.000000</td></tr>
<tr><td>50%</td><td>2.000000</td></tr>
<tr><td>75%</td><td>4.000000</td></tr>
<tr><td>max</td><td>58.000000</td></tr>
</table>


</td></tr>
<tr><td>Functionality</td><td>CTC is able to receive AD statuses of all AD route segment.</td></tr>
<tr><td>Assessment</td><td>We have observed through comparative visualization at CTC and Volvo Cars that AD statuses of all AD route segments are updated and synchronized. AD statuses are also logged at Volvo Cars for end-to-end latency calculation.</td></tr>
</table>

Ericsson Interchange node

The interchange node is responsible for the message exchange between CTC and Volvo Cars, thus the functionalities are mainly indirectly assessed through the successful sending and receiving of messages at CTC and Volvo Cars.

Functionality	The interchange node is maintaining the AMQP server that is able to support message exchanges between CTC and Volvo Cars.
Assessment	The function of interchange node is indirectly observed by the message transmission and reception at CTC and Volvo Cars.

Volvo Cars cloud

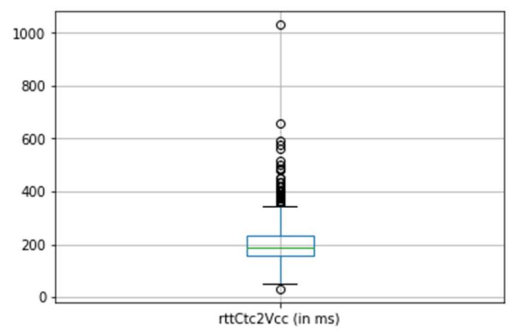
Volvo Cars cloud manages the AD on/off based on information from different sources including that from CTC. If the AD advisory message has a confidence level of "CERTAIN", Volvo Cars cloud will disable the AD mode and responses to CTC.

Functionality	Volvo Cars is able to receive AD advisory from CTC and adapts AD mode accordingly.
Assessment	It has been observed from VCC operating platform that the AD advisory messages are received and logged.
Functionality	Volvo Cars is able to disable AD mode based on its own decision criteria and information from AD advisory such as upon reception of a "CERTAIN" advisory.
Assessment	It has been observed at Volvo Cars operating platform through the AD mode on/off status, and also map visualization at both Volvo Cars and CTC.
Functionality	Volvo Cars is able to update the AD ON/OFF statuses to CTC.
Assessment	It has been observed at both CTC and Volvo Cars that AD ON/OFF status is continuously updated and synchronized.

End-to-end (E2E) system

The ultimate project makes it possible that AD vehicles are able to switch off AD mode when an EV is approaching and give way, and switch ON AD mode once the EV has passed. The E2E functionalities are listed as follows.

Functionality	The AD vehicles switch OFF AD mode upon approaching EV and give way accordingly. Technically, this is done at Volvo Cars by reception of AD advices with 'CERTAIN' statuses.
Assessment	We have observed during a public demonstration that the AD vehicles received AD OFF command before EV is approaching and then gave way to EV.

<table>
<tr><td>Performance - E2E latency</td><td>The E2E latency here is the round-trip time (RTT) from an AD Advice is sent from CTC until an AD Response is received at CTC (i.e., CTC -> Volvo Cars -> CTC).</td></tr>
<tr><td>Assessment</td><td>The RTT is calculated based on the 1813 AD advisory and their corresponding acknowledge messages. Average RTT is 202.57 ms.</td></tr>
<tr><td>Statistical summary</td><td>
<table>
<tr><th></th><th>rttCtc2Vcc (in ms)</th></tr>
<tr><td>count</td><td>1813.000000</td></tr>
<tr><td>mean</td><td>202.570916</td></tr>
<tr><td>std</td><td>70.777248</td></tr>
<tr><td>min</td><td>31.252861</td></tr>
<tr><td>25%</td><td>156.244755</td></tr>
<tr><td>50%</td><td>187.510252</td></tr>
<tr><td>75%</td><td>234.375238</td></tr>
<tr><td>max</td><td>1031.264067</td></tr>
</table>


</td></tr>
</table>

Summary of functionality

As shown in the above tables, the major functionalities of the AD Aware Traffic Control with emergency vehicles have been achieved and demonstrated at different occasions. Performance metrics including the mission update frequency, number of incidents, number of advices, latency between SOS Alarm to CTC, end-to-end latency between CTC and Volvo Cars have been studied with available data logs. Mission update interval is decided by SOS Alarm system, and the average update interval is about 23 seconds. Latency (single trip) between SOS Alarm and CTC is in average 253 ms, while round trip time between CTC and VCC is 203 ms. In average for each mission, 13 incidents are detected, and MPP has been re-calculated 7 times. For each incident and the affected road segment, averagely 3 advices are generated with ‘probable’ status before an advice with ‘certain’ status is generated. In average, the ‘certain’ advice is repeated 4 times for the incident and the affected road segment.

Distributing sensitive information

EV information is a type of sensitive information as it may relate to the personal information of a patient, the victims at a traffic accident, etc. It is thus important to protect such information from misuse. The common practice is that such information is kept within the emergency response systems.

EV is a special type of vehicle that on the one hand need to execute its mission as efficient as possible, on the other hand need to make sure safety and information security are not compromised. In the complex city traffic environment, cooperating with other road vehicles and infrastructure will help to facilitate the EV and avoid potential safety risks. For such purposes, EV information needs to be exchanged with other systems such as road infrastructure or other vehicles. The current practice with Siren is not optimal as it may cause difficult situations for other drivers to give way, especially in Sweden where a common practice to give way doesn’t exist. Sharing EV information through different channels may help the other road users to give way in a safer manner, allow the infrastructure to adapt its status such as traffic to give priority, thus assisting the EV passage. In view of the benefits, emergency vehicle approaching has been considered one of the Day-1 services and has been under pilot in different EU countries. Depending on the platforms use by the EV, different concerns exist for distributing EV information.

Current practices to distribute EV information

The current practice in C-ITS is to distribute EV information locally through C-ITS network. The C-ITS cooperative awareness message (CAM) and Decentralized Environmental Notification Message (DENM) is able to carry EV specific information and broadcast to all surrounding connected vehicles and road infrastructure to allow other road user to react ahead of time and infrastructure to adapt the statuses The range of the broadcast messages is down to 150 m in a dense city environment up to 500 to 800 m in open areas with line of sight. This follows the same procedure of Siren and Alarm while the only difference is that information is sent digitally. Under such scope, the distribution of EV information is protected by the security framework within C-ITS. In addition, as declared in C-ITS, messages exchanged through C-ITS network are considered as personal information, thus protected by GDPR. As a temporary measure C-ITS message broadcast is proposed to be based on “contract fulfilment” but in the longer term “public interest” is the preferred solution, but that might take many years of legislative work. As also suggested by US DOT, connected vehicle information should be only used locally, meaning no personal information will be logged for any purposes including law enforcement, thus minimizing the possibilities of being misused. It is thus expected in such cases, EV statuses should not be able to be tracked for the whole trip.

In the case of sending EV information through cellular networks, the work is similar to what has been done within C-ITS except the realization technologies. Since sending information through cellular networks involve middle partners, e.g., cellular operators, OEM clouds, the situation requires organizational collaboration and consensus for distributing such information. Up to now, this is done in an ad hoc way, while clear rules for EV information sharing and logging is not available. In addition, sending C-ITS information through cellular networks is one work task under investigation by e.g., the 5G automotive association 5GAA and up to now it is GDPR that applies for C-ITS information. In the meanwhile, works in e.g., C-ROADS, ACEA are under investigation for a vehicle data sharing platform that could provide a solution for future EV information sharing.

In Sweden based on our interview, this is no such EV distribution framework, and such information sharing is under consideration, driven by SOS Alarm in a national level and rescue agency in a local level. Due to the fact the emergency response is mostly at a region and municipality level, the collaborative framework is mostly happening at the local level with an ad hoc fashion. Distribution of EV information may apply if a service agreement is signed to make sure the security of information. And in the case of ambulance, such a framework already exists for patient information protection, it is suggested to check and follow the patient information protection procedures for EV information distribution. However, same challenges exist for ambulances as they don’t yet communicate with other vehicles, thus no information sharing.

AD Aware traffic control - EV information distribution

AD Aware traffic control is a cellular/cloud-based solution for emergency vehicle warning which involves middle partners including service providers, cloud providers as well as OEMs. EV information is only shared from SOS Alarm to CTC at the current stage, while there is no exact EV information shared with other partners. Instead of direct EV information, an AD Advisory message is shared with OEMs indicating the existence of EV on a certain road segment. With a long road segment, it is essentially not possible to tell the exact location of EV.

In comparison to emergency vehicle approaching in C-ITS, in addition to the network part, there are many differences which may have both advantages and disadvantages. AD aware traffic control considers autonomous vehicles. In such cases, AD advisory with potential existence of EV on the road segment is only shared to the OEM cloud, not the road vehicles themselves. It is thus generally not possible for each individual vehicle to track the existence of EV. The security and integrity responsibility are thus mostly an organizational issue, i.e. all the middle partners bear responsibility to protect the information. Assuming a proper setup of organizational agreement and proper installation of security mechanism, the information is well protected. This may be an advantage over C-ITS as even with GDPR and security methods, due to the broadcasting nature of C-ITS messages, it is not impossible to track certain vehicles once large number of records are collected.

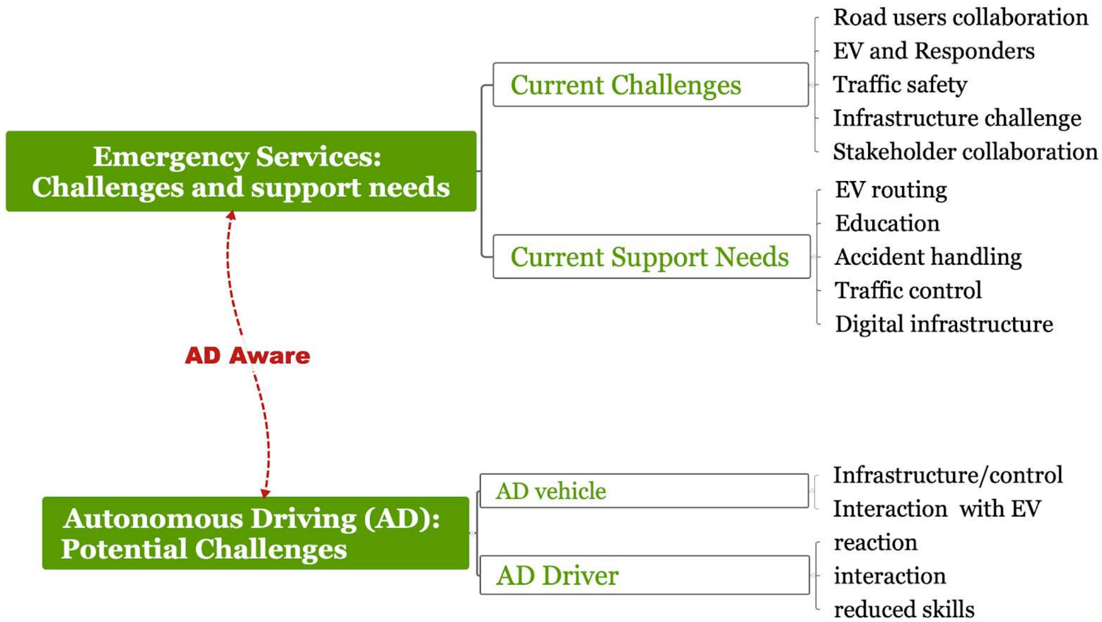
On the other hand, without exact location and intention, it may be hard for other road vehicles or the OEM cloud decision unit to come out a proper plan when exactly the related vehicle should give way. Up to now, it is binary information (EV on the road or not, AD on/off), and it is expected more detailed maneuver plan can be produced with more exact EV information.

Based on our observation, the AD vehicles are able to receive proper indication to turn off AD when EV is approaching, indicating correct decision has been made at the OEM cloud. This partially proves the effectiveness of distributing the “not exact EV information” in such as fashion. Much more detailed investigation is yet to be done to prove the effectiveness, and to identify potential issues, advantages and disadvantages of such a method.

Societal impact

To identify current challenges related to emergency and rescue services and how these challenges might be addressed by a system such as AD Aware Traffic Control - Emergency vehicles, a series of interviews was conducted with key stakeholders in Sweden including the Swedish Association of Local Authorities and Regions (SKL), Swedish Transport Administration (Trafikverket), Swedish Civil Contingencies Agency (MSB), Emergency services in Halmstad, SOS Alarm, and EVAM. The interviews were open-ended and lasted from 30-60 minutes. In addition, three workshops were organized where the topic was discussed in more detail: one with the organizations participating in the project, one with the Emergency services in Gothenburg (Räddningstjänsten Storgöteborg), Göteborg, Sweden, and one with the rescue team in Mölndal, Sweden.

The information collected in the interviews and the workshops was then summarized and analyzed using information reduction methodology. From this, commonly themes were identified. These are presented in the following figure and discussed in more detail in the following sections.



Current challenges

In this section we present common themes related to current challenges that emerged in the interviews and workshops.

One common theme mentioned in the interviews and workshops was the lack of **collaboration and common understanding between different road users**. To start with, warning sirens and lights on emergency vehicles are commonly used today to make other road users aware of the approaching emergency vehicles. However, when other road users hear/see such warnings it is often too late in terms of clearing the path for the emergency vehicles. Many drivers experience such situations stressful, especially when the emergency vehicles are approaching from behind. This, in combination with insufficient knowledge on appropriate actions when emergency vehicles are approaching, leads to behaviors that are in general difficult to foresee by the drivers of emergency vehicles. To exemplify:

> *Oberäkneliga trafikanter, man vet inte hur de reagerar när man kommer, vissa tvärbromsar, flyttar sig åt fel håll.*
>
> *Vanligt att andra trafikanter upptäcker att brandbilen kommer försent om de använder telefoner, radio etc. Mest problematiskt när brandbilen kommer bakifrån*.

Furthermore, it is not uncommon that some drivers choose to move to the left while some others move to the right, and thereby make it even more difficult for emergency vehicles to pass by. On top of that, some drivers try to pass before emergency vehicles. One possible explanation is that they suspect that the road may get closed when the rescue services arrives to the accident place:

> *Vissa trafikanter vill trängas förbi. Ofta tror de att vägen blir avstängd när utryckningsfordon kommit fram och då vill de passa på att åka förbi.*

An additional issue is that other road users try to record the situation (e.g., traffic accident) on video or take photos instead of paying attention to traffic:

> *Farligast när brandmännen kommer ut ur fordonen vid en trafikolycka…de förbipasserande filmar etc. vilket kan skapa osäkra trafiksituationer*

Even when drivers do everything right, a common misconception is that there is only one emergency vehicle coming and when that vehicle passes the drivers go back to their ordinary positions. This slows down the rest of emergency vehicles:

> *Svårast när ett utryckningsfordon kommer förbi och andra trafikanter börja röra på sig, och då kommer nästa utryckningsfordon som får det svårare att komma – och det är inte enkelt för långtradarna att flytta på sig åt sidan fort.*

Other road users are, however, not the only ones causing confusion. The intentions of emergency vehicles are sometimes rather unclear and other road users are having difficulties to anticipate their paths.

Another theme yet was **lack of prior knowledge on emergency missions**. To start with, the first responders usually do not have details about accidents and people involved in these accidents. By knowing, for example, the number of involved, injury type and type of vehicle they could prepare they actions in advance. However, an additional challenge is that there is often only one responder per emergency vehicle (driver) and there is limited opportunity for preparation. Furthermore, drivers of emergency vehicles currently do not obtain detailed information on the traffic situation along the way to the accident, which could sometimes lead to delays in traffic.

Various aspects of **traffic safety** were also discussed. A major challenge, especially related to road accidents, is to create a secure accident zone. That is, to ensure that potential risks are contained and that first responders are not exposed to some additional threats. Eliminating the risk of secondary accidents is, however, not an easy task as some drivers act in inappropriate and unpredictable way (e.g., trying to pass by, taking photos).

An additional theme includes **infrastructure challenges** such as small roads making it difficult to reach the destination for some emergency vehicles such as fire-trucks. Small roads are also challenging from the perspective of other road users as the space for clearing the roadway is limited. As a consequence, emergency vehicles are sometimes driving in the opposite direction to the traffic flow:

> *Det kan hända att utryckningsfordon kör mot trafik, då utsätter vi oss för stor fara och får krypköra. Om folk har ingenstans att ta vägen så står vi still. Man tutar och så småningom kommer vi fram. Ibland går någon av trafikanterna ut och dirigerar.*

Road re-constructions are also challenging for the first responders. Road authorities provide emergency services with some overall information about larger road reconstructions, but details are often unknown in advance. On top of that, roadworks is rather dynamic and change all the time:

> *Ombyggnation av vägar, dålig information kring detta. Fruktar all vägombyggnation under de kommande 10 åren. Får information men det händer mycket och det händer fort.*

Traffic light priority is also something that is lacking today and that could make emergency missions more efficient and smoother.

Collaboration between different stakeholders was mentioned as an obstacle, and something that could be improved in order to make the work of first responders more efficient. Authorities should work more on informing and educating public on how to act and interact with emergency vehicles. Today, there are only a few road signs informing road users on how to clear the path for approaching emergency vehicles. In some other countries, this topic is clearly emphasized in the driver license education.

Current support needs

One of the major support needs is to **ensure that both EV drivers and other road users show their intentions**. As such a solution that makes them to plan their path would be useful. It is, however, important that the information about the EV path is not broadcasted to all but only to those who are in the vicinity. Since EVs change their path frequently and information might quickly become invalid.

Educating other road users in proper behavior in interactions with emergency vehicles might also be necessary. This is a task mainly for the Swedish Transport Administration. There are some ongoing discussions, especially regarding road signs on which lanes should be cleared for emergency vehicles. It may help with some standardized rules communicated either via static or dynamic road signs, for instance, if there are three lanes, the EV will pass in the middle lane. Also, this should be included in the driver license education to a larger extent than today.

Today, the emergency vehicle drivers do not use much technical support. While vehicles are equipped with navigation systems, the EV drivers often select routes based on their experience and knowledge about the area. In some rescue centers, there are also digital screens showing the real-time video from some key traffic cameras (e.g., from tunnels) that EV drivers can check prior to departing to get a better situation awareness. Future **navigation systems should motivate their suggestions** to gain acceptance of EV drivers.

Another potential support is a **system informing the first responders about the vehicle(s) involved in the accident**. Useful information includes type of vehicle, type of crash, engine powering, batterie type and status, etc. This will come to SOS -Alarm in the EU eCall (vehicle VIN number) from all new vehicles from now on.

Green wave for EV vehicles is also something that would optimize emergency missions. That is, EV should be able to communicate with traffic lights for warranty that the EV get green traffic signal.

On the road infrastructure side, it would helpful with **adaptive speed bumps** that become flat when emergency vehicles are approaching. Speed bumps are especially challenging for fire trucks.

While these means could contribute to reduced arrival time, it is even more important to **optimize the time spent at the accident scene**. Today, it is common that removal of vehicles and other obstacles from the accident scene takes long time, exposing the first responders to an unnecessary long risk as well as contributing to traffic congestions. The work process itself needs to be optimized as well as the arrival of towing-vehicles. In addition, digital solutions to protect the work zones such as geo-fencing could be introduced.

Benefits of AD Aware or similar system

The **ability of automated vehicles (AV) to handle poor infrastructure and temporary traffic regulations** were frequently discussed themes. One of the questions raised was whether AVs will be able to recognize various gestures that are today used at accident scenes. Related to this, it was highlighted that AV need to be able to **handle various types of exemptions** when interacting with EVs. As such a system that makes AVs aware of EV and their trajectory was perceived as essential.

Two control regimes of AVs were discussed, one where the AV handles EV in its own way and one where the AV gives maneuvering control to human driver when EVs are approaching (i.e. like in the current version of AD Aware Traffic Control). On the one hand, it was positively perceived that the AV gives control to the driver. On the other hand, several concerns that could jeopardize safety were raised such as the ability of human drivers to react on time and to create a sufficient situation understanding when requested to take over control as well as skill degradation.

Different stakeholders' requirements and contributions to the system

The AD Aware traffic control platform involves some of the major partners in the emergency response system including the SOS Alarm, service providers (i.e., Carmenta), communication solutions (i.e., Ericsson), as well as one OEM (i.e. Volvo Cars).

From SOS Alarm perspective, any efforts that can help EVs to reach the destination efficiently are welcome. SOS Alarm already starts sharing EV information to service providers such as CTC for better situational awareness, and better and more frequency EV update could be possible in the future. Sharing sensitive information is thus challenging, and information security and privacy have to be properly handled in such a system.

CTC is the control center in such a system which handles the EV information, the traffic situation, the potential conflict with AD vehicles, as well as advice generation for OEMs. In order for a better decision, more accurate and frequency EV position update will be needed. In addition, more advanced algorithms will be needed for predicting the potential EV routes, as well as the conflict with AD vehicle routes. For such purposes, historical EV route information is very valuable.

Ericsson provides cloud solutions that enables reliable message exchange between different stakeholders during the rescue process. This will be a must in any of the future connected rescue systems. Capacity analysis is needed to make sure that the system is scalable for supporting more EVs and in the future more OEMs.

Volvo Cars as a representative of OEMs has contributed with their cloud solutions to control the AD vehicles. It receives AD advices from CTC via Ericsson cloud and makes decisions based on that together with other sources of information. For a safe and efficient interaction between AD vehicles and EV, in the near term before fully automated vehicles, human drivers must be included in the investigation. System may need to be improved by considering the needs of both EV and other road vehicles including drivers.

Report part C:
Autonomous Driving Aware Traffic Control Advanced Cooperative Driver Assistance
December 2019

Version History

V0.1 20191210	First skeleton	Mikael Gråsjö, Carmenta
V0.2 20191217	Added text to System solution	Mikael Gråsjö, Carmenta
V0.3 20191218	Added “Ericsson” parts Added the rest of Carmenta parts	Anders Fagerholt, Ericsson Mikael Gråsjö, Carmenta
V0.4 20191220	Added CEVT parts	Christina Mylona, CEVT
V0.5 20200107	Added VCC, Ericsson, clean up	Anders Fagerholt, Ericsson
V0.6 20200108	Fixed some typos	Mikael Gråsjö, Carmenta
V0.7 20200109	Updated info about RISE, changed from “RISE Viktoria” to RISE	Azra Habibovic
V1.0 20200110	Final approved version	Anders Fagerholt, Ericsson

Table of Contents

Version History
Table of Contents
Glossary
Executive Summary
Project participants
  Volvo Cars
  Ericsson
  Carmenta
  RISE
  CEVT
System description
Basic principles
System solution
  Use Cases
Systems part of the end-to-end data flow
  The CEVT Car
  The CEVT Cloud/CEVT Command Center

The Central Traffic Cloud/Carmenta TrafficWatch™
The Interchange Node
The Volvo Cloud/Volvo Cars Command Center
The Volvo Car
Findings
Conclusions
International liaisons
Future Work
Plan for commercialization and growth
Appendix D – Deliverables
WP1 - AD/ADAS Information Exchange
WP2 – AD/ADAS Cooperative Guidance
WP3 – Volvo Cars Traffic Control
WP4 – CEVT Traffic Control
WP5 – Update of AD Aware Interchange to Nordic Way profile
WP 6 – Evaluation & Societal Benefits

Glossary

ACEA	European Automotive OEM association
AD	Autonomous driving
ADAS	Advanced Driver Assistance Systems
AMQP	Advanced Message Queuing Protocol
C-ITS	Cooperative Intelligent Traffic System
C-Roads	EU project to harmonize and cross boarder test C-ITS https://www.c-roads.eu/platform.html
CAM	ETSI Cooperative awareness message
CEVT	China Euro Vehicle Technology (Geely / Volvo Cars owned OEM)
CoordCom	Carmenta´s emergency control room and communication product
CSD	Center Stack Display
CTC	Central traffic cloud (Drive Sweden Innovation Cloud)
DATEX II	EU standard for communication between traffic management centers
DENM	ETSI Decentralized Environmental Notification Message
DriveMe	Volvo Cars family of autonomous drive projects
EATA	European Automotive and Telecom Alliance
EV	Emergency vehicle
EVA	Emergency Vehicle Approaching
EVI	Emergency Vehicle Information
EU	CEF EU project type, Connecting Europe Facility
GPS	Global Positioning system
HLA	Hazard Light Alert
IHU	Infotainment Head Unit

ITS-G5	ETSI standard for short range ad-hoc communication, 5.9 GHz
MPP	Most probable path (of the emergency mission)
MSB	Swedish Civil Contingencies Agency
MQTT	Message Queuing Telemetry Transport
NIRA	NIRA Dynamics https://niradynamics.se/
OEM	Original Equipment Manufacturer (Car manufacturer)
PSAP	Public safety answering point
Rakel	Tetra radio network for public safety agencies
RISE	Research Institutes of Sweden
RSI	Road Surface Information
TETRA	Trans-European Trunked Radio Access
TLS	Transport Layer Security
UI	User Interface
UX	User Experience
VCC	Volvo Car Corporation
VTI	Swedish Road and Transport Research Institute
Zenit	The System of SOS alarm

Executive Summary

This Appendix is the concluding report of a joint public private project that has run from November 2018 to December 2019. The project was financed in part by Vinnova / Drive Sweden with partnership including Volvo Cars, Carmenta, Ericsson, CEVT and RISE. The goal of the project was to extend the previously established AD Aware Traffic Control platform with functions to demonstrate how Hazardous Location Warnings can be collected from several OEMs and safely shared between stakeholders through a Central Traffic Cloud. Existing international standards were successfully used for all message exchange and the AD Aware TC platform was also complemented with more support for C-ITS standards.

The project has demonstrated how the sharing of traffic situation data through a central level can provide a wider and more direct understanding of the real-time traffic situation and transmit this to connected entities. This means better guidance to OEMs operating AD vehicles as well as improved driver support through OEM ADAS Clouds.

Having full traffic situation awareness is a cornerstone for safer and more efficient operation of AD and ADAS vehicles fleets. The project could show concrete examples how the sharing of data in a collaborative manner improved the overall situational awareness as well as provided Advanced Cooperative Driver Assistance to specific vehicles.

The main deliverable from the project was a demonstration of the system showing a complete end-to-end message flow between Volvo Cars and CEVT vehicles over the AD Aware Central Traffic Control Cloud. The demonstration was held at Lindholmen Science Park in late November 2019.

The project utilized and built upon a lot of the already existing cloud infrastructure developed for the **Drive Sweden initiative.**

Project participants

Volvo Cars

Volvo Car Corporation have high ambitions when it comes to sustainable mobility solutions, especially within electrification and autonomous drive. Its leading position within self-driving cars is based on the world first and largest pilot for autonomous driving with real customers on public roads, Drive Me in Gothenburg. Important building blocks to secure its journey to commercial autonomous driving offer includes the joint project with Uber, extensive recruiting in Gothenburg and Zenuity (a new joint venture company with Autoliv) which will develop software for autonomous driving. The work on autonomous driving builds upon 89 years of safety know-how.

Ericsson

Ericsson is a global leader within communication systems and services. 40% of mobile calls are made through Ericsson systems and more than 2 billion people use its networks. Now, Ericsson is leading the development towards a Networked Society, where everything that benefits from being connected will be connected. The Transport sector will benefit extensively from getting connected, cooperative and automated. Ericsson is now developing and implementing communication services and cloud services to support this development. The next generation of mobile networks, 5G, is now being developed to fully support connected automation and new mobility services. Drive Sweden is a key project, with leading partners and use cases to ensure relevant and innovative input the development of 5G and related services.

Carmenta

Carmenta is a privately held Swedish company, founded in 1985, with offices in Sweden, Germany, France and Spain. Carmenta has been supplying world-class software for mission-critical systems for more than 30 years – systems in which superior situational awareness is the key to success.

Carmenta provide high performance software products, develop client-specific solutions and offer a wide range of services that help some of the world's most technologically advanced customers optimize their operations using real-time geospatial information. Its technology is designed to meet the highest standards focusing on high performance, high availability, openness and scalability, and ease of use. Carmenta's customers are found globally with a concentration in Europe.

Carmenta provides command and control technology for connected and autonomous vehicles which helps traffic network operators to improve traffic control and increase road safety. Background maps with integrated sensor data, weather forecasts, video streams and other information provide the type of common operational picture that will be necessary for the command and control systems of the future.

RISE

RISE Research Institutes of Sweden is Sweden's research and innovation partner. Through our international collaboration programs with industry, academia and the public sector, we ensure the competitiveness of the Swedish business community on an international level and contribute to a sustainable society. Our 2,800 employees engage in and support all types of innovation processes. RISE is an independent, State-owned research institute, which offers unique expertise and over 100 testbeds and demonstration environments for future-proof technologies, products and services. Developing and demonstrating research and innovation related to safe and efficient transportation of people and goods is one of our key areas. In this project, our focus was mainly on evaluating technical performance of the AD Aware platform and its social aspects.

CEVT

CEVT (China Euro Vehicle Technology): Developing Cars for a different tomorrow. CEVT is an innovation center for the future cars of the Geely Group with the purpose of being at the forefront of new developments in the automotive industry. The whole industry is now undergoing a transformation with new ways of thinking about the car as a product. CEVT is a fast growing, fast moving and exciting company where no day is like the other – where the challenges of tomorrow is on our working table today. CEVT currently consists of some 2000 people with offices in Gothenburg and Trollhättan in Sweden. CEVT currently works on projects for the car brands Volvo Cars, Geely Auto and Lynk & Co. CEVT is a subsidiary of Zhejiang Geely Holding Group.

System description

A systems of system solution based on the AD Aware Traffic Control platform was developed and extended with functions for receiving alerts from and sending warnings to VCC and CEVT vehicles. A new external web service connection was also established with the NIRA RSI system that was used to provide near real-time road condition data to the project. Using analytical functions developed in the project, hazard light alert data from VCC and CEVT was fused with information about road condition data to detect hazardous road segments. Following a set of criteria (rules) enhanced Hazardous Location Warnings could then be sent to both VCC and CEVT. The project also added the capability for CTC to unpack messages in one format and package it to the other format (DATEX II from/to ETSI DENM).

In another part of the project the EVI service developed in a previous AD Aware project was re-used with the added possibility to send Emergency Vehicle Approaching (EVA) warnings to the CEVT control system as ETSI DENM messages.

The developed system is described in more detail in the following chapters.

Basic principles

The following basic principles have been used as starting points for the project:

- OEMs have different approaches and use various solutions when implementing AD and ADAS support in their vehicle fleets. Sharing data through a central level makes it possible to collect information from several OEMs, normalize it and then dispatch it in a way each OEMs prefer to receive it (“neutral server” concept)
- Striving for the re-use of AD Aware Traffic Control as well as other Innovation Cloud services
- Finding and using international standards everywhere possible (e.g. DATEX II / ETSI / ISO). Extending standards if necessary.
- Collecting data from multiple separate sources should lower the risk of failure caused by a single source data outage.
- Combining information collected from several OEM vehicle fleets should improve the quality of information leading to better decisions.
- To centrally collect information from OEMs and then compare it, and possibly fused it with data from other connected sources should make even more informed decisions.

- If establishing an end-to-end message data flow with 100% automation the whole system should be able to execute without any manual intervention, besides monitoring.
- The AD Aware TC Operator UI should solely be used for monitoring the traffic situation.

System solution

Following on the work done in the previous AD Aware Traffic Control project, the system solution has been extended by adding a communication channel for ADAS information to the CEVT Cloud, the vehicle control center system operated by CEVT.

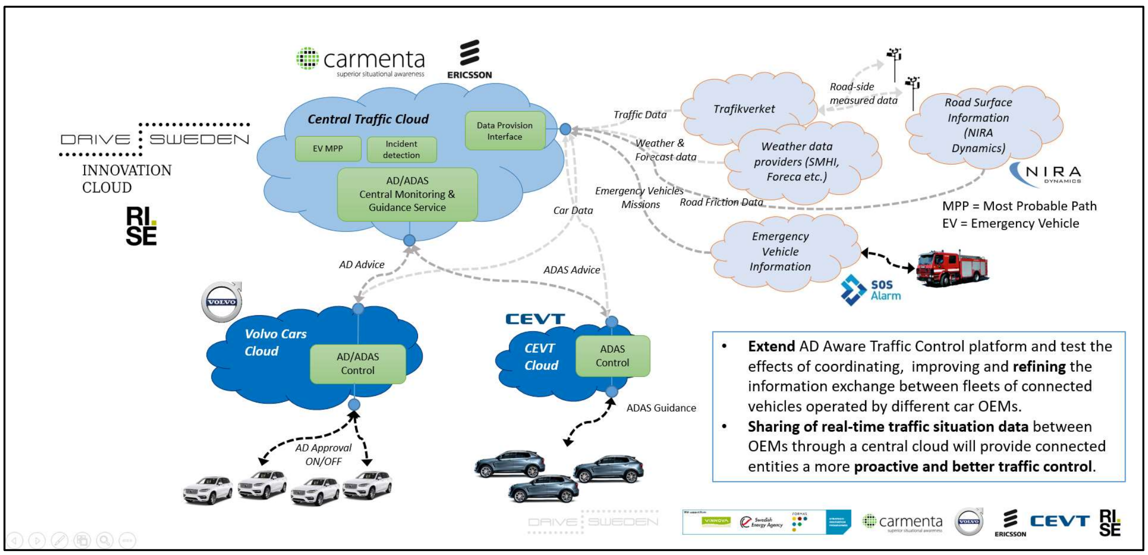


Figure 9. Schematic overview of the AD Aware Traffic Control systems of systems.

The CTC Cloud is designed to serve any number of OEM clouds by aggregating data of interest, including information about traffic, weather and ongoing rescue missions. The CTC Cloud's central function is to monitor the overall situation and with automation support trigger alerts to the OEM clouds if there are hazardous events detected in the road network. The CTC implements a publish/subscribe and request/response mechanism for data exchange based on messaging following the DATEX II standard. For the current project the CTC was extended to also support V2X data exchange using the ETSI DENM standard.

The figure below shows an updated overview of the CTC solution. The CEVT cloud system is connected through a standard AMQP message broker and the new NIRA RSI (REST) service is connected through HTTPS.

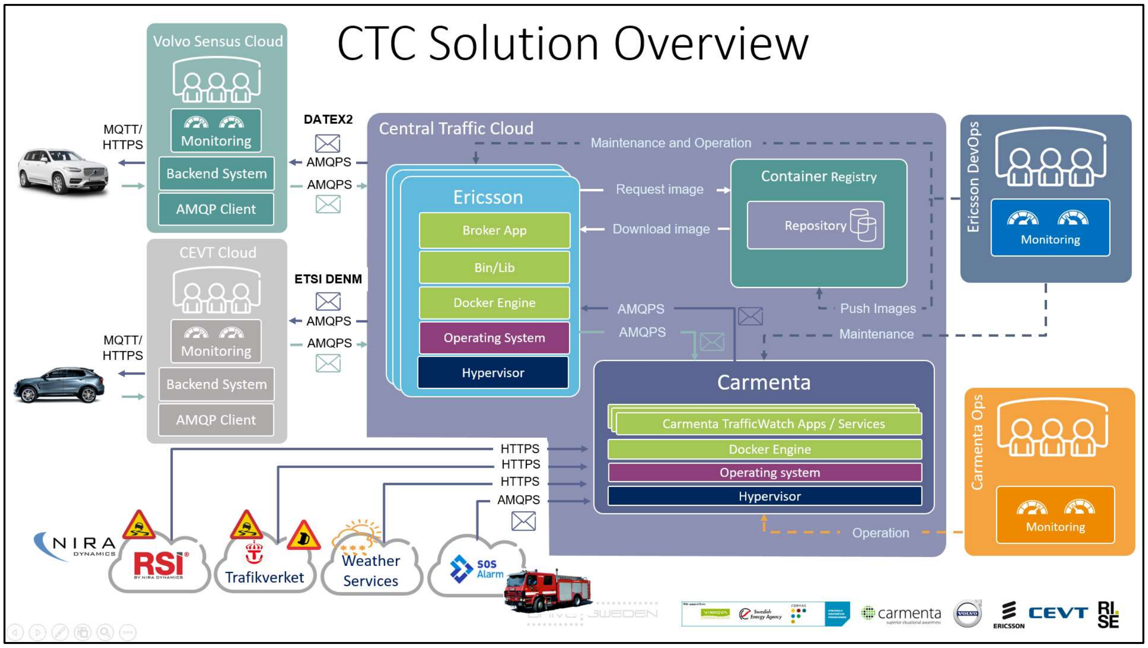


Figure 10. Diagram showing an overview of the CTC Solution after adding the CEVT command center and vehicle as well as the NIRA RSI service.

Use Cases

Two Use Cases were selected in the project to test, verify and demonstrate the data flow to support cooperative driving. The first Use Case; "Emergency Vehicle Detection and Warning", aimed to detect where and when Emergency Vehicles (EV) and their predicted paths conflicts with AD and ADAS vehicle driving.

The project re-used the EVI service developed in a previous AD Aware project and added the possibility to send Emergency Vehicle Approaching (EVA) warnings to the CEVT control system as ETSI DENM messages. Functions were also added to the Central Traffic Cloud for sending a "Bounding Box" covering the Emergency vehicle's Most Probable Path. The Bounding Box geo coordinates was sent to CEVT that then filtered out the vehicles currently driving inside the Box. Only these vehicles would then get the EVA warnings from CTC (see Figure below).

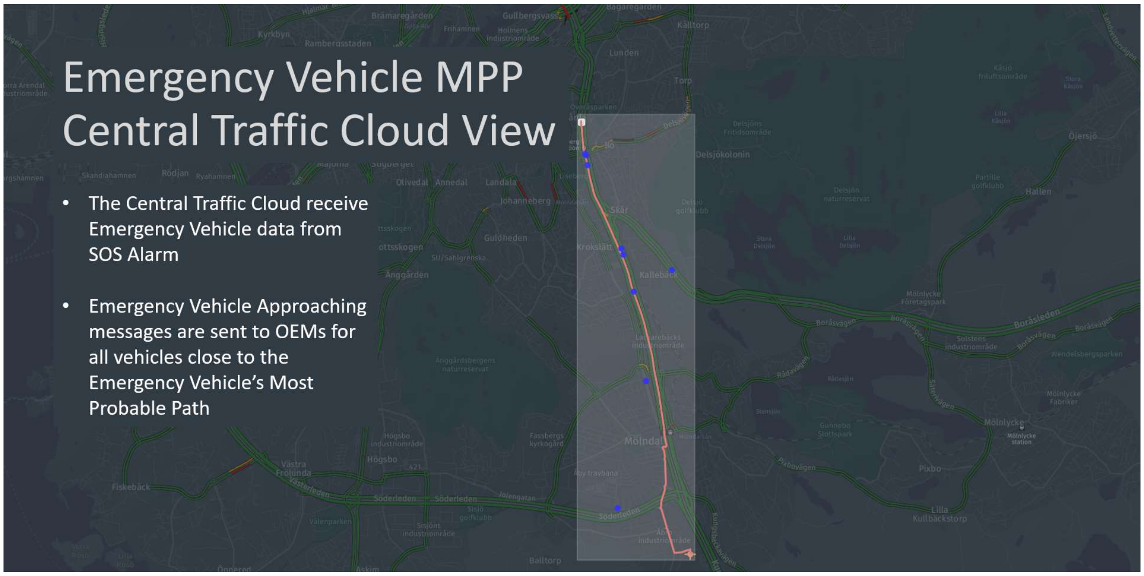


Figure 11. Screenshot from the CTC Operator UI showing the Emergency Vehicle MPP (orange line), the Bounding Box (semitransparent gray) and vehicles detected to be inside the box (blue plus signs).

The second Use Case tested and demonstrated the handling of "Dangerous traffic situations" with the collection, aggregation and distribution of "Hazardous location warnings". This was tested by setting up an end-to-end data flow where alert signals were sent to CTC from VCC and CEVT vehicles when hazard lights were turned on. The CTC then compared the locations coming in from the OEMs and took actions for sending enhanced warnings back to the OEMs depending on different situations.

In order to demonstrate how the hazardous location warnings from OEMs can be combined with data from other sources, the project did a Proof-of-Concept integration with near real-time data about low friction roads provided by the Road Surface Information[17] (RSI) service supplied by NIRA Dynamics. The RSI service continuously gathers vital road information – such as road roughness and friction – by smartly fusing information from existing sensors in cars. NIRA Dynamics have ongoing data collection from a large number of vehicles roaming the Gothenburg area thus being able to provide very good data for the project.

[17] https://niradynamics.se/road-surface-information/

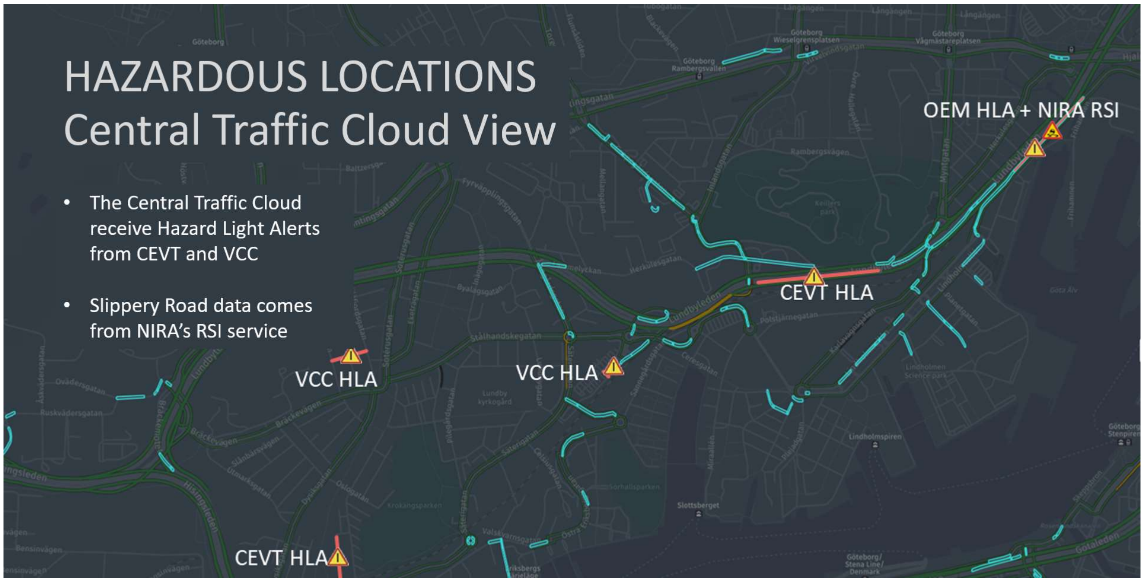


Figure 12. Screenshot from the CTC Operator UI showing Hazardous locations (red lines with warning signs) from VCC and CEVT, as well as low friction road segments from NIRA RSI (turquoise lines). Up to the right an incident is registered where OEM Hazard light alerts coincide with a low friction road segment thus creating a more serious hazard warning.

The CTC analyzed the incoming hazard light alerts from VCC and CEVT and compared their locations against each other as well as against road segments with a friction level below a threshold. This made it possible to send warnings of different types and “severity”. The following warning types were used and tested in the project:

- **Relayed Warnings**; Single hazard light alerts just relayed from one OEM to the other.
- **Multiple OEM Warnings**; Two or more hazard light alerts from both VCC and CEVT are registered simultaneously on the same road segment. These warning messages are sent with a higher ”severity level” because multiple and separate OEM vehicles report hazards on the same road segment.
- **Combined Hazard Warnings;** One or more hazard light alerts are registered on the same road segment where low friction road conditions are detected. These warnings have the highest ”severity level” because several separate data sources have registered hazards on the same road segment. These messages were also enhanced with information about slippery roads being the cause.

The project also added the capability for CTC to unpack messages in one format and package it to the other format. CTC then used the DATEX II standard for communicating with VCC and ETSI DENM for CEVT.

The end-to-end data flow is explained in more detail in the next chapter.

Systems part of the end-to-end data flow

The information exchange between the different systems in the project constitutes an end-to-end flow of messages starting from one OEM (i.e. CEVT) vehicle and going to the other OEM (i.e. VCC) over a central cloud (i.e. CTC) and back. The figure below illustrates the data flow and the systems it passes. Following in this chapter are more detailed descriptions on how each system

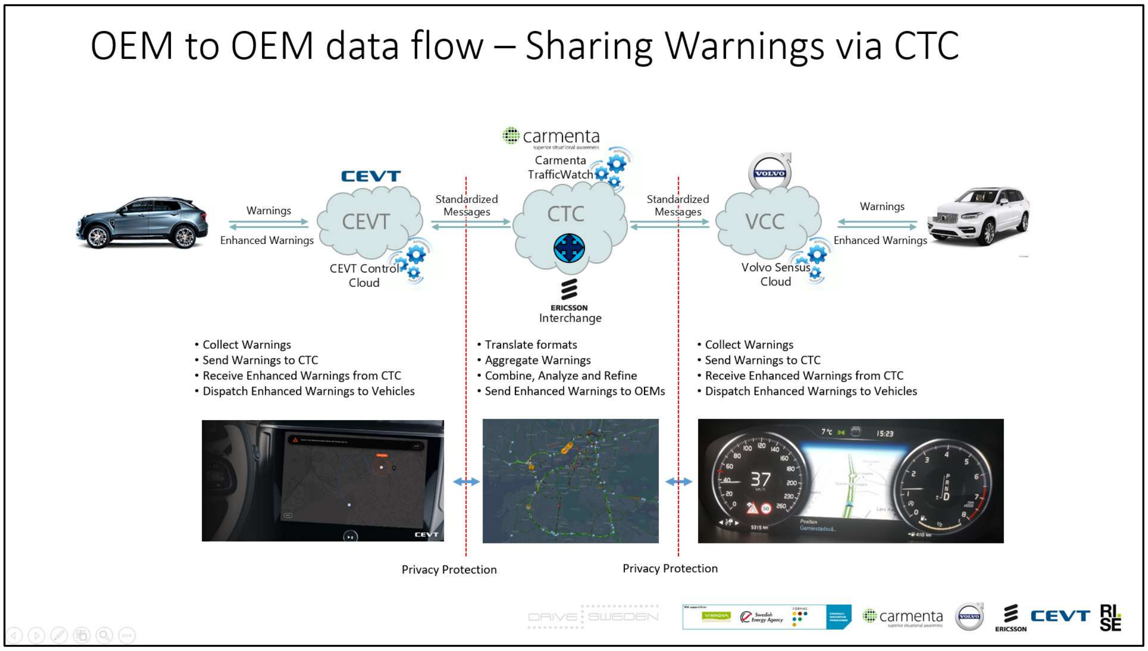


Figure 13. Schematic overview of the end-to-end data flow to/from VCC and CEVT vehicles.

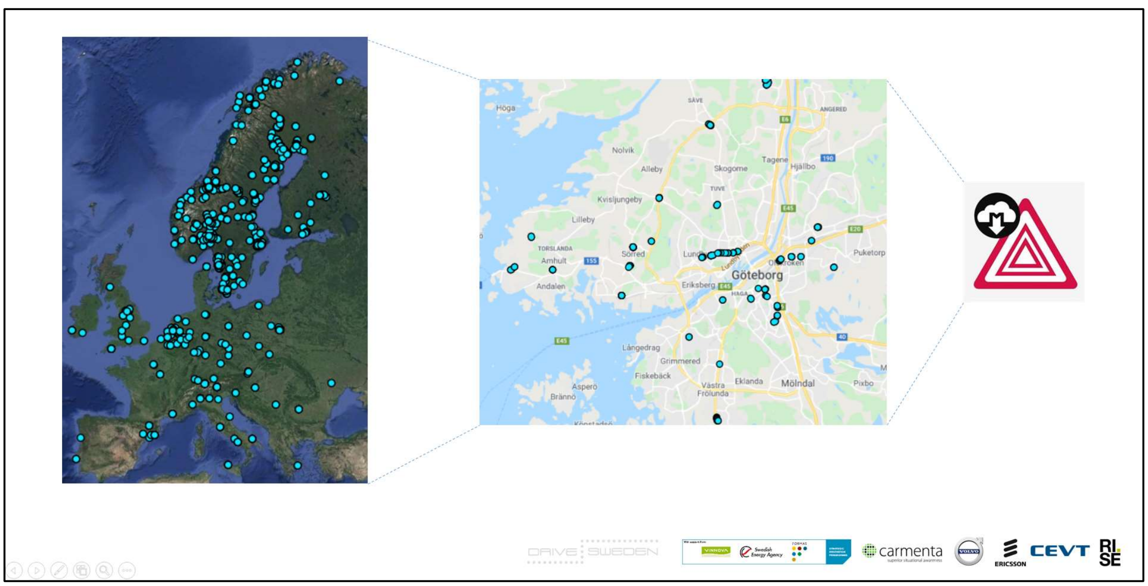


Figure 14. Screenshot of real-life hazard light alert messages from Volvo production cars.

The CEVT Car and Cloud

Technical Solution

An application prototype was developed and flashed on the Infotainment Head Unit (IHU) of a testing vehicle. The application included a Hazard Light activation button, for test purposes. The driver used this application during the live vehicle testing, to send Hazard Light alerts and vehicle-positioning messages to CEVT cloud, which then forwarded them to CTC. The application also included the functionality to receive CTC messages for hazard alerts (Hazard Lights activated by other OEM vehicle drivers) and incoming Emergency Vehicles.

When CTC identifies that another OEM vehicle has activated a Hazard Light alert in proximity to a CEVT vehicle, an alert message is pushed from CTC to the CEVT Cloud, then to the vehicle IHU and then displayed in the Center Stack Display (CSD). Also, when CTC detects that a CEVT vehicle is within an approximate area of an Emergency Vehicle's most probable path, an "incoming EV" alert message is pushed from CTC to the CEVT Cloud, then to the CEVT vehicle IHU and then displayed in the CSD.

Specification of User Experience design concept

CEVT has developed a User Experience concept and specification on how to communicate the project-related information to the drivers. The main purpose is to increase situational awareness, while not causing unnecessary information overloading. The UX specifications are following the design guidelines from the design system "Material" (https://material.io/components/).

The following interaction scenarios where developed, for the 5 different types of message exchanges:

1. Hazard Light Activation in vehicle

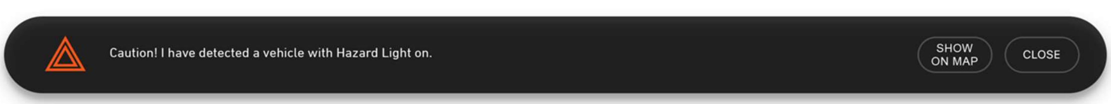
When the driver activates the Hazard Light button, the following should be displayed on the Center Stack Display (CSD):

A banner notification, with text informing that the Hazard Light Alarm has been sent to nearby vehicles. The banner should include the action "Close", to dismiss the notification.

2. Hazard Light Alert from single vehicle

When the system receives a Hazard Light Alert from a nearby vehicle, the following should be displayed on the CSD:

A banner notification, with a Hazard Light icon, text that informs Hazard Lights have been activated by a nearby driver, a warning to "Be aware" or change path, and the following actions: A. "Close", B. "Show on Map".



If the driver selects action B, "Show on Map", the following should be displayed:

I. A map visualization, with the current location area of the driver.
II. An icon symbolizing the driver's vehicle on the map and the most probable path of the vehicle,
III. An "Hazard Light On vehicle" icon, symbolizing the location of the other vehicle that is sending Hazard light alert message,
IV. A "back" button, to return to the previous CSD display, as it was before the event.

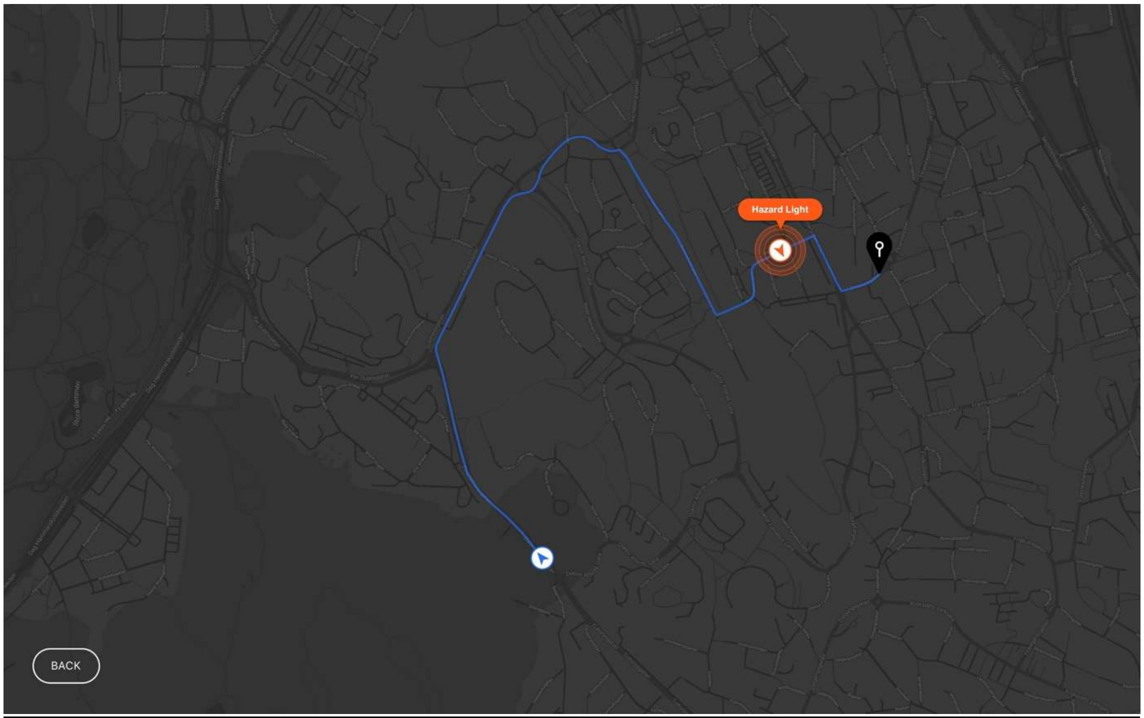


Figure 15. Map display of Hazard Light Alert from single vehicle.

3. Hazard Light Alert from multiple vehicles

When the system receives an enhanced Hazard Light Alert (from many vehicles), the following should be displayed on the CSD:

A banner notification, with a Hazard Light icon, text that informs multiple Hazard Lights have been activated nearby, a warning for "Caution" or "Be aware" or change path, and the following actions: A. "Close", B. "Show on Map".

If the driver selects action B "Show on Map", the following should be displayed:

I. A map visualization, with the current location area of the driver.
II. An icon symbolizing the driver's vehicle on the map and the most probable path of the vehicle,
III. An "Hazard Lights - On Area" icon, symbolizing the location where multiple Hazard Lights have been activated,
IV. A "back" button, to return to the previous CSD display, as it was before the event.

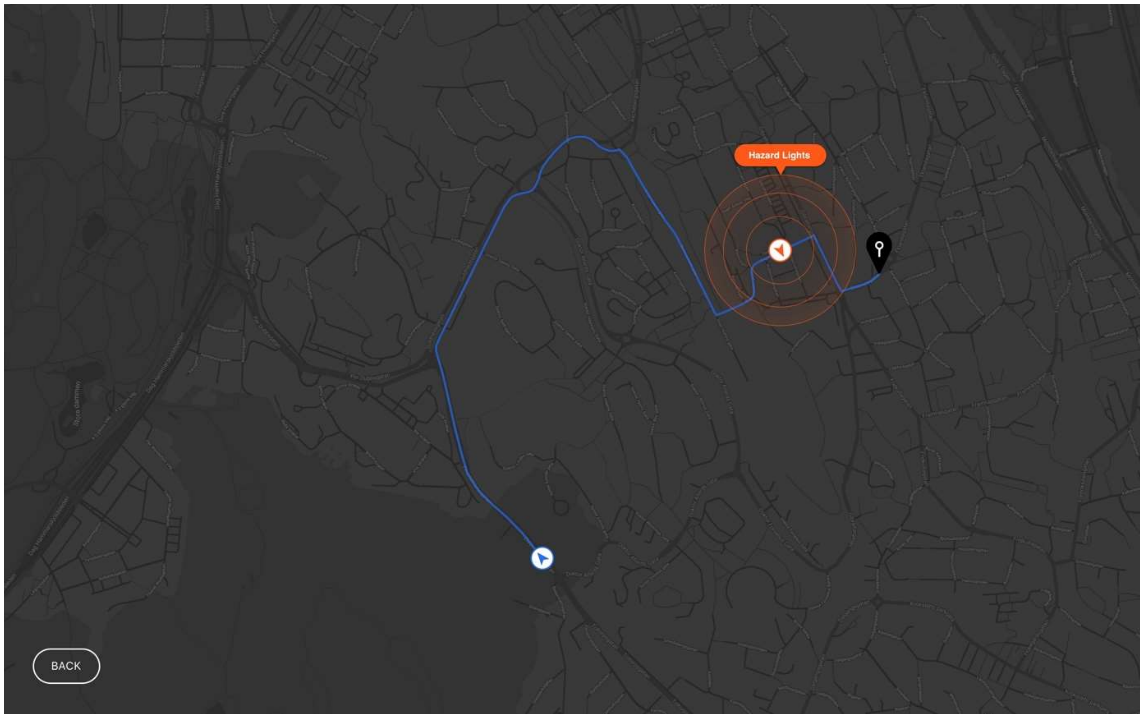
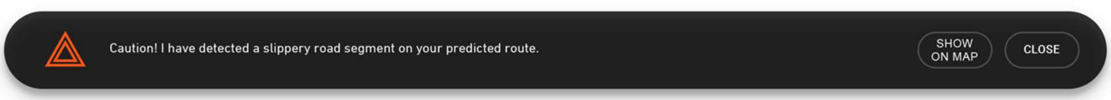


Figure 16. Map display of Hazard Light Alert from multiple vehicles.

4. Slippery Road Alert

When the system receives an enhanced Hazard Alert (from NIRA IRS services), the following should be displayed on the CSD:

A banner notification, with a Hazard Light icon, text that informs a Slippery Road Segment has been identified, a warning for “Caution” or “Be aware” or change path, and the following actions: A. “Close”, B. “Show on Map”.



If the driver selects action B “Show on Map”, the following should be displayed:

I. A map visualization, with the current location area of the driver.
II. An icon symbolizing the driver’s vehicle on the map and the most probable path of the vehicle,
III. A “Slippery Road Segment” icon or visual street symbolization, showing the location of the hazardous condition of Slippery Road,
IV. A “back” button, to return to the previous CSD display, as it was before the event.

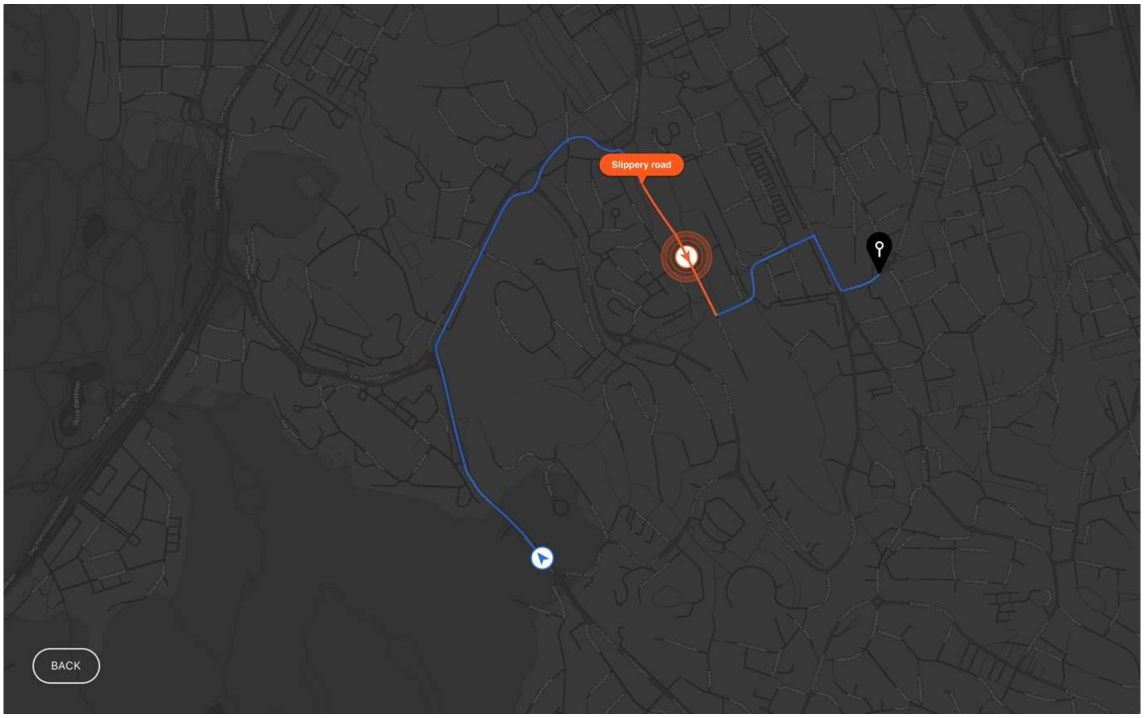
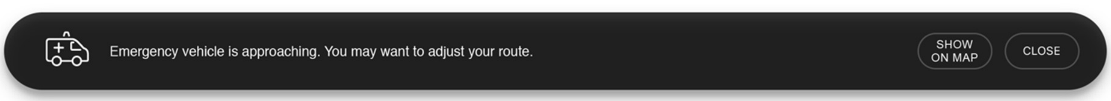


Figure 17. Map display of Slippery Road Alert.

5. <u>Emergency Vehicle Incoming</u>

When the system receives a message about an incoming Emergency Vehicle in the vicinity of the driver's most probable path, the following should be displayed on the CSD:

A banner notification, with an Emergency Vehicle icon, text that informs that an EV is approaching, the approximate time of meeting the EV on the road, a warning for "Caution" or "Be aware" or change path, and buttons with following actions: A. "Close", B. "Show on Map".



If the driver selects action B "Show on Map", the following should be displayed:

I. A map visualization, with the current location area of the driver.
II. An icon symbolizing the driver's vehicle on the map and the most probable path of the vehicle,
III. An "Emergency Vehicle" icon (symbolizing the location where the EV currently is), the most probable path of the EV and an icon for the location where driver and EV are expected to meet.
IV. A "back" button, to return to the previous CSD display, as it was before the event.

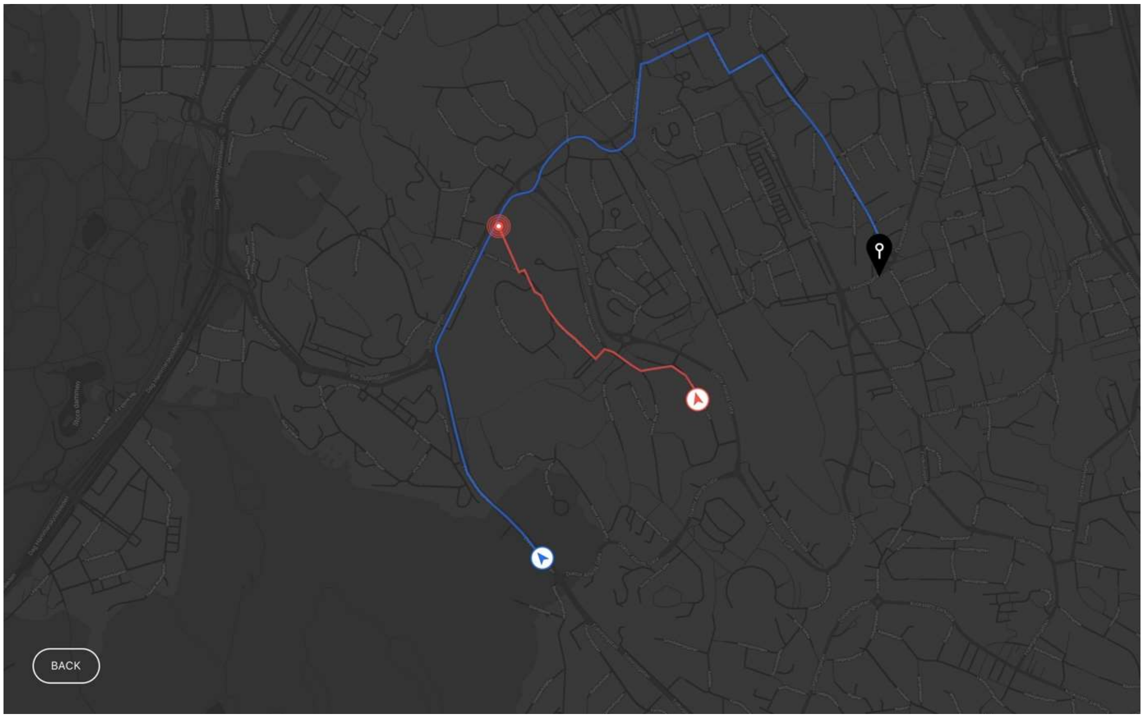


Figure 18. Map display of Emergency Vehicle Incoming.

The Central Traffic Cloud/Carmenta TrafficWatch™

The main capabilities provided by the AD Aware CTC platform and Carmenta TrafficWatch in this project are to create and maintain an aggregated traffic situation picture at a central traffic management level to automatically as well as interactively dispatch guiding messages (example driving 'recommendations') to connected OEMs. The traffic situation picture established in this project and used for testing was mainly composed of the following data layers:

- A detailed background map of the supervised region (Göteborg)
- The geometry and characteristics of the physical road network
- Real time traffic information from Trafikverket
- Hazard light alerts from connected OEM vehicles
- Weather data including road conditions
- Low friction road segments from the NIRA RSI service

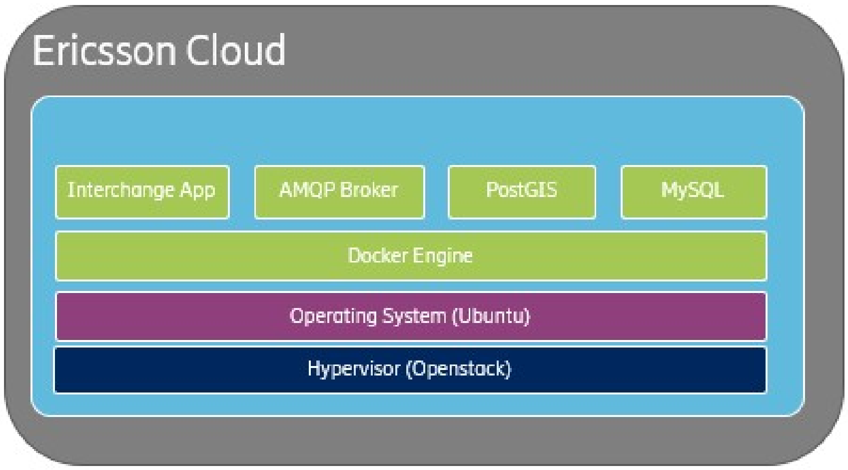
In the data flow; CTC receives hazard light alerts from VCC and CEVT through the Interchange Node. The incoming alerts are analyzed and their locations compared against each other as well as against road segments with a friction level below a threshold. Based on the analysis result warnings of different types and "severity" are then sent "downstream" to receiving OEMs.

The Interchange Node

In the first AD Aware TC project the interchange function just connected Volvo Cars and Carmenta. In the second project ports were added for dummy OEM´s. In the meantime, Nordic Way 1 and 2 further developed the interchange. In the AD Aware TC Cooperative Driver Assistance project the latest version of the Nordic Way interchange was reused. The project added support to use the concept of “private channels” that are only seen by selected users. The interchange is an AMQP broker – a publish / subscribe mechanism. See figure below for a schematic view of the solution.

The Nordic Way Interchange consists of the following components

- AMQP Broker
- PostGIS (geo look-up function)
- MySQL (logging tool)
- InterchangApp



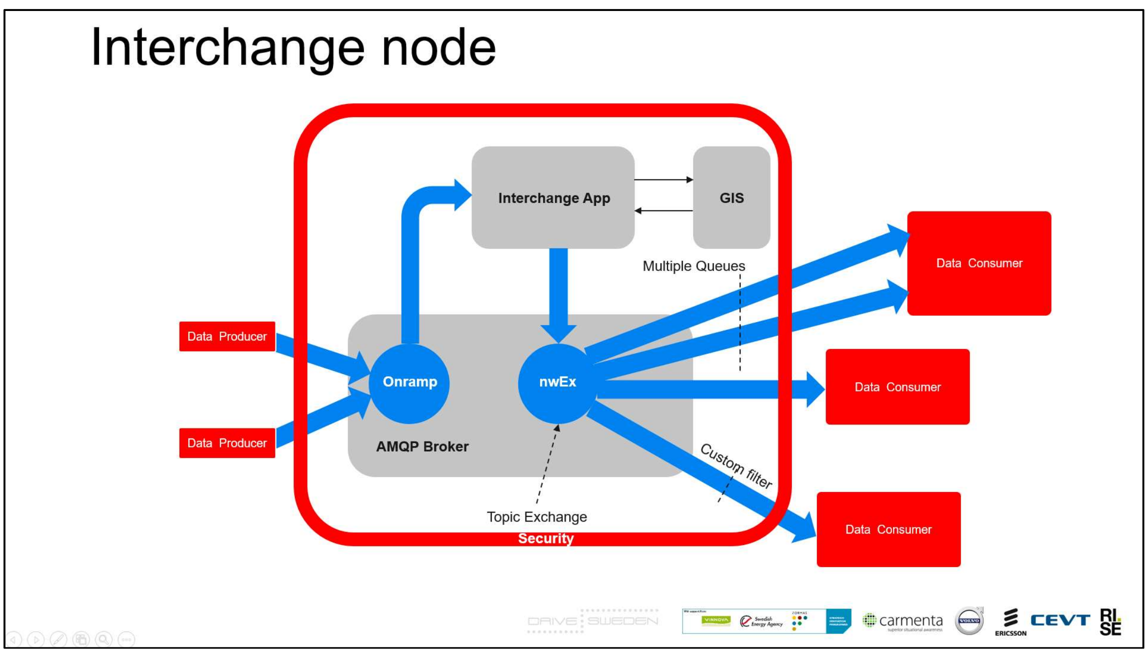


Figure 19. Schematic view of the Interchange Node.

The Volvo Cloud/Volvo Cars Command Center

The processing required to realize the Connected Safety function is located within the Volvo cloud and provides a global service to all its cars. All Volvo cars that have this option enabled communicate their position to the cloud at regular intervals and each position is mapped matched to a road, then for each car a most probable path is calculated.

If any of these cars detects a situation or activates its hazard lights this is also sent to the cloud and again map matched.

Then if any car has a most probable path that intersects an ongoing situation a warning can be sent to the car to be displayed to the driver.

These situations can be seen in the cloud and the screenshot below is an example of the situations around the Göteborg area during a winter morning.

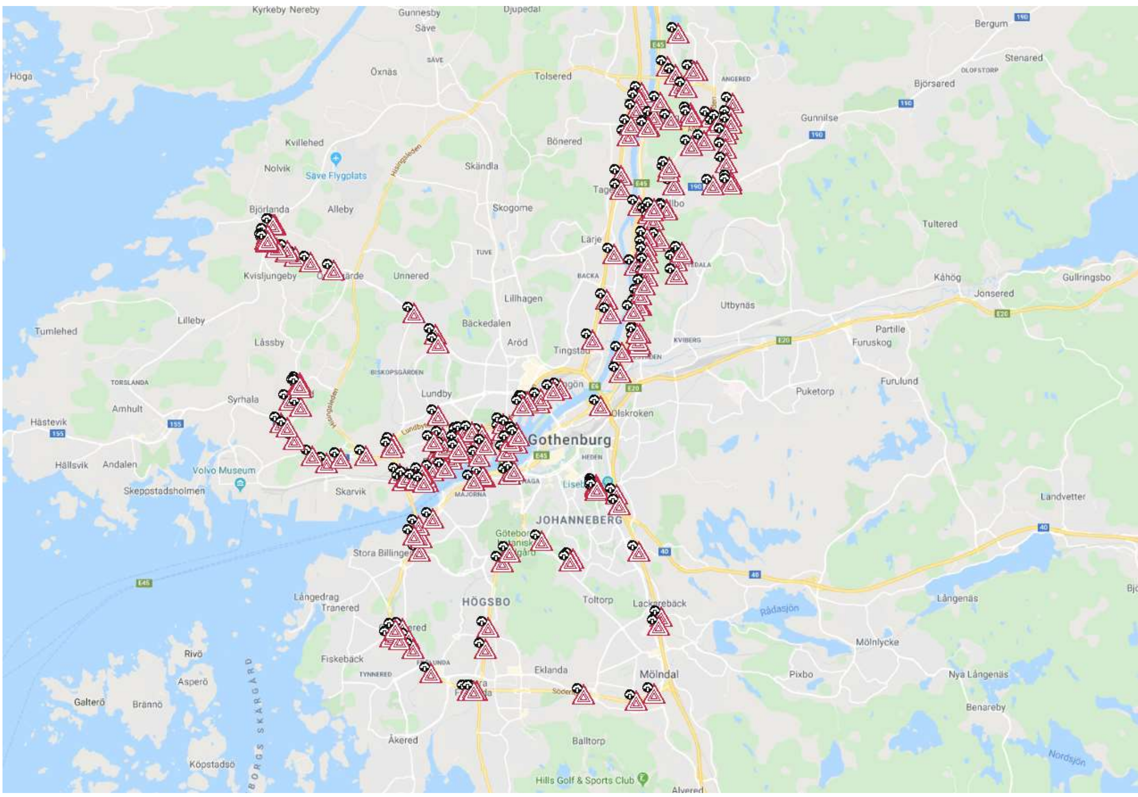


Figure 20. Screenshot showing an example of the situations around the Göteborg area during a winter morning.

Each situation has a time to live and the more cars that report the same situation the greater confidence the situation will have.

The Volvo Car

The Connected Safety function used in this project informs the driver whether another vehicle further ahead on the same road has activated its hazard warning flashers. The function is intended to make a driver aware that there may be a potentially dangerous traffic situation further ahead on the same road.

The test vehicle was equipped with head-up display where the warning symbols for Connected Safety is also shown there.

If a car's hazard warning flashers are activated, information on this will be sent to vehicles approaching the car's own position.

When a car approaches a vehicle with its hazard warning flashers activated and it has received information about this vehicle, this symbol is displayed in the instrument panel.

When a car is close to a vehicle with flashing hazard warning flashers, the symbol doubles in size.

Findings

Conclusions

Some of the project findings and conclusions are:

- The cooperation in Drive Sweden works very well and the Innovation Cloud platform proved its usefulness when adding more systems and services.
- The project delivered a platform prototype for;
    - A working OEM to OEM communication through a Central Traffic Cloud
    - A message delivery solution that was secure and reliable
    - Privacy protection in a system to system context
- The AD Aware Traffic Control could effectively handle;
    - Traffic hazard aggregation and analysis of real-time vehicle information
    - Multiple message standards simultaneously to support different OEMs
    - Sharing and enhancing information from AD and ADAS vehicles for early reaction
    - Extended functions for Emergency Vehicle Approaching warnings allowing communication to more partners through V2X communication standards

Some identified key factors and challenges for future cooperative guidance are:

- Identification of stakeholder’s requirements, individual needs, and coordination gaps
- Recognizing the potential in the sharing of traffic- and vehicle-related data for a common good
- Continued standardization of message exchange

Carmenta specific findings

These bullets summarize Carmenta’s most important findings:

- An AD Aware project; successful re-use of technology through innovation cloud
- Safer operations through shared information
- Enhanced guidance based on information from many sources
- Tested ”in the field”

Volvo Cars specific findings

These bullets summarize Volvo Cars’ most important findings:

- Integrated into production cars using production technology
- End to End test with approved latency and accuracy

- In line with Volvo's desire incorporate other OEM generated safety data into its product offerings
- In line with Volvo's desire to exchange safety related data with other OEMs via a neutral platform

CEVT specific findings

These bullets summarize CEVT's most important findings:

- Established End to End information flow with another OEM, through the CTC service.
- Developed a communication solution that can support new safety functionalities, through connected services.
- Developed a User Experience concept to present the information accurately and increase situational awareness.
- Set collaboration with multiple stakeholders.

Ericsson specific findings

These bullets summarize Ericsson's most important findings:

- Merging the solutions in AD aware/Drive Sweden Innovation Cloud with Nordic Way
- Enabling message transfer
- Prepared for taking on "European standard" for AMQP traffic messaging via C-Roads Task Force 4 specifications so that we in next step (Nordic way 3) can enable a pan European V2X cloud back end eco system

RISE specific findings

RISE works on both technical and impacts evaluation of the AD aware traffic control system and concludes that the system is addressing some of the key challenges of cooperative intelligent transport systems (C-ITS) through cellular communications and provides near to market cloud solutions. The system echoes the global development of connected vehicle eco system and demonstrate the potential of cooperative advanced driver assistance. More specifically,

- Cellular communications are proven to support C-ITS services which contributes to the EU initiative on hybrid communication support
- Multiple OEM involvement demonstrates the cross-OEM data sharing which is under intensive development globally
- Multiple protocol support demonstrates the interoperability of C-ITS with different formats of messages which contributes to the EU work on hybrid protocols
- Cloud platform and multi-source data integration demonstrates the possibilities to employ artificial intelligence for robust and reliable decision making, which provides innovation platform for AI based system development
- Multiple stakeholder collaboration contributes to future system of system development

International liaisons

The findings and insights gathered in AD aware 1, 2 and 3 combined with Nordic Way 1 and 2 has formed a strong Swedish (and Nordic) voice – lead by Trafikverket, supported by industry, in the European V2X standardization and harmonization in C-Roads where "services" are handled by TF2, "messages" by TF3 and "hybrid" = using also long range cellular connections and cloud to cloud communication by TF4.

Future Work and plan for commercialization and growth

Nordic Way 3 – granted by EU, but the actual work will start after NW2, January 2021 will carry on all V2X use cases in an EU standardized/harmonized fashion and take it to the "edge of deployment" including the AD aware use cases. The Nordic Road Transport Administrations has a Grant Agreement with EU (INEA) for Nordic way 3. In Sweden a consortium made up of industry, academia and public bodies (cities, public transport) is forming and use cases to implement are discussed. On a high level the ambition of NW3 is seen in the picture below:

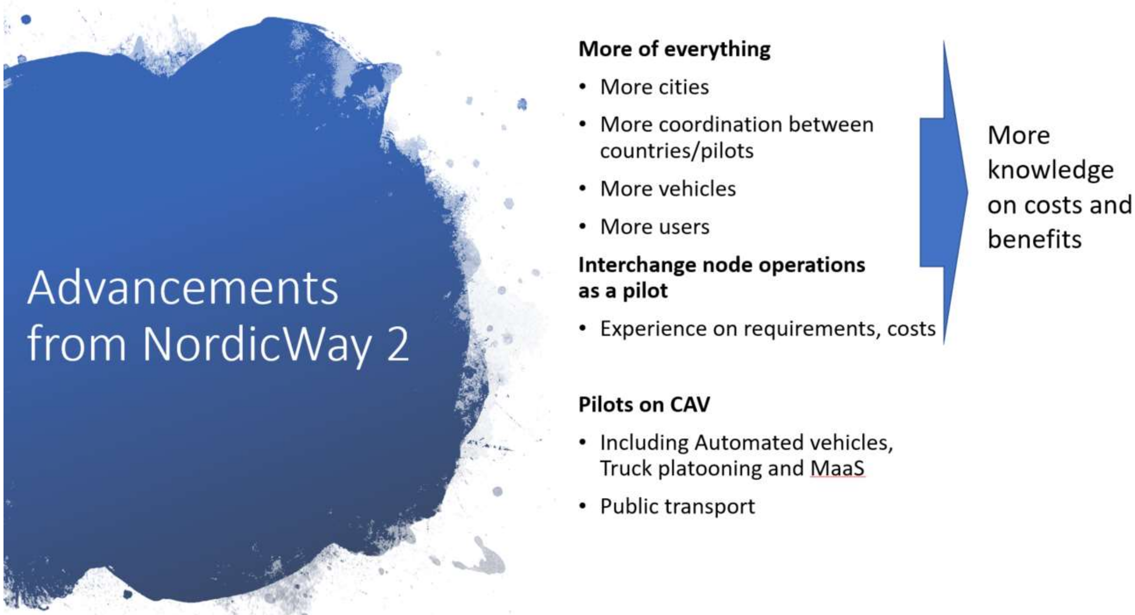


Figure 21. High level ambition of Nordic Way 3.

The ambition is to harmonize use cases, messages and data interfaces with the pan EU C-Roads effort for the hybrid C-ITS communication thus laying the foundation not only for a pan Nordic but also for a pan EU system roll out. Not only the technical issues but the legal issues (privacy, liability) and business case and models will be covered. The project will be (actively) running between 2021 and 2023.

On the wish list for Emergency Vehicle Warnings are two things:

1. More frequent emergency vehicle position, today 20 – 30 seconds, wanted 1 – 5 seconds
2. Indication if the emergency mission has blue lights and or sirens on or off

Today the Tetra/RAKEL system has limitations, either they can be overcome or the upgrade to an LTE based communication system replacing RAKEL will enable unlimited data transfer.

Near future

- Continuous technical development
  - Prove system performance
  - Improvements based on feedback
  - Drive Sweden as a platform for innovation
  - Extending the use of vehicle sensor data
- Including human in the loop

- Driver experience feedback
- Control Center Operator feedback
- Other stakeholders in the AD Aware system

Long-term

- System extension and advancement
  - Integrating with more OEMs
  - Connecting the infrastructure
  - Being part of the emerging C-ITS services
  - Additional functionalities and intelligence
- Stakeholder collaboration
  - Data sharing and regulation
  - Public and authority readiness
- Standardization
  - C-ROADS: C-ITS services, messages and AMQP routing (June 2020)
  - DATEX II extension

Appendix D – Deliverables

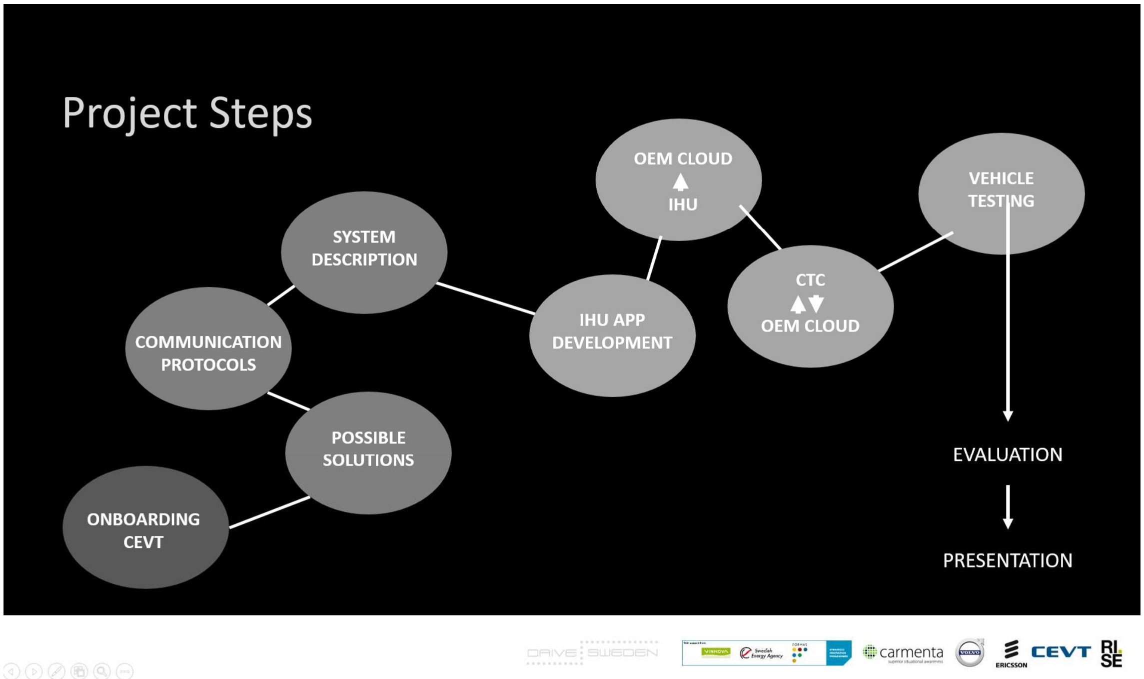


Figure 22. Visualization of how the project was realized.

All stakeholders collaborated smoothly throughout the project.

During the first stages, CEVT was onboarded by the other stakeholders, who explained the findings of previous AD Aware projects. Discussions continued to define the goals of each stakeholder and a working plan was set. Then the teams started to explore the possible system solutions, choosing communication protocols and describing the system. Next stages included the development of an Infotainment Head Unit (IHU) application (for CEVT), setting up the information flow between vehicle IHU's and OEM Clouds, and then connecting to CTC directly (CEVT), or through the Ericsson Interchange Node (Volvo). CEVT has developed a User Experience design concept, on how to present the information to the drivers. The end -to -end information flow was tested and demonstrated through a synchronized live vehicle testing, while both OEMs drove vehicles through the city street in real conditions and exchanged information through the CTC service. The collected data was analyzed and evaluated by RISE. They produced a report on the verification of the functionality, the performance of the solution and the generated societal value. The results of this project were compiled to an official report and presented to the general public during a "Drive Sweden" event. Further Information about the project will be available for the public on the "Drive Sweden" online webpage (drivesweden.net).

WP1 - AD/ADAS Information Exchange

D1.1. Description of used and proposed interfaces and the flow of information

We have established a fully functional technical solution in the AD Aware Traffic Control platform for receiving alerts from and sending warnings to VCC and CEVT vehicles. A new communication channel was developed and successfully tested that connects a CEVT control cloud to the Central Traffic Cloud. Furthermore, a new external web service connection was established with the NIRA RSI system that was used to provide near real-time road condition data to the project.

Using analytical functions developed in the project, the CTC fused hazard light alert data from two separate OEMs with information about road condition data to detect hazardous road segments. Following a set of criteria (rules) enhanced Hazardous Location Warnings could then be sent to both VCC and CEVT. The project also added the capability for CTC to unpack messages in one format and package it to the other format (DATEX II vs ETSI DENM).

In another Use Case the project re-used the EVI service developed in a previous AD Aware project and added the possibility to send Emergency Vehicle Approaching (EVA) warnings to the CEVT control system as ETSI DENM messages.

The end-to-end dataflow with the interfaces used in the project are described in more detail in the previous chapters.

D1.2. A demonstrator within the AD Aware Traffic Cloud

This was held November 27:th 2019 at Lindholmen Science Park.

D1.3. A summarizing chapter in the final report

Part of this report.

WP2 – AD/ADAS Cooperative Guidance

D2.1. Description of used and proposed interfaces and the flow of information.

We have successfully extended the previously developed AD Central Traffic Cloud platform to collect, analyze and use data from two separate OEMs (Volvo Cars and CEVT) for integration with other traffic-related information. The project fulfilled the expectation to implement, test and demonstrate a fully automated bi-directional data flow of hazard warnings from one OEMs connected vehicles to another OEMs connected vehicles. By running the data flow through the Central Traffic Cloud, the messages could be enriched on-the-fly with data from other on-line sources. We specifically showed how hazards registered by vehicles could be combined with information about slippery road segments from a NIRA RSI service to provide better and more specific warnings.

The project has demonstrated how the sharing of traffic situation data through a central level can provide a wider and more direct understanding of the real-time traffic situation to connected entities. This means better guidance to OEMs operating AD vehicles as well as improved driver support through OEM ADAS Clouds.

Having full traffic situation awareness is a cornerstone for safer and more efficient operation of AD and ADAS vehicles fleets. The project could show concrete examples how the sharing of data in a collaborative manner improved the overall situational awareness as well as provided Advanced Cooperative Driver Assistance to specific vehicles.

D2.2. A demonstrator within the AD Aware Traffic Cloud

This was held November 27:th 2019 at Lindholmen Science Park.

D2.3. A summarizing chapter in the final report

Part of this report.

WP3 – Volvo Cars Traffic Control

D3.1. Report with findings, lessons learned and recommendations.

This document.

D3.2. Description of used and proposed interfaces and the flow of information

This document.

D3.3. A demonstrator within the AD Aware Traffic Cloud.

This was held November 27:th 2019 at Lindholmen Science Park.

D3.4. A summarizing chapter in the final report.

Part of this report.

WP4 – CEVT Traffic Control

D4.1. Report with findings, lessons learned and recommendations

This document.

D4.2. Description of used and proposed interfaces and the flow of information

This document.

D4.3. A demonstrator within the AD Aware Traffic Cloud.

This was held November 27:th 2019 at Lindholmen Science Park.

D4.4. A summarizing chapter in the final report.

Part of this report.

WP5 – Update of AD Aware Interchange to Nordic Way profile

D4.1. Report with findings, lessons learned and recommendations

This document.

D4.2. Description of used and proposed interfaces and the flow of information

AD Aware Interchange is implemented on the top of Nordic Way Interchange.

An advanced combination of AMQP1.0 and routing/binding implementation is used to realize AD Aware 3 functionality.

Carmenta gets data from all the OEMs, aggregates and distributes data. There are concepts of receive and sink queues.

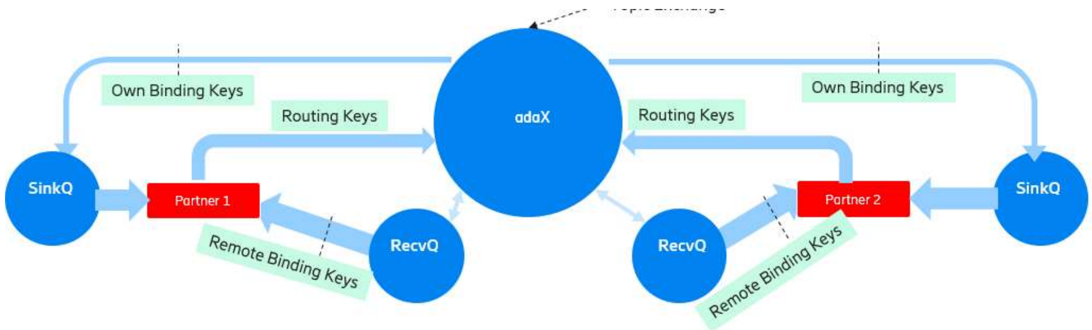


Figure 23. Interchange Setup – AD Aware project as described in this document

D4.3. A demonstrator within the AD Aware Traffic Cloud.

This was held November 27:th 2019 at Lindholmen Science Park.

D4.4. A summarizing chapter in the final report.

Part of this report.

WP 6 – Evaluation & Societal Benefits

Societal impacts

Cooperative intelligent transport systems (C-ITS)[18] is under trial and will be soon at the phase for implementation. At the EU level, C-ITS delegated act (DA) was rejected by the EU council. It was mostly relying on ITS-G5, the EU standard on dedicated short-range communications (DSRC) but contained references to future use of also cellular communication for C-ITS. At the time of writing, it is unclear what will happen to the proposed DA. In the meanwhile, the C-Roads project is working on harmonized standards for services, messages and data interfaces for C-ITS using both short range and cellular communication. Additionally, as emerging technologies, artificial intelligence demonstrates benefits based on rich data collected through connected vehicles and is enabled by cloud computing infrastructure. This project has demonstrated some of the key technologies that form the future cloud-based cooperative advance driver assistance and tackles some of the key challenges for cellular communications to support C-ITS services.

C-ITS through cellular networks

C-ITS has very well-defined applications and has been published in the first set of standards. Furthermore, in C-ITS platform, it has been recommended services with focus on traffic safety should be implemented in the coming years, i.e., the so-called day 1 services. Example day 1 services include hazardous location notification such as:

- Emergency brake light
- Emergency vehicle approaching
- Slow or stationary vehicles
- Traffic jam ahead warning
- Road works warning
- Weather conditions

[18] https://ec.europa.eu/transport/themes/its/c-its_en

as well as signage applications such as;

- In-vehicle signage
- In-vehicle speed limits
- Probe vehicle data
- Shockwave damping
- Signal violation/intersection safety
- Traffic signal priority
- Green light optimal speed advisory GLOSA

Though C-ITS started with ITS-G5, most of the day 1 applications can be already supported with today's connected vehicles through cellular communication. *The AD Aware traffic control platform addresses most of the day 1 hazardous location notification services such as emergency vehicles and weather conditions. In addition, through hazard lights information collection, aggregation, and redistribution, and in combination with multi-source information, services such as emergency brake light warning, road works warning, traffic jam ahead warning, slow or stationary vehicle warning could also be supported. Furthermore, with data aggregation and analysis over the cloud, it is possible to deploy advanced artificial methods for more accurate and robust decision making.*

However, before standardized C-ITS services can be implemented in commercial cars, there are some key challenges need to be solved.

1. **The communication and data sharing platform:** In comparison to ITS-G5 where certain services could be done without infrastructure through direct vehicle to vehicle communications among cars with different brands, cloud-based platform requires infrastructure support for communication and information exchange. As will be also discussed later, a number of connected vehicle platforms are emerging and cars with the same brand are already able to exchange information. However, the cross-OEM platforms are yet to be developed. *The AD Aware Traffic Control is built on Ericsson connected vehicle cloud (for automotive OEM´s) and provides vehicle end to end communication support. From the technology perspective, the Central Traffic Cloud platform is under pilot and ready for commercialization. The challenge mostly lies on the organizational level such as platform owners and business model. A stakeholder needs to run and maintain such a platform and there will be quite a significant amount of data exchanging through the cloud platform, thus data costs.*
2. **Interoperability**: To support C-ITS services discussed above, different messages have been defined in the C-ITS standards. The most important two set of messages are cooperative awareness message (CAM) and the decentralized environmental notification message (DENM).
    - **CAM** is a heartbeat message that is broadcasted frequently by a vehicle to notify its existence. This is mostly supported by the ITS-G5 through broadcasting at the dedicated channels.
    - **DENM** is an event-triggered message which is only used for certain situations such as hazardous warning and can be broadcasted with even higher frequencies.

    Cellular networks are not designed for high-frequency broadcasting of short messages, which means simply reusing CAM and DENM in cellular network is not feasible. On the other hand, supporting those C-ITS services doesn't need to have such high frequency broadcasting if information can be delivered in time and reliably to the related vehicles. This is possible with cellular communications and proper reliable communication protocol. Furthermore, CAM and DENM are short messages with limited information mostly due to the limited frequency band, the short radio range in combination with high vehicle speeds for ITS-G5. With cellular communication, rich information can be exchanged. Within transport sector, **DATEX II**[19] defines the communication messages in Europe for exchange of traffic information for many different purposes. In C-ITS with ITS-G5, information is broadcasted and are available locally. With cellular communications, data is always collected at the cloud part which means AI methods could be used for generating insights for decision support. *AD Aware Traffic Control aims at an intelligent platform that* data, which has been used by most of ITS systems. It is thus important to achieve interoperability between C-ITS messages and DATEX II messages, as also can be illustrated by the collaboration of DATEX II and C-Roads[20]. *In AD Aware Traffic Control, interoperability is demonstrated through the message translation between DENM and DATEX II messages. VCC uses DATEX II to exchange information with traffic cloud, while CEVT uses DENM messages. Message translation is done at the traffic cloud and interoperability is thus realized.*

Data intelligence: Connected vehicles constantly generate large amounts of data that could be used for *provides situational awareness through multi-source data aggregation. First of all, traffic data from different sources are aggregated, giving better road traffic information. For emergency vehicle warning, the most probable path (MPP) is generated for predicting the near future trajectories of emergency vehicles with potential insights from history information of emergency vehicle mission. This information is then shared with autonomous driving (AD) vehicles, enabling interaction between AD vehicles and emergency vehicles, thus realizing emergency vehicle warning C-ITS services in a different way. For hazardous location warning, hazard light information is firstly collected, that information is then combined with multiple source traffic information to identify different hazardous situations such as stationary vehicle, slippery road, and so on.*

Access to connected vehicle data

According to Frost & Sullivan, a connected vehicle is able to generate as much as 25GB data per hour, and by 2020, 98% of new cars are expected to be connected. In total, up to 50 million connected vehicles will be on the road globally by 2020. The potential of connected vehicle data is enormous but remains to be investigated. It is clear that traditional telematics, map and navigation suppliers are helping OEMs to connect their vehicles, which can be illustrated by the large number of OEM customers by e.g., TomTom, Harman, WirelessCar, Xevo and Here. In addition, realizing the needs for transmitting large amounts of data for future connected cars, telecommunication and information technology companies are also building communication and cloud platforms for vehicles. Examples such as Ericsson connected vehicle platform, which is in partnership with Geely and Volvo cars; Microsoft connected vehicle platforms with is in partnership with telematics companies such as WirelessCar and TomTom, and with OEMs such as Volkswagen and Renault Nissan Mitsubishi alliance. However, those systems are more or less OEM specific and support each OEM to connect their own vehicles, with no or seldom connectivity to vehicles from other OEMs. This creates many automotive data silos, indicating many challenges ahead to bridge the gap and to connect data from different OEMs for a better utilization.

[19] https://datex2.eu/

[20] https://datex2.eu/news/european-harmonisation-c-its-taken-next-level

For taking advantage of vehicle data, within C-ITS, the concept of neutral server was proposed back in 2016, where a third party could be established to connected vehicles from different OEMs and to provide equal access to the vehicle data. The following principles have been specified

- **Consensus**: Data provision is based on consent and there is always opt-out option for the end customers.
- **Fair and undistorted competition**: All service providers should be in an equal, fair, reasonable and non-discriminatory position to offer services to the data subject.
- **Data privacy and data protection**: For privacy, competition, and/or security reasons, there is a need to have the vehicle and movement data protected.
- **Tamper-proof access and liability**: Access to the vehicle data resources should not endanger the vehicle functionality and should not impact the liability of the vehicle manufactures regarding the use of the vehicle.
- **Data economy**: Data access favors interoperability between different applications, and facilitates the common use of same vehicle data and resources

Accordingly, the German association of the automotive industry VDA classifies the data in more detail including

- Category 1 – **Data for the improvement of road traffic safety**: anonymized data is exchanged between contributing parties (including public authorities) to enable a significant improvement in traffic safety. Example data includes vehicle data such as activation of hazard warning lights, and infrastructure data such as emergency vehicle position.
- Category 2 – **Data for cross brand services**: a defined cross OEM dataset consisting of non-differentiating anonymized vehicle data. Example data includes ambient temperature, traffic flow.
- Category 3a – **Data for brand specific services**: a differentiating OEM specific dataset consisting of OEM specific anonymized data and data with particular IP relevance. Example data includes lane marking, chassis sensor data determining road condition.
- Category 3b – **Data for component analysis and product improvement**: a differentiating component specific anonymized dataset that is made available by the OEM only to the relevant component development partner for product improvement purposes. Example data include fuel pump performance data.
- Category 4 – **Personal data**: a defined cross OEM as well as OEM specific dataset which is made available to parties authorized by the customer to process the data by law, contract or consent. Example data includes vehicle positions associating with the identity.

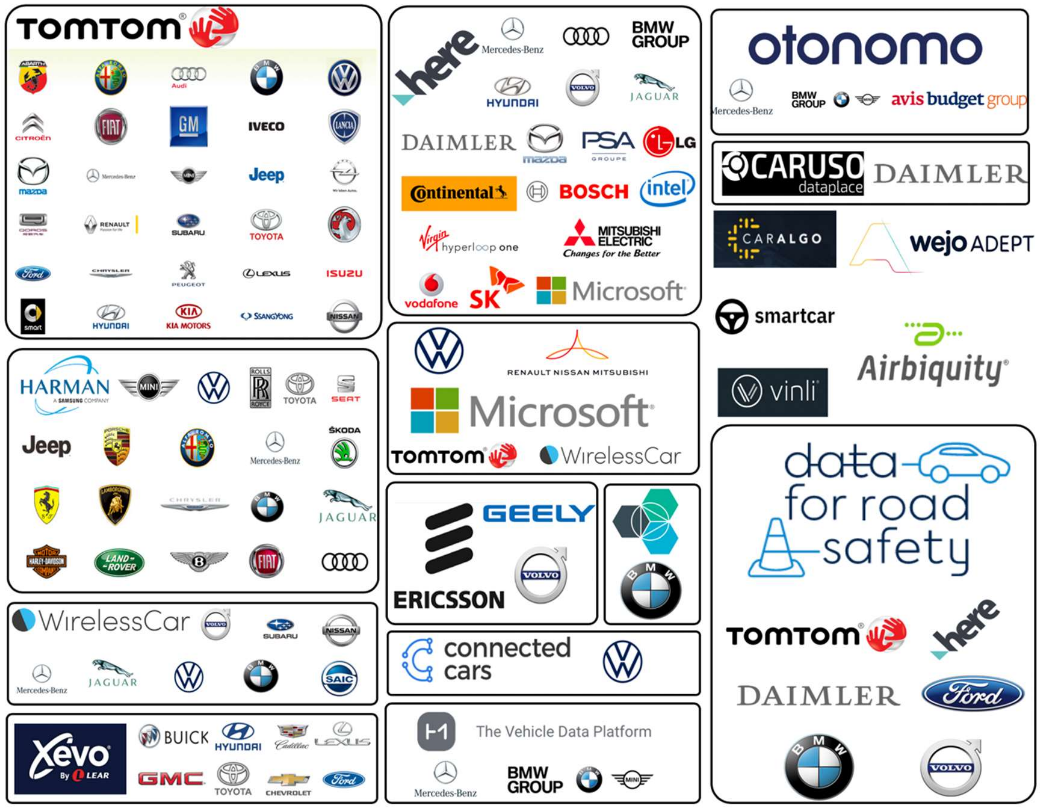


Figure 24. A non-exhaustive illustration of connected vehicle and data sharing eco-system

After several years' development, actors start to appear to provide neutral server services. Several automotive data marketplaces emerge and continue to grow. To name a few, Otonomo works with 10 global OEMs such as Mercedes Benz, BMW, which accounts for 2 million cars and provide aggregated data services to over 75 clients. Those include insurance, automotive suppliers, authorities, repair shops, etc. Other examples such as that Caruso works with Daimler, Connected Cars works with Volkswagen, High Mobility works with Mercedes-Benz, BMW and Mini, while IBM Bluemix servers as the neutral server for BMW CarData. The neutral server aggregates vehicle data from single or different carmakers and makes it available for third parties such as app developers and insurance companies. Privacy is protected by GDPR. In between, business models could be established where data can be monetized.

In addition to monetize the vehicle data, traffic safety related data is also under consideration. As already mentioned, VDA define category 1 data for traffic safety, and the data is expected be exchange for improving the traffic safety. However, there are still many concerns regarding technical, organizational as well as legal issues regarding the usage of such data. To address those issues and to improve traffic safety with connected vehicle data, a proof of concept project, data for road safety, was launched in June 2019 by the European Data Task Force (DTF). Within the project, OEMs including BMW, Ford, Mercedes Benz, and Volvo cars will share traffic safety related data through service providers Here and TomTom. Participating countries include the Netherlands, Spain, Finland, Germany, and Luxembourg. A general and non-exhaustive overview of the current eco-system is shown in the above **Figure 24**.

Essentially, though the ownership of the platform is an open question, AD Aware Traffic Control is a connected vehicle data sharing platform that leverages connected vehicle data from multiple OEMs and generates situational awareness and decision support to improve traffic safety. In this regard, the platform addresses all above challenges and exemplifies a communication and data sharing platform, an interoperable multi-OEM data exchange platform, as well as a data-driven decision support platform.

OEM acceptance

Connected safety is part of the Volvo cars offer and as discussed, slippery road warning is covering most of their cars. Similar perception of the usage of connected safety can be perceived by CEVT, which can be reflected by the internal discussion within CEVT and their views on potential application of the AD Aware system.

- Increased Safety and ADAS: the system can be utilized during scenarios of autonomous driving, to recall the attention of drivers/passengers, when human judgement is needed
- Supporting new technology within the vehicle: Integrated sensors can map driver behaviour and send data to be processed in CTC, to cover needs from different areas, such as health emergencies etc. The collection of driver behaviour data can be used for research purposes.
- Providing new services and solutions: The flow of available information can improve the overall experience, not only the safety aspects, by detecting and sending dynamic and updated information of traffic dangers.
- In a long-term vision, the scaled solution can result in a well- directed mobility ecosystem, that moves in safer and more predictable ways, since it will follow specified courses during autonomous drive.

System evaluation

With above-mentioned challenges on C-ITS over cellular network as well as the state-of-the-art of data automotive data sharing, it is rather straightforward to conclude that AD Aware Traffic Control is a communication and data sharing platform that 1) enables multiple OEM vehicle communication and data sharing, 2) achieves message interoperability between DATEX II and C-ITS messages, and 3) leverage cloud platform and AI for advanced situational awareness and decision support.

Functional evaluation

Within the project, evaluation has been focusing on verifying and validating the functionalities to make sure the system works as expected. This has been mostly done by observations to make sure the functional requirements are fulfilled. Following the development stages, there have been in total three half-day demo meetings to demonstrate and validate the functionalities, as well as the on-going live testing.

From the functional requirements perspective, major functionalities are achieved, those include the major functions at each stakeholder’s system and summarized as follows:

- Central Traffic Cloud
  - Real-time traffic information aggregation and dissemination
  - Emergency vehicle warning generation and dissemination
  - Hazard lights information aggregation and Hazardous location warning dissemination

  - Interoperable data exchange between multiple OEMs with different message protocols, C-ITS and DATEX II
  - Situational awareness at CTC and intelligent decision support
- VCC Cloud
  - Hazard lights reporting and consumption based on DATEX II
  - In-vehicle testing of Hazard location notification
- CEVT Cloud
  - Hazard lights reporting and consumption based on C-ITS messages
  - In-vehicle prototype of Hazard location notification
- Drive Sweden Innovation Cloud
  - Scalable and reliable cloud-based communication and message exchange
- AD Aware Traffic Control
  - Vehicle End-to-End communication and data exchange
  - C-ITS services including
    - Emergency vehicle warning
    - Various hazardous location warning based on aggregation of hazard lights information
    - Weather information

Performance evaluation

As one parallel task for evaluating the functionalities, performance metrics are also important. In C-ITS standards, all services have clearly defined performance requirements, including the communication range, reliability, message delivery frequencies and latency. In comparison to ITS-G5 which is broadcast based, cellular networks are IP-based. With proper Quality of Service (QoS) requirements, the reliability can essentially be guaranteed. The current AD Aware Traffic Control uses the latest message exchange middleware AMQP which can guarantee security and reliability with proper settings and resources. In this regard, we focus more on the message delivery latency, i.e., if the message can be delivered on time with accordance of the C-ITS standard specifications. For doing so, we have set up time stamp collection at each of the segment that covers vehicle end to end, as shown in the following figure.

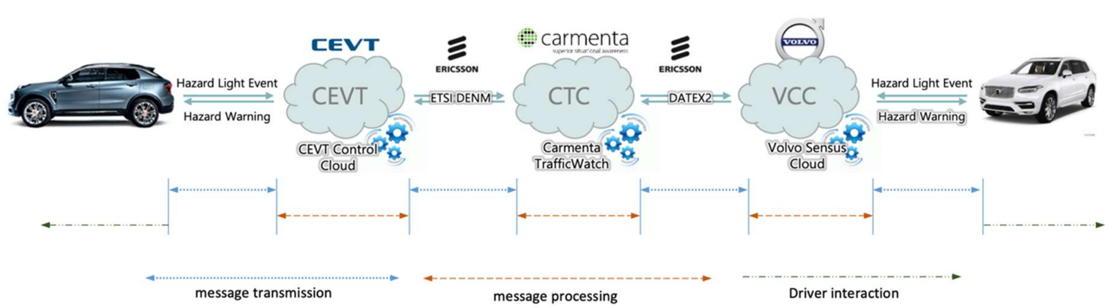


Figure 25. *Delay segments for message exchange.*

The aims to collect such timestamps are multiple folds. First of all, end to end latency can be calculated to compare with C-ITS specifications regarding each of the services. Secondly, bottlenecks of the end to end latency can be identified. This could be congestion in the public 4G networks, processing delay at the cloud unit due to algorithms, etc. Lastly, driver interaction as one of the important factors could be analyzed to evaluate the effects of such services. We acknowledge the work in this part is on-going with live test and data collection.

User perception

Driver perception on the delivering of different information into the vehicles may lead to positive impacts on drivers, thus traffic safety. The implementation of AD Aware Traffic Control services in vehicles could influence positively the driver behaviour, the driving conditions and the mobility ecosystem in different ways, as was indicated by interview studies from CEVT.

- Driver Behaviors which are expected to be influenced:
  - Decreased Driver Anxiety: By knowing that a potentially stressful situation is about to occur, the drivers may experience less anxiety when the event happens, as they will have adequate time to process the information and prepare a reaction.
  - Faster Reaction times: When informed about an existing hazard or incoming EV, the drivers are expected to react faster to the situation.
  - Danger Avoidance, Better Reaction to the situation: Due to more time to process the situation, the drivers are expected to make better and safer choices, adapting to the street conditions.
  - Building on the trust in the Information Systems and future Autonomous Drive solutions: A common subject of discussion is how the human driver will trust and let go of the ownership of driving and the feeling of control. Trust to the system must be gradually built. One of the known heuristic guidelines for good user experience, is to inform the users/drivers on what activity the system is doing in the background. By informing the drivers on what is the street condition or why the vehicle needs to follow a new course, the driver may develop the feeling of awareness, communication and further trust on the navigation system.
- Driving Conditions which are expected to be influenced
  - Less Congestion on streets, which can result in easier navigation and faster arrival times.
  - Overall Increased Safety, due to better reactions by other drivers
- Mobility Ecosystem:

  When the system solution is scaled to include a significant number of vehicles, the network of available information and the information flow within the vehicles can result in a new model of mobility ecosystem, which will answer new and more needs of the users.

While it is generally positive to deliver digital information into vehicles, there are more details to work on what and how such information should be delivered. There has been some discussion with CEVT on those topics such as

- Avoiding Cognitive Load: The presentation of the information can be adjusted to suit the user's preference and tolerance for information, to avoid cognitive load. The user should be informed adequately, to gain the positive effects of the information. But the information should not be provided too often, or in a distracting or invasive way, since that would increase the possibilities of stress and danger.
- Personalization of information: The notification system can be further personalized, to reflect individuals needs and preferences, such as the use of multimodal communication from vehicle to driver. The driver should be able to choose between and activate haptic, visual and/or aural notifications.

- Notifications should be divided in degree of danger and significance, so that a minimum of safety and situational awareness is always guaranteed. The extra information should be available on demand.

Future works

We acknowledge that the system is under live testing and data collection and we foresee the following on-going and future work to evaluate the system from different perspectives.

- Performance evaluation: Only after enough data is collected can the latency metrics be analyzed for quantitative analysis. This potentially will be combined with other types of data such as location to evaluate the correctness and effectiveness of the information.
- Driver perception and interaction: As partially done with internal interview study with OEMs, some general topics have already been identified on how such information should be introduced into the vehicles. Specific tasks and evaluation methods will be investigated in future works.
- Automotive data sharing: Automotive data marketplaces are emerging, and business models are surfacing. Utilizing the automotive big data for other purposes such as safety, efficiency, insurance, city planning could lead to many societal benefits. A continuous work is to follow closely such trend and to work together with OEMs for potentially utilization of their data.
- Traffic safety: While European data task force is piloting safety data sharing among OEMs, the Swedish Transport Administration is developing future digital infrastructure. Combining those efforts may help to find a solution for data-driven traffic safety e.g. what information should be shared and who owns the platform for such information.
- Stakeholder collaboration: Automotive data sharing involves mostly stakeholder of OEMs and suppliers, while traffic safety involves social-technical systems that require collaboration of all stakeholders. AD Aware Traffic Control has a good constellation with SOS Alarm, OEMs, telecom industry and telematics. A natural next stage is to move into implementation which requires integration of different systems such as SOS Alarm, vehicles, and road infrastructure. This indicates a system of system integration which will join the hands with on-going projects on system of systems engineering for emergency response[21].
- Innovation with AI: With more and more data collected at the cloud, machine learning algorithm can be developed for certain tasks such as predicting emergency vehicle trajectories, predicting hazardous situations based on hazard lights information, for cooperative advanced driver assistance. This has been considered during the project and will be extended with more data available.

[21] https://www.ri.se/en/what-we-do/projects/system-systems-efficient-emergency-response-and-urban-mobility