CloudKonkret
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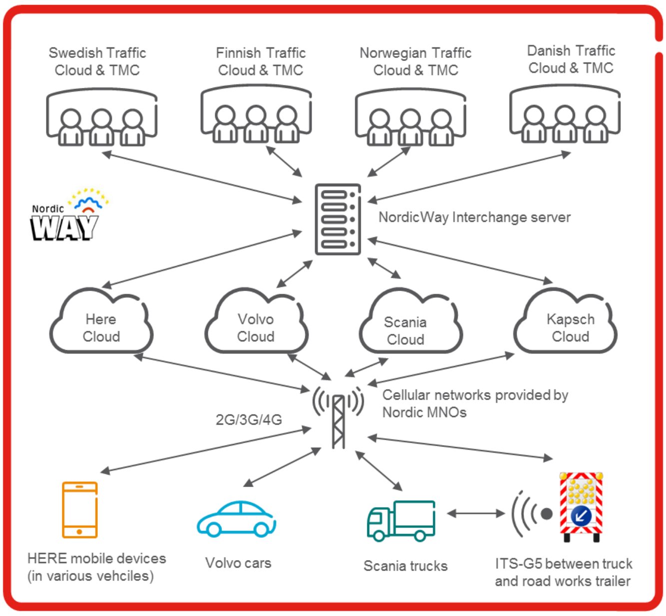
Ein Projekt finanziert im Rahmen der Verkehrsinfrastrukturforschung 2015 (**VIF2015**)

Oktober 2017



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CloudKonkret POC Technical Report

Ein Projekt finanziert im Rahmen der

Verkehrsinfrastrukturforschung

(VIF2015)

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Contents

1 DOCUMENT INFORMATION

This document describes the results and findings in CloudKonkret Project and Proof of Concept.

CloudKonkret Project was assigned by FFG (Österreichische Forschungsförderungsgesellschaft mbH, FFG Födernummer: 6429163 / 854617) and carried out in cooperation between FFG, ASFINAG (Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft) and Ericsson.

1.1 Document Objective

According to objectives given by CloudKonkret Project, this document will elaborate on:

- the state of art in modern Connected Traffic Clouds, technologies, and services capabilities, in context of newly emerging requirements, responsibilities and operational changes that a modern road operator such as ASFINAG is facing in a world of connected transport industries and individuals
- different Traffic Cloud implementations based on the recent and ongoing research projects/programs such as NordicWay, DriveSweden, Talking Traffic (Beter Benutten) and outline similarities and differences between them and the concept realized for ASFINAG CloudKonkret
- the implementation of CloudKonkret reference prototype or Proof of Concept and its use cases, validating new real-time operations capabilities of a Traffic Cloud
- finally, this document will outline important findings in CloudKonkret and based on that, provide recommendations in respect to deployment and operations of cloud services in context of a connected road traffic operator. Potential future work will be outlined as well.

In addition to this document, Ericsson provides a complementary consulting report [1] that further details:

- the role and importance of C-ITS tailored 4G/5G Network Slices, Federated Networks Slicing, and a C-ITS real-time routing network, which can link Automotive, Rail, Road-Authorities and MNOs in one viable and efficient connected traffic eco-system
- technical, operational and commercial implications and considerations in deploying and operating C-ITS cloud services in a cross-party, cross-authority and in an international context
- recommendations for ASFINAG on new requirements, forward looking system designs, interactions with new services, and operational efficiency gains

1.2 Definitions, Terms and Abbreviations

CloudKonkret Glossary	
Abbreviation	Explanation
3PTC	3rd Party Traffic Cloud
5G	5th Generation of cellular network communication, following LTE
AD	Autonomous Driving
AMEEC	Automotive Edge Computing Consortium
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
App	Application
C-ITS	Cooperative ITS
CRM	Customer Relationship Management
CTC	Connected Traffic Cloud
CVC	Connected Vehicle Cloud
EnTM C-ITS WG	Enhanced Traffic Management C-ITS European workgroup
ESB	Enterprise Service Bus
FOT	Field Operation Tests
GLM	Geo Location Messaging
GPS	Global Positioning System
ICT	Information and Communication Technology
INEA	The Innovation and Networks Executive Agency
IoT	Internet of Things
ITS	Intelligent Transportation Systems
ITS-G5	Vehicular communication protocol, ETSI ITS G5 alias 802.11p
LTE	4th Generation of cellular network technology
MEC	Mobile Edge Computing
MNO	Mobile Network Operator
OEM	Referring to vehicle (or car) manufacturers
PoC	Proof-of-Concept
RHW	Road Hazard Warning (messages)
RWW	Road Works Warning
SC	Service Consumers
SOA	Service Oriented Architecture, software design principles
SP	Service Providers
SRTI	Safety Related Traffic Information
TCC	Traffic Control Center
TMC	Traffic Management Center
TMP	Traffic Management Plan
UC	Use Case
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VMS	Variable (electronic) Message Signs
VPN	Virtual Private Network, method for encrypting and securing IP networks
WP	Work Package

1.3 References

[1] SEA-OA-01-2017-1022 CloudKonkret Consulting Report.pdf

[2] 20170516 CloudKonkret Overview.pdf

[3] NordicWay Interchange Client Specification - ASFINAG - v3.pdf

[4] RWW_sample.xml

[5] TMP_sample.xml

[6] NordicWay_SystemDesign

[7] NordicWay-I project

[8] DriveSweden strategic innovation program

[9] Talking Traffic (Beter Benutter) initiative:
http://www.automotiveweek.nl/partners/beter-benutten
http://www.beterbenutten.nl/talking-traffic

[10] CAMINO project

[11] AMQP standard

[12] SPICE EU project „Smart Procurement for Better Transport
http://spice-project.eu/

[13] DevOps explained

https://en.wikipedia.org/wiki/DevOps
https://www.versionone.com/devops-101/what-is-devops/

[14] IoT Accelerator (former SEP=Service Enablement Platform)

https://www.ericsson.com/ourportfolio/industries-solutions/iot-accelerator?nav=solutioncategory042

[15] Connected Urban Transport (alias Connected Traffic Cloud)

https://www.ericsson.com/en/industries/intelligent-transport-systems/solutions/connected-urban-transport

[16] Connected Vehicle Solutions

https://www.ericsson.com/en/industries/automotive/offerings

[17] CONVERGE project

[18] EU-DSGVO, or EU-GDPR (General Data Protection Regulation), becoming effective May 25th, 2018.

[19] CloudKonkret_bericht.pdf (Work packages and Milestones)

2 CLOUDKONKRET PROJECT INFORMATION

2.1 Project Objective

The objective of the CloudKonkret Proof of Concept (PoC) is to demonstrate potential use of cloud services, based on couple of selected use cases, for providing information from the ASFINAG Traffic Management Center (TMC) to a connected vehicle to assist driving and increase road safety.

ASFINAG collects and aggregates traffic-relevant data from many sources such as cameras, sensors, etc. and then further refines and enriches this data at the TMC and by internal processes, which results in various directives and information for drivers. Examples are road construction warning, speed limits due to dangerous road conditions, alternative routes due to traffic congestion, traffic signs or emergency situations.

As shown in Figure 1, for the CloudKonkret Proof of Concept (PoC), ASFINAG will expose Roadworks Warning and Traffic Management Plan information as DATEX II messages to a reference Traffic Cloud (depicted as Test Track Traffic Cloud in the figure below). The reference Traffic Cloud will then distribute those messages to emulated connected vehicles (to which this particular information shall be of interest). In case of the CloudKonkret PoC, messages will be displayed on the client tablet app, to help drivers avoid potentially dangerous situations or drive more efficiently. In perspectives of extensions beyond the current project, the reference Traffic Cloud could forward relevant messages to various Vehicle Manufacturers Clouds (aka OEM Clouds) instead of directly to the emulated vehicles. The receiving OEM Clouds would take on the responsivity of forwarding the messages to the affected vehicles. The vehicle systems itself would display the information according to the manufacturers' HMI policies.

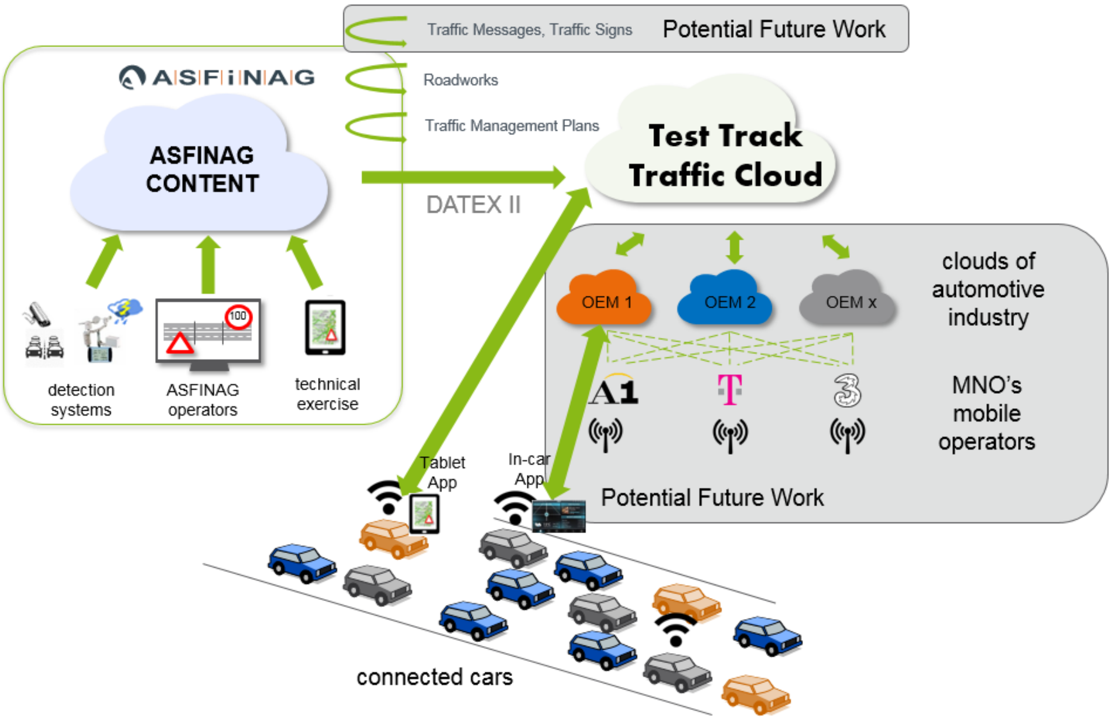


Figure 1 Traffic Cloud Services

Apart from the prototype, the project objective is to examine other potential applications of traffic cloud services and important aspects of a complex traffic eco-system where the reference cloud should link all stakeholders such as national road authorities, vehicle manufacturers, transport companies etc and enable and ensure the collaboration and real-time data sharing between all. Hence, the prototype is accompanied with a technical and consultancy reports, which take into consideration the latest research programs and other important aspects, to draw conclusions and recommendations for ASFINAG regarding potential deployment and operation of different services in mentioned traffic cloud eco-systems.

2.2 Project Phases and Deliverables

CloudKonkret project phases, work-packages, milestones and deliverables are described in detail in CloudKonkret_bericht document [19].

3 CONNECTED CLOUDS

More and more cloud-based platforms and system-services are appearing in the market. Customers for such cloud-based platform-services are, for example, vehicle manufacturers, connected vehicle services organization, Mobility-as-a-Services providers, or travel agencies. These platforms differ in respect to the targeted customer segments, the focused service offerings, their operations, ownership models, or on the specific assets which they build upon. An example for the latter is HERE. HERE builds on the NOKIA map assets which were jointly acquired by Daimler, BMW and Audi in 2014.

In the following we focus on two Ericsson cloud platform services, namely the Connected Vehicle Cloud (CVC) and the Connected Traffic Cloud (CTC). Both have many system platform functions in common but differ in respect to their ownership models and the targeted customer groups.

The CTC and CVC are based on the former Ericsson Service Enablement Platform Architecture (SEP), currently known as IoT Accelerator [14]. IoT Accelerator is developed by Ericsson's Business Units in collaboration with Ericsson Group Function Technology. It serves as a blueprint for product development units and business units when developing products and creating solutions for the Internet-of-Things (IoT) domain. It defines a set of architectural principles and technical capabilities that are needed to meet the requirements of future solutions.

Solutions based on the new architecture have a high degree of loosely coupled platform components and thereby require much less customization than traditional industry solutions. These platform components constitute a Service Oriented Architecture design with internal communication capabilities following asynchronous and real-time messaging principles.

3.1 Connected Vehicle Cloud

The targeted customer group for an Ericsson **Connected Vehicle Cloud** (CVC) offering comprises vehicle manufacturers with embedded connected vehicle services operations.

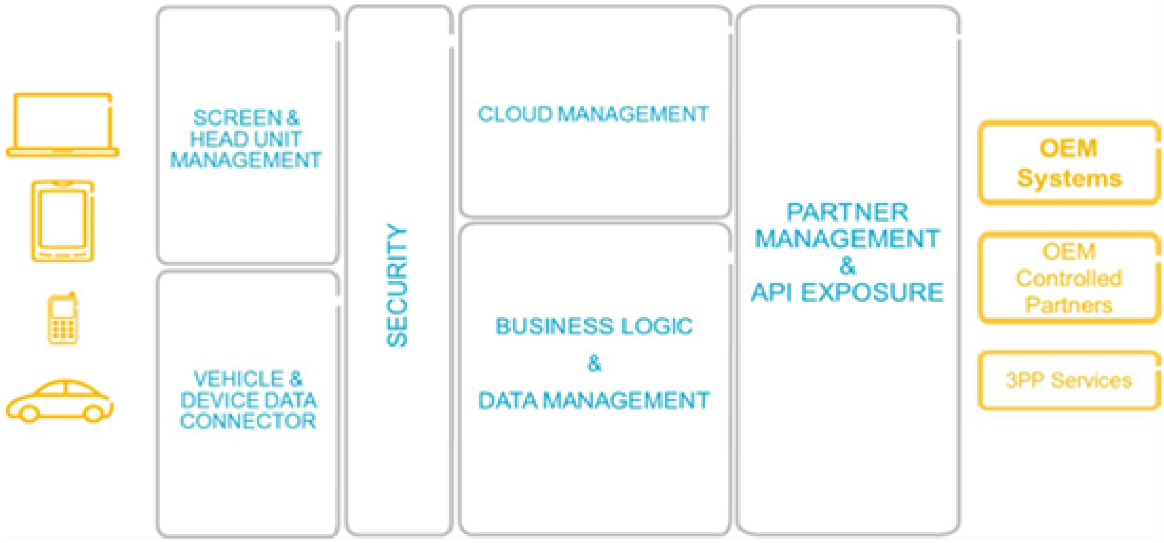


Figure 2: Connected Vehicle Cloud - high-level structure

A CVC cloud instance, including all attached licensing cost, is owned by the purchasing customer, such as a vehicle manufacturer. The cloud system hosting, and the 24/7 managed services operation, is provided by Ericsson, on behalf of the owning customer. CVC is deployed within a private cloud setting with one central reference node instance, plus regional CVC nodes, e.g. one per continent, for performance and market adaptation reasons. The purchasing customer owns all those regional CVC nodes.

The CVC solution is leveraging many of the IoT Accelerator functions (see e.g. Talking-Traffic (Better Benutten) project in Chapter 4.2, and IoT Accelerator [14]) in combination with automotive industry specific extensions. The left-hand side of a CVC instance (see Figure 2) connects to the individual vehicles of “the CVC owing vehicle manufacturer”. The IT-Back-end systems of a CVC owning OEM, plus the IT systems of the OEM’s contracted 3rd party service providers, are integrated to the right-hand side of a CVC instance in Figure 2.

Different and vehicle specific protocols are being converted at the Vehicle & Device Data Connector unit. The Business Logic at the center of the CVC blueprint adds commerce management functions, customer billing procedures and all functions needed for ordering, provisioning and activating connected vehicle services remotely and instantly, at per individual connected vehicle.

The Cloud management function block provides additional functionality for steering regional cloud instances, market adaptations and cross-country operations.

From an outside perspective, the CVC appears as back-end integration point for all OEM connected vehicles, for OEM enterprise services, and for all 3rd party services according to the OEM customer contracts with that said 3rd party.

The CVC setting allows for an "*integrated service experience*" at the connected vehicle and within the end-customer service portals. Worth noticing is that the systems of particular 3rd parties are not at all integrated with each other's, thanks to dynamic information and permission handling mechanisms provided by the CVC, i.e. rule engines, commerce engine, catalog management functions.

3.2 Connected Traffic Cloud

The Connected Traffic Cloud (CTC) is addressing customers such as road operators, road authorities and city operation organizations. Similarly to a CVC instance, the CTC constitutes a composition of generic enabling functions from the Ericsson IoT Accelerator [14] and customer segment specific extensions, according the target customer segment. All these generic functions are developed and provided and (typically) owned by Ericsson, to facilitate smooth and seamless software maintenance, upgrade management, and to provide a systems evolution roadmap.

The composition of those coherent functional entities is called the "Connected Traffic Cloud" (CTC). It is provided as-a-service (aaS) offering to end-customers, such as traffic management centers. It is being offered as 24/7 managed service operation (rental of fully operational backend software plus IT systems, with all what is needed).

The CTC enabling functions are software instances, each constituting a "system service" in a SOA[1] design principle. These software services execute on a highly scalable und virtualized compute environment. In fact, a private cloud for ITS business-to-business operations (see CloudKonkret Consulting report [1]). They integrate with the specific IT systems of a certain road traffic management center via dedicated high-speed (fiber) connection lines. The security setting follows highest enterprise operation standards.

[1] SOA = Service Oriented Architecture software design principle

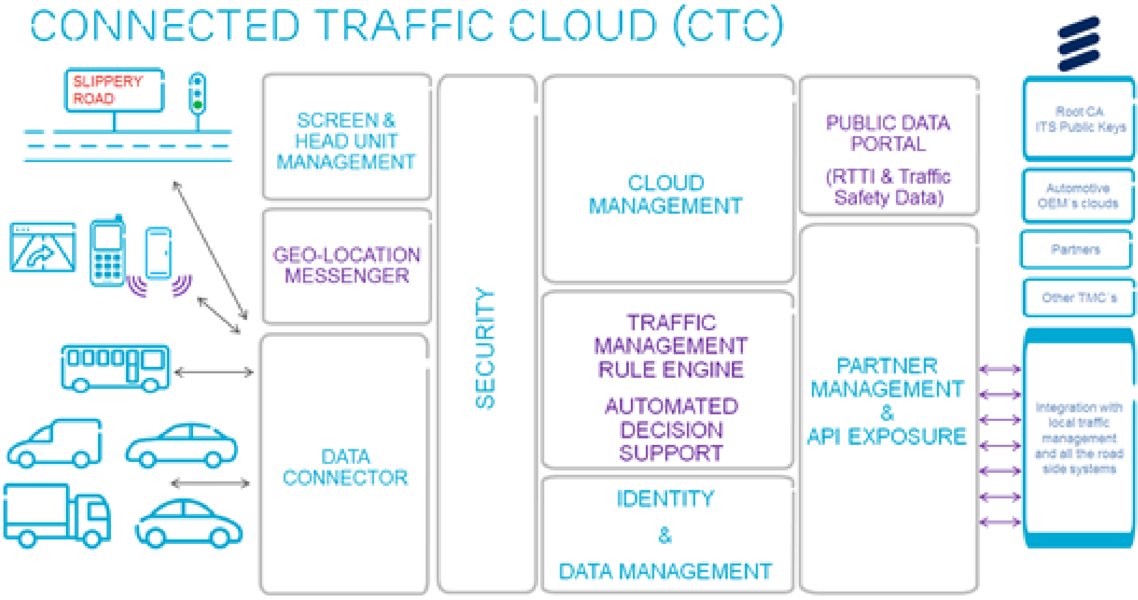


Figure 3: Connected Traffic Cloud - high-level structure

Figure 3 illustrates a high-level blueprint of a CTC instance. It obviously compares to a CVC instance (Figure 2) from a systems solution approach. Given the different types of customers that would connect to a CTC cloud instance the system provides special enabling functions, such as Geo-Location-Messaging (Figure 4) and Hybrid Communication support (chapter 3.2.2) to address multi-channel communication demands and maximum flexibility at the integration platform.

3.2.1 Interfaces between Service Provider and Connected Traffic Cloud

The Ericsson IoT Architecture and CTC include a complete set of services and functions that allow both service providers and partners to manage service offerings and let end-users or consumers discover and purchase new applications, services, and digital content. Furthermore, it facilitates the dynamic onboarding of content and services providers and of 3rd party system functions.

As outlined below, there are **six groups of Interfaces** between Service Providers (SP), Service Consumers (SC) and CTC, that will typically be **used when putting an end-to-end solution into operation:**

- **Interface Group 1 (Service Provider):**

- Register / Unregister a SP to / with a Connected Traffic Cloud (CTC)
- Provide / accept / withdraw SP security and access permission credentials
- Establish SP VPN[2] connections between SP IT-systems and CTC IT systems
- Register SP description (machine and human readable), stating the role and responsibilities of said SP in general terms and the group of services which said SP is providing (and to which customer groups)
- PUBLISH SP details and thereby activate SP within the CTC connected eco-system

- **Interface Group 2 (Service Provider Services):**
  - Purpose is to make Service Provider Services discoverable and ready for becoming invoked for end-to-end use cases.
  - Register / Unregister specific services (or system functions) with the Connected Traffic Cloud. Per SP-service, provide a "Service Description" of that particular "service" in a machine and a human readable format, including the anticipated service consumer groups and required KPIs
  - Provide machine and human readable formats for automated input/output/failure processing and for automated fail-over solutions
  - Provide information about the service access permissions / service access credentials requested, commercial terms of that service, KPIs provided by the SP on the service data quality, and minimum KPIs required for the end-to-end service delivery
  - PUBLISH a particular service from a pre-registered SP and thereby activate this service or external system function to be used within the CTC connected eco-system

- **Interface Group 3 (SP Service Use-Case Execution):**

[2] VPN = Virtual Private Network, a secured end-to-end IP connection

- Information details for a specific use-case of a certain service group (incl. host/IP-Address, port, credentials handling, SW stubs / Interface invocation information (e.g WSDL), etc.)
- Use case interaction protocols and data formats
- PUBLISH access and invocation information for CTC 3rd parties to connect to a specific pre-integrated use-case

- **Interface Group 4 (Service Consumer):**
  - Information about Service Consumer (SC) management. This is different to the Service Provider subscription management.
  - Discover services according to search criteria
  - Discover SP requirements for selected services (Use Case x) delivery
  - Register and subscribe to a certain service (or services group) with one specific SP or with a group of SPs, incl. security settings, access authentication and authorization management, usage permissions, logging and contractual terms)
  - Service Provider – Service Consumer INTERACTION

Note: One specific organization may have multiple roles simultaneously, e.g. providing information (=SP) and receiving information (=SC). Thus, one organization may register with a Connected Traffic Cloud in a SP role and in a SC role simultaneously (see CONVERGE project [17] for a description of roles and actors).

- **<u>Interface Group 5 (Service Consumer Use Cases)</u>**
  - All use case specific interaction protocols, data models and the format of a certain use case (UC) belonging to a “service group”, provided by a specific service provider (SP) or a SP group.
  - The UC specific interaction interface may be similar within a use-case group, of service group.

- The UC interaction interfaces between different services group may differ depending on the service grouping categorization chosen
- UC EXECUTION in and end-to-end invocation

Note: ASFINAG CloudKonkret prototype focused purely on Interface Group 5 (specific use cases) for simplicity reasons and due to limited PoC time/budget. This was good enough for a demo purposes, but not sufficient for a sustainable reference PoC for future operations, which would need to consider/implement all Interface Groups. Going forward, a full set of operation interfaces shall be implemented (see recommendations in Chapter 6)

- **Interface Group 6 (Clearing):**
  - Safely and completely clear off all permissions, registrations, logging and bills for all registered items
  - Clear off a specific use case
  - Clear off a use case group (respective service category)
  - Clear off a SP or a SC from the Connected Traffic Cloud IT system
  - CLEARING all left overs and data traces, according to EU data protection rule EU-DSGVO[3] [18].

3.2.2 Geo-Location Messaging and Hybrid Communication

[3] or EU-GDPR (General Data Protection Regulation), becoming effective May 25th, 2018

Real-time Geo-Location Messaging (GLM) enablement is a unique capability provided within the Ericsson Service Enablement Platform and is part of the Ericsson CTC solution (see Figure 3). It is optimized for very low end-to-end latency on application level to allow vehicle-to-vehicle and vehicle-to-infrastructure messaging applications of various types. It provides road traffic operators a tool to signal directly to all GLM connected vehicles and travelers, in an arbitrary geographic area (freely and ad-hoc definable).

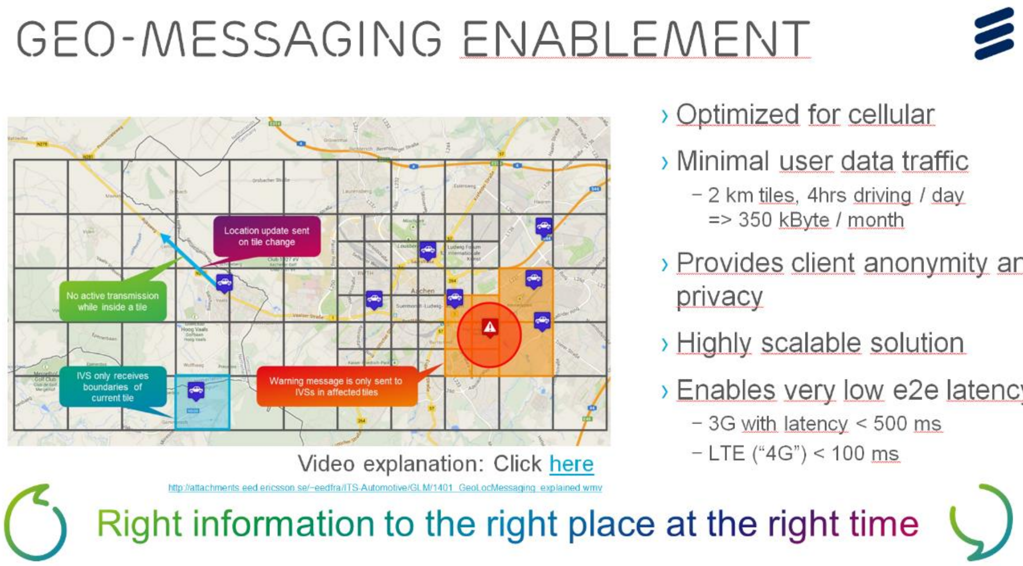


Figure 4: Geo-Location Messaging using cellular networks

GLM is built as a cloud system function that links with a GLM client proxy function at the connected vehicle or traveler device on one end, and with a connected traffic management center system, for example, on the other end. It functions across different mobile networks and supports 3GPP 3G, 4G and 5G technologies.

Within the CONVERGE research project [17] the GLM solution has been extended to support also ETSI ITS G5 (DSRC) communication technology. Integration with ETSI DENM event messaging has been demonstrated live at the ITS World Congress 2015 (Figure 5). The GLM function has been integrated with the live incident management system of Austrian road operator ASFINAG within the Camino research project (Figure 6).

Figure 5: Hybrid Communication using cellular and ETSI ITS G5

Thanks to protocol adapters at the Ericsson cloud platform, the GLM system supports JSON formats, MQTT intake, ETSI ITS DENM posting and DATEX-II interfaces. In combination with the publish-subscribe mechanisms provided by the Ericsson platform it gives real-time push warning or advise messages from road authorities a firm destination.

With these enabling functions, a TMC operator on duty at a traffic management center's control room, could get a "red button" to straightly and direly shout-out "Wrong-Way Driver Warning – THERE!" notifications to all potentially affected vehicles in an arbitrary geographic target area, using all kinds of real-time capable communication channels (cellular, ETSI ITS G5 or Variable Message Signs (as complementing optical channel).

3.2.3 Camino research project

Ericsson has already validated key solution aspects in proof-point prototype projects. Two of those shall be mentioned.

Real-time routing of traffic incident information, to road users at a particular road segment, and the integration with an early prototype of Connected Traffic Cloud instance, has been validated in scope of the CAMINO research project together with the Austrian road operator ASFINAG.

The ASFINAG incident database system has been connected to an Ericsson CTC prototype via DATEX-II (Figure 6). Triggered incidences were delivered via the Ericsson Geo-Messaging solution (see Figure 4) to all connected test vehicles in an ad-hoc and freely definable geographic area or motorway segment. On top of this communication channel ASFINAG has integrated the geo-messaging functionality with their public app ASFINAG Unterwegs within the Kompagnon module. Furthermore, road traffic managers were equipped with a special smartphone app to enter road traffic data to their operations systems.

The Camino PoC has been shown with live integration at the ITS World Congress in Bordeaux in Oct. 2015 at the Ericsson and the ASFINAG booth.

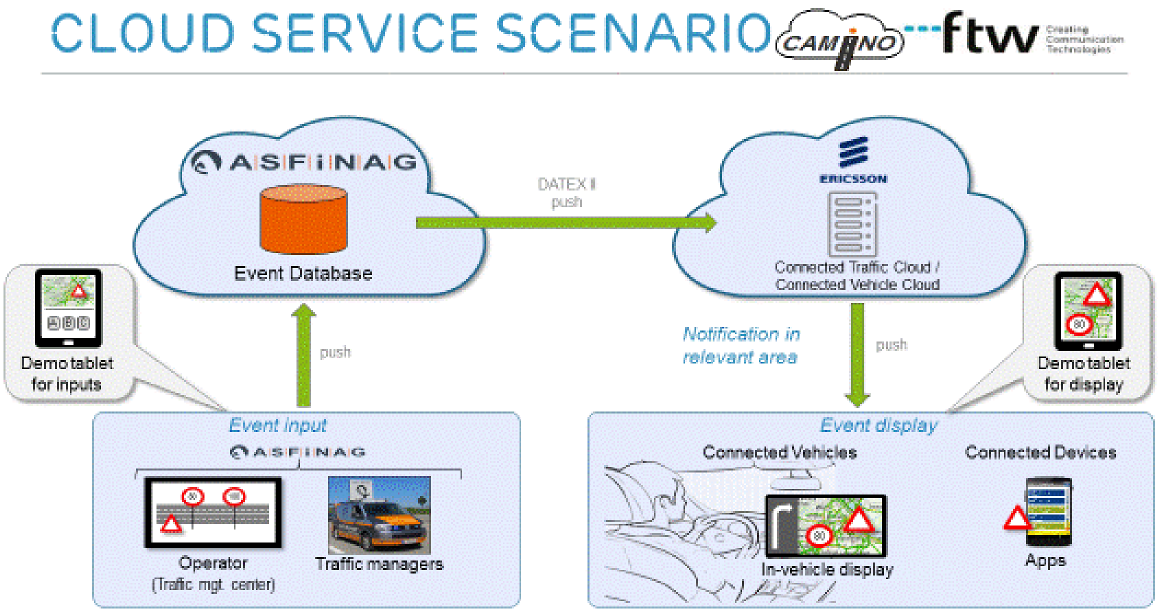


Figure 6: CAMINO Reference prototype linked to Ericsson CTC prototype

Although the Ericsson GLM solution can reach cellular connected clients (e.g. cars) in far less than 100ms (typically in less than 40ms, validated by the CoCarX research project with LTE communication and in-vehicle integration), the Camino PoC revealed sometimes end-to-end latencies of 1-3 minutes.

The root cause for these sometime very long delays was found in the ASFINAG internal system design. Messages had to travel different components, had to be stored at a database, retrieved from that database by periodic pulls, e.g. one-poll-per-minute, before updated messages got pushed out again and towards the Ericsson CTC prototype instance.

This design principle, in between, hinders all “real” real-time constrained end-to-end KPIs. Further on, scalability and internal system load at the ASFINAG database is becoming a serious issue when increasing the pull-database frequency to orders of 50ms or below.

These findings are leading straight to recommendations given at Chapter 6, which consider complementing existing ASFINAG internal system design with a fully event-driven architecture blue-print for real-time processing and real-time forwarding of short time-critical notification messages. The latter is a “must-have” capability for guiding and for active steering of fully automated vehicles. The reader may study the recommendations given at the CloudKonkret Consulting Report [1] for further details and broader rational.

4 OVERVIEW OF TRAFFIC CLOUD SERVICES IMPLEMENTATIONS

4.1 Drive Sweden Program

The vision of the Drive Sweden strategic innovation program is about a set of completely new, automated mobility services for both personal transportation and for goods and logistics. The technical approach is to ensure that vehicles, travelers, and actors are connected and cooperating digitally through smart communication and by connected and cooperating cloud services.

Drive Sweden is one of several Strategic Innovation Platforms[4] that is sponsored by the Swedish Innovation Agency. These platforms get a basic funding (20 MSEK/Year) for 12 years, with tollgates every 3rd year. This is to enable a long-lasting partnership and a better ability to create projects, national or international, like H2020. Drive Sweden started in 2015 and has now 56 partners[5].

Drive Sweden mission entails following:

- a catalyst & magnet for projects and other activities in this domain

[4] https://www.drivesweden.net/en
[5] https://www.drivesweden.net/en/partners

- has a holistic perspective on vehicle automation and works in close cooperation between government, industry and academia
- has a clear coordinating role for national activities and a comprehensive overview of all relevant projects, including international activities
- assures world-leading projects and competence within this domain
- cooperates with all stakeholders to prepare for the next generation mobility (incl. financing, legal framework, integrity, safety and technology as shown in Figure 7 below)

Figure 7 Drive Sweden Framework

One of the “strategic projects” within the Drive Sweden program is “Systems and Services for mobility”. Figure 8 below depicts an overview of the main Work Packages (WP1-WP7), APIs (Application Programming Interfaces) and Test sites (Stockholm, Highway and Gothenburg) of this project. The substantial part of the project is to implement a basic cloud infrastructure for the entire Drive Sweden program, including IoT (Internet of Things) connectivity functionality, charging/billing platform as well as full access to 5G test networks. This base-line cloud infrastructure will allow for connected vehicles system integration and for providing initial cloud services for data collection, traffic management, analytics, plus interfaces for partner interactions and external service invocation.

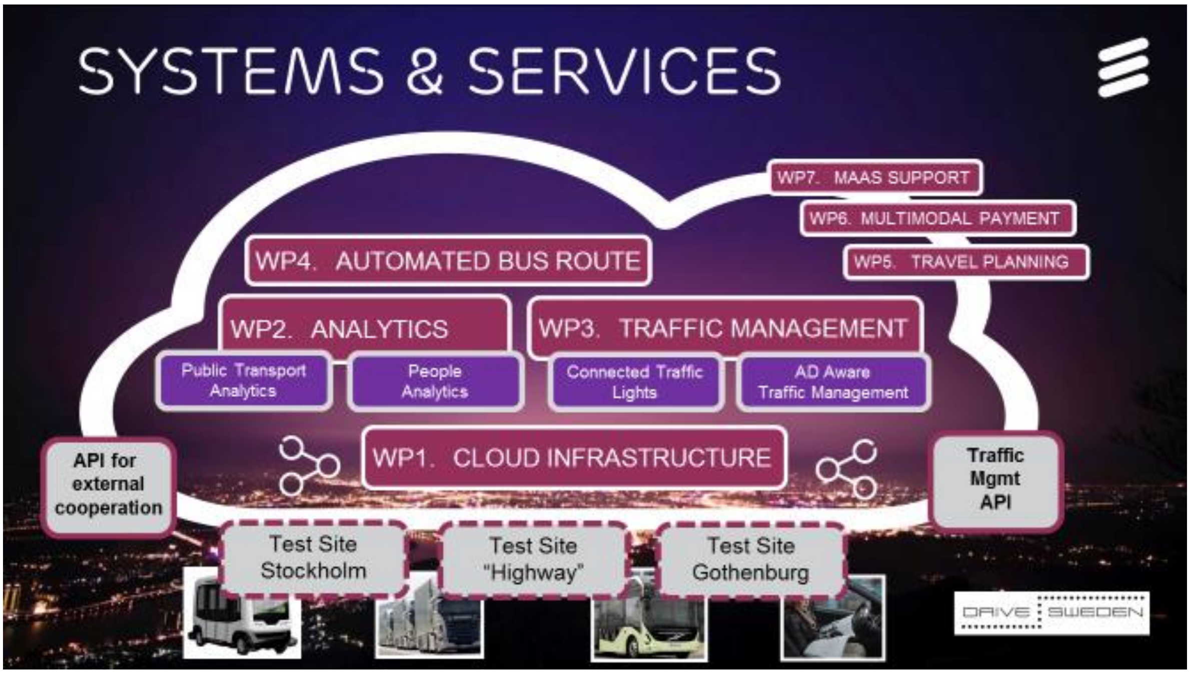


Figure 8 Drive Sweden Project "Systems & Services"

Cloud Infrastructure (WP1. in Figure 8), together with the API for external cooperation, and the API for Traffic management, constitutes the so called “Drive Sweden Innovation Cloud”. The purpose of this cloud is to be a long-lasting resource for a multitude of projects under the Drive Sweden umbrella. Many different (open) data sources are connected to the cloud via the API´s: real-time public transports vehicle-position and -timeliness, traffic lights, surveillance cameras, real-time bus-stop time-tables, TMC DATEX message streams etc. The NordicWay Interchange Node (4.3.2) and DATEX-II functions are incorporated as well.

The Drive Sweden Innovation Cloud is based on state of the art cloud functions and processes, such as microservices in Docker containers, that are used to isolate functions and projects so that they can run in parallel. Highly secure, policy-driven platforms such as Kubernetes and Apcera enable deployment, orchestration, and governance of diverse application workloads. They are also key to control the right of access to data by different partners/projects in the cloud. Ericsson Enterprise Cloud Billing keeps track of all transactions and use of resources, its monetarization, if required, and corresponding settlements with producers or consumers, plus it has ability to enrich data in a flexible way.

Finally, the cloud is built for “DevOps” [13], with continuous development and operation, with cloud instances for Testing, Staging, and two redundant Production instances. These cloud instances have different capacity, Quality of Service and level of support.

Ericsson is in charge of Drive Sweden Innovation Cloud solution life cycle management and daily operation and support.

4.1.1 Autonomous Drive Aware Traffic Control

The first cloud project in Drive Sweden is “Autonomous Drive (AD) aware Traffic control”. The project is a proof of concept and joint effort of several partners: Volvo Cars, Ericsson, Carmenta, Trafikverket, and the City of Gothenburg. The working system and use cases described in the next chapters were successfully demonstrated in June 2017.

AD aware Traffic control is based on the Volvo Cars Drive Me project that is briefly summarized in the Figure 9 below.

Figure 9 Drive Me Project Overview

The vehicles used in the project are intended for Level 4 automation on a "certified road" in Gothenburg, which has carefully chosen road architecture as shown in the Figure 10.

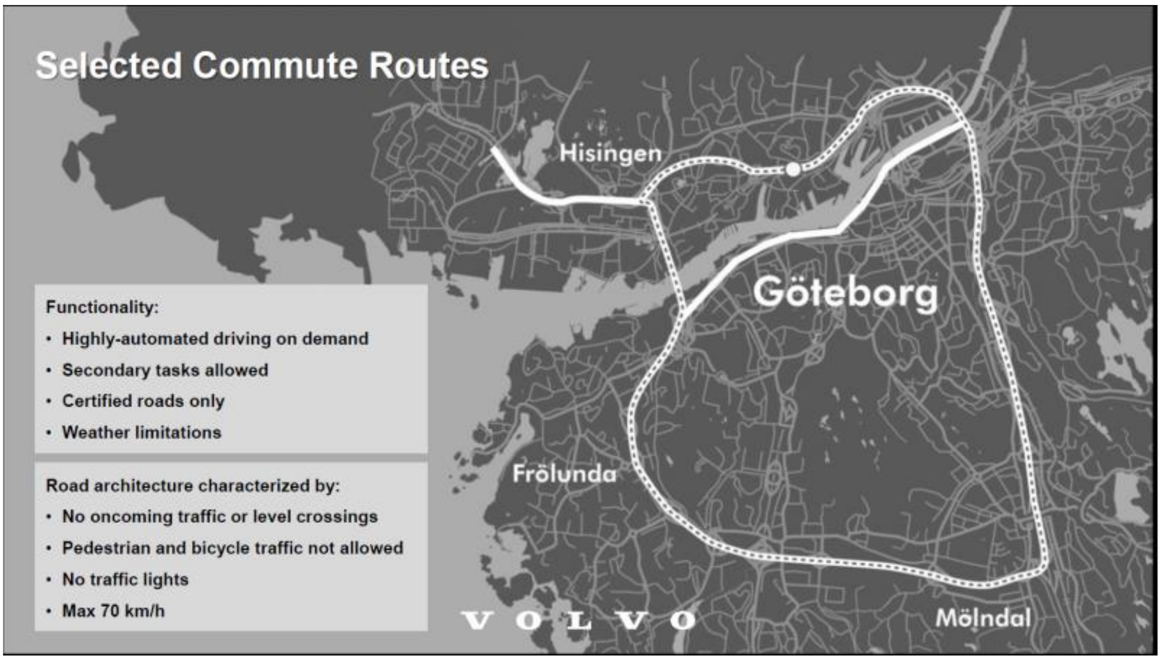


Figure 10 Drive Me test road segments

The Drive Me basic principle is that Volvo Cars enterprise is taking full liability if a certain vehicle travels in AD mode. This means that Volvo Cars must be able to execute that responsibility and allow or revoke AD driving permissions in real time.

The next chapters provide more insight into the implemented technical solution, including the architecture of the system, use cases and information flows that support the AD driving scenario.

4.1.1.1 Architecture

As shown in Figure 11, the architecture is composed of a Central Traffic Control (CTC) cloud instance that is hosted in Drive Sweden Innovation Cloud, a number of OEM-clouds such as Volvo Car Sensus Cloud and external data sources, including Swedish Road Authority Trafikverket.

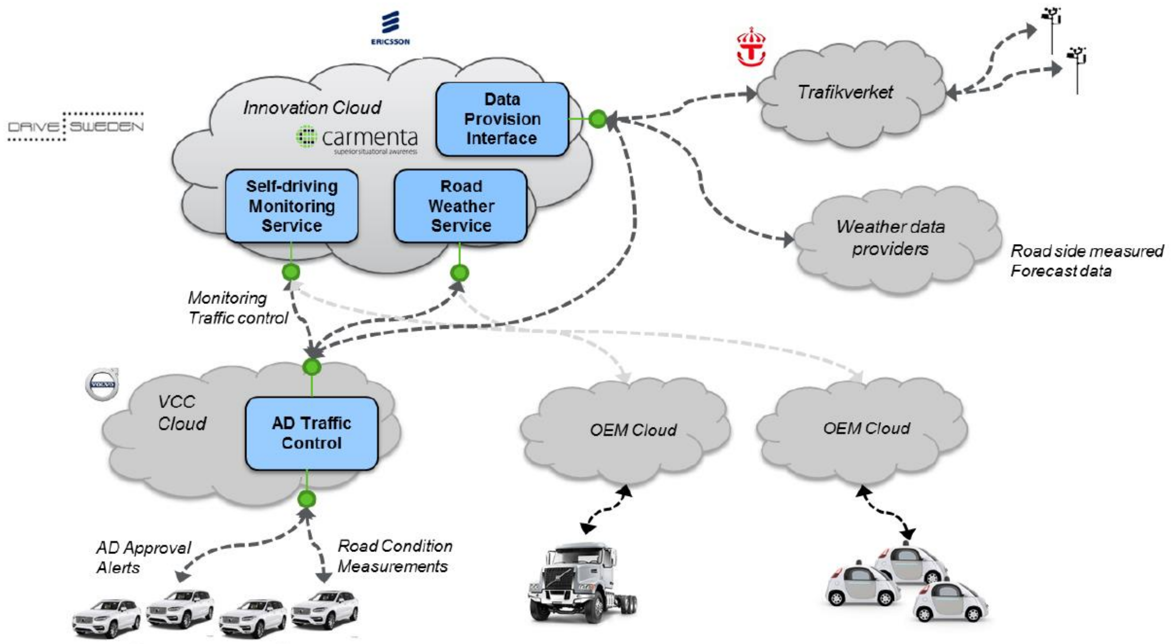


Figure 11 Drive Sweden Architecture

The Autonomous Driving or AD-enabled instance of the OEM Cloud, masters the communication to and from the vehicles which in turn send the route, position and other data to the OEM cloud. The OEM cloud owns the AD traffic control function. Because the OEM knows all details about its vehicles and their AD capability, the OEM can take on the responsibility and liability of vehicles, they turn on the AD mode.

With some inspiration from the NordicWay project (4.3) and the gained insight that many OEM´s will have the same need for traffic and weather data, the Central Traffic Control (CTC) Cloud was introduced in Drive Sweden. It is assumed that the CTC shall operate in a Public or a Public Private Partnership instance, to gather all traffic and weather data and to serve any number of OEM clouds by aggregating all data of interest.

The CTC cloud has a publish/subscribe and request/response mechanism based on AMQP, same as in NordicWay. An instance of the NordicWay Interchange Node (see 4.3.1) is included in the CTC, in order to collect Road Friction Information from Volvo Cars and Road Works Warnings from the Kapsch cloud.

A DATEX-II stream from the Swedish Road Authority Trafikverket into the CTC is used to monitor the traffic situation and weather data, while weather forecasts are taken from FORECA and other sources. The data exchange between the CTC cloud and OEM clouds also use DATEX-II standard. Some extensions to facilitate the AD use cases have been added.

4.1.1.2 Interfaces

Figure 12 depicts the main Interfaces used in the AD-Aware Traffic Control architecture.

An AMQPS (SSL/TLS) messaging system provides standard APIs for partners and OEMs to exchange messages with CTC.

The information provided by the CTC to the OEM cloud is propagated via the AD traffic control to connected vehicles over HTTP/MQTT10.

External traffic, weather, map services are provided to CTC over HTTPS.

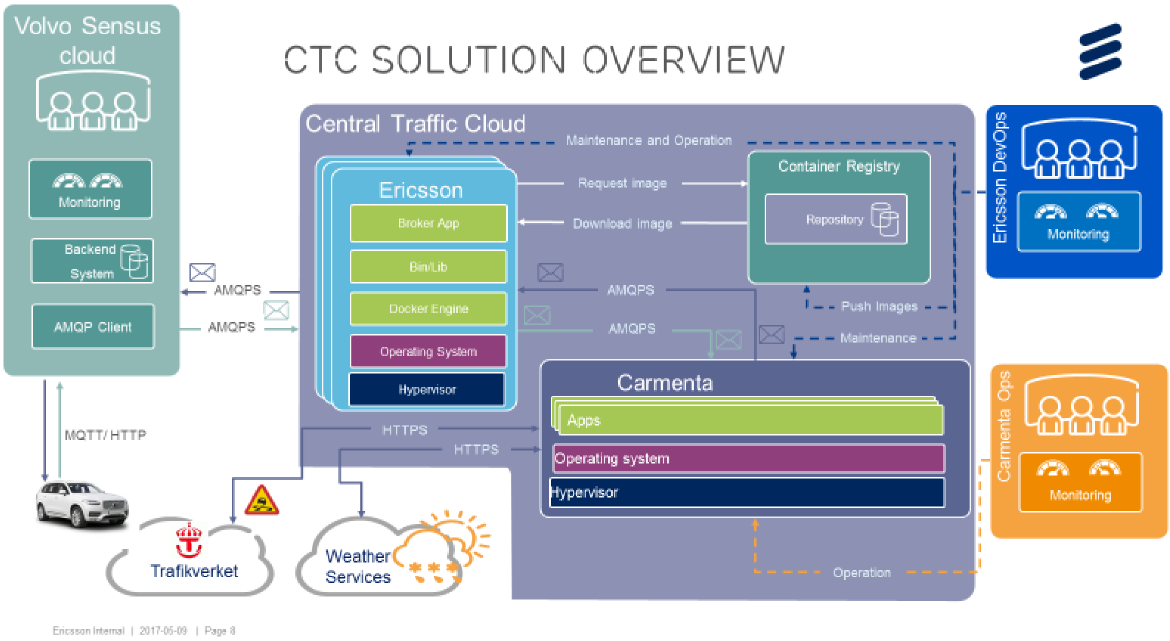


Figure 12 Drive Sweden Central Traffic Cloud - Interfaces Overview

4.1.1.3 Use Cases

The AD-Aware Traffic-Control use-cases build on two main services. The first service is **Transfer of certified road segments map data** from the OEM to the CTC. 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.

The following Use Cases have been implemented in the AD-Aware Traffic Control project:

1. **CTC advice on AD driving based on situation**

The CTC reads the DATEX-II message stream from Trafikverket and maps out the events on the certified roads which it monitors. If some alarming occurs, e.g. road conditions like: lane closure, road blockage, construction sites, faulty signs on a road segment; the CTC 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.

2. **CTC advice on AD driving based on 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 lane, road or object visibility on a specific section of certified road, extreme precipitation, snow, strong winds, low friction or aquaplaning risk on a specific section of certified road.

3. **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.

4. **Density (flow) of AD vehicles in AD mode**

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.

5. **Safe stop alert**

A “Safe Stop Alert” from the OEM AD control to the CTC will be based on aggregated data (e.g. 3 safe stops within 3 km and 3 minutes). In order to protect privacy, the OEM AD control does not expose the position of an individual AD vehicle that made a safe stop.

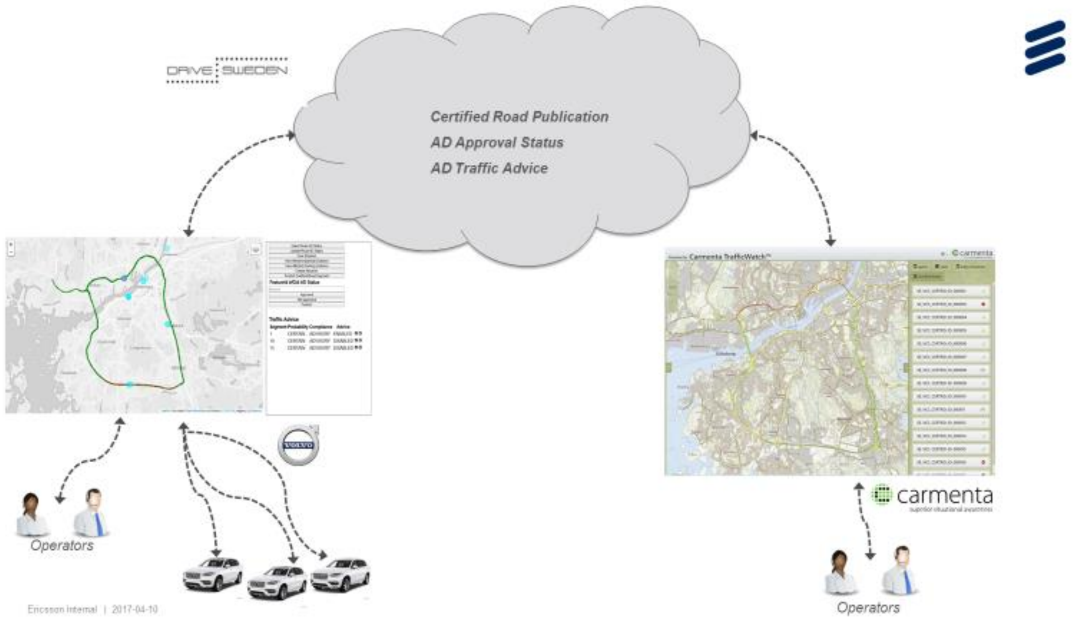


Figure 13 Drive Sweden AD Services

4.1.1.4 Next steps

A follow up project “AD aware Traffic Control – Emergency vehicle information” started in August 2017. The system architecture will include an integration with the Swedish alarm centers (PSAP) “SOS-Alarm”.

The “most probable path” of ambulances and fire engines will be mapped to the planned route of AD-vehicles in AD mode. If a conflicting situation is detected, actions such as manual overtake, driving on the hard shoulder, or choosing another route, can be taken.

Apart from more functionality, the next project phase would also include more content by adding another OEM and their AD-vehicles. This would enable testing the complexity of handling a many-to-one mapping of, for example, status of certified road segments in the CTC.

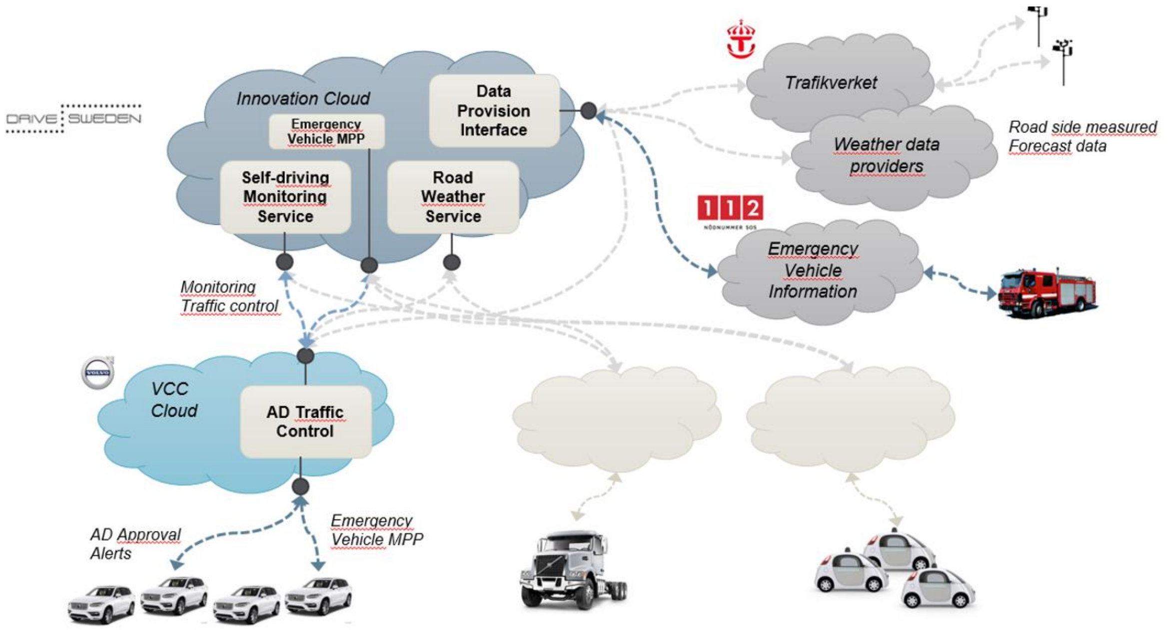


Figure 14 AD-aware Traffic Control - Emergency vehicle information

4.2 Talking Traffic (Beter Benutten Program)

The Netherlands has rolled-out a national program called “Beter Benutten” (“Talking Traffic”). The goal is to significantly reduce congestion on the roads by optimizing their usage.

> *“More asphalt is not always the solution to our traffic problems. Our infrastructure can be optimized by providing personalized information to individual travelers.”*
>
> Melanie Schultz van Haegen
> Dutch Minister of Infrastructure and the Environment

This is done by sharing data between roadside equipment and vehicles and by connecting 25% of all traffic lights.

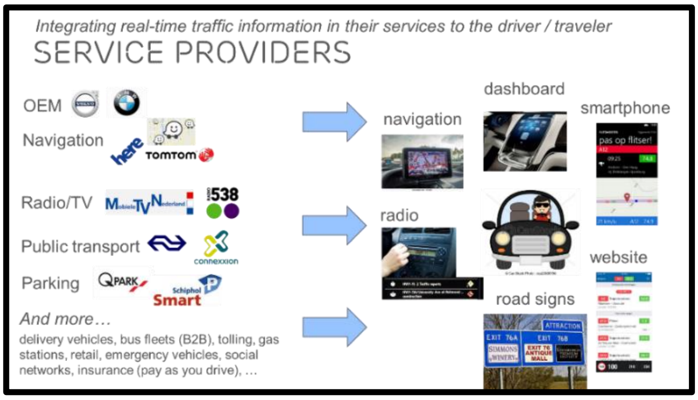
A nation-wide Cloud platform handles the data collection and sharing and the private sector is challenged by the Ministry to introduce new business models with local governments and travel service providers.

The goal of the Dutch road authorities is to create a self-sustained eco-system (more details on the eco-system below). In order to kick-start the process, the government has funded the first 3 years of operation.

The Dutch road authorities imagine an eco-system consisting of three main players:

- End-user service providers (Cluster 3)
  - in-vehicle or over-the-top mobile-phone based services
- Infrastructure providers (Cluster 1)
  - Providing real-time information from ITS assets
- Information Brokers (Cluster 2)
  - Connecting the two other parties and enhancing available information, providing a compelling offering to end-user service providers.

The picture to the right provides an overview of the extent of this eco-system.



Ericsson, together with partners Siemens and Simacan (local GIS party), have been awarded a contract as a “Cluster 2” party in 2016.

Cluster 2 partners Siemens and Simacan each do provide a part of the overall offered functionality, with Ericsson being the “connecting element” in the overall solution. The actual end-user interaction is being handled by Cluster-3 parties, while the Ericsson’s solution is providing corresponding correlated and enriched information to these parties.

4.2.1 Architecture

A high-level view of the architecture of the “Beter Benutten” solution is outlined in Figure 15.

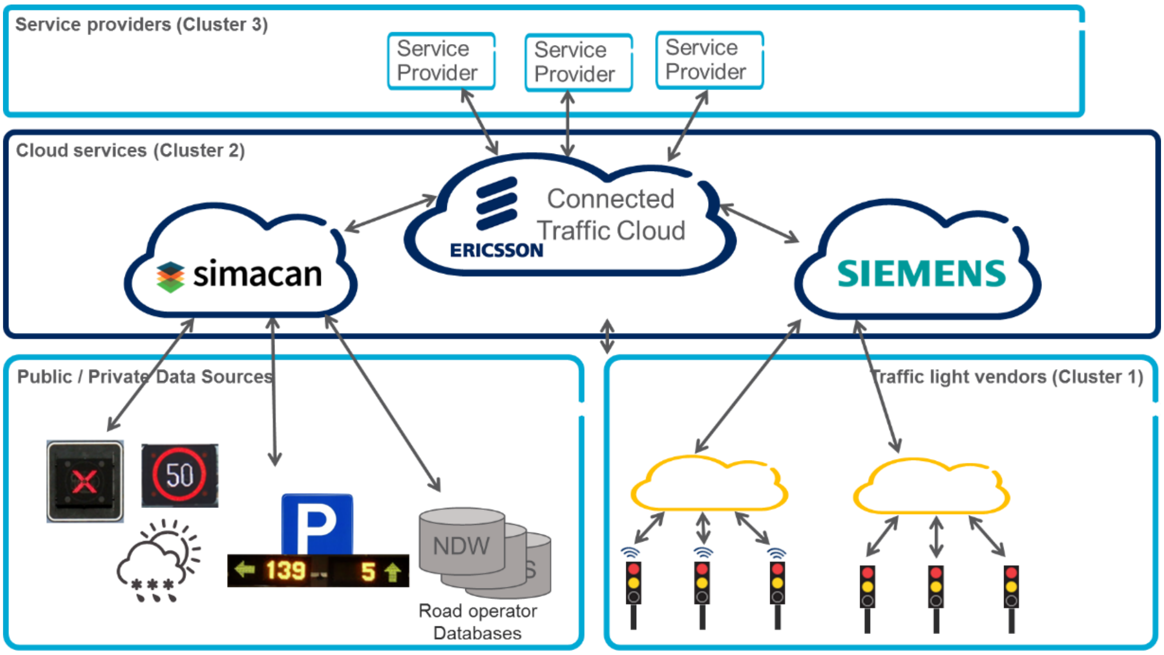


Figure 15 Beter Benutten High Level Architecture

The Siemens cloud is providing road-asset (traffic light) information, Simacan is enriching that information with public data sources and is providing GIS functionalities, and Ericsson ties everything together via its Connected Traffic Cloud, being the main interface between Service Providers and mentioned Cluster-2 parties.

The Ericsson Beter Benutten cloud solution also includes functionality for Partner onboarding, Service Catalogue, SLA Management, Security and Identity Management and Monetization and Billing. As shown in Figure 16, Beter Benutten specific use-cases and interfaces are complemented by Connected Traffic Cloud generic enabling functions (depicted in dark blue) and Interface groups such as described in chapter 3.2.1. The combined setting is providing a secure, scalable and customizable end-to-end solution.

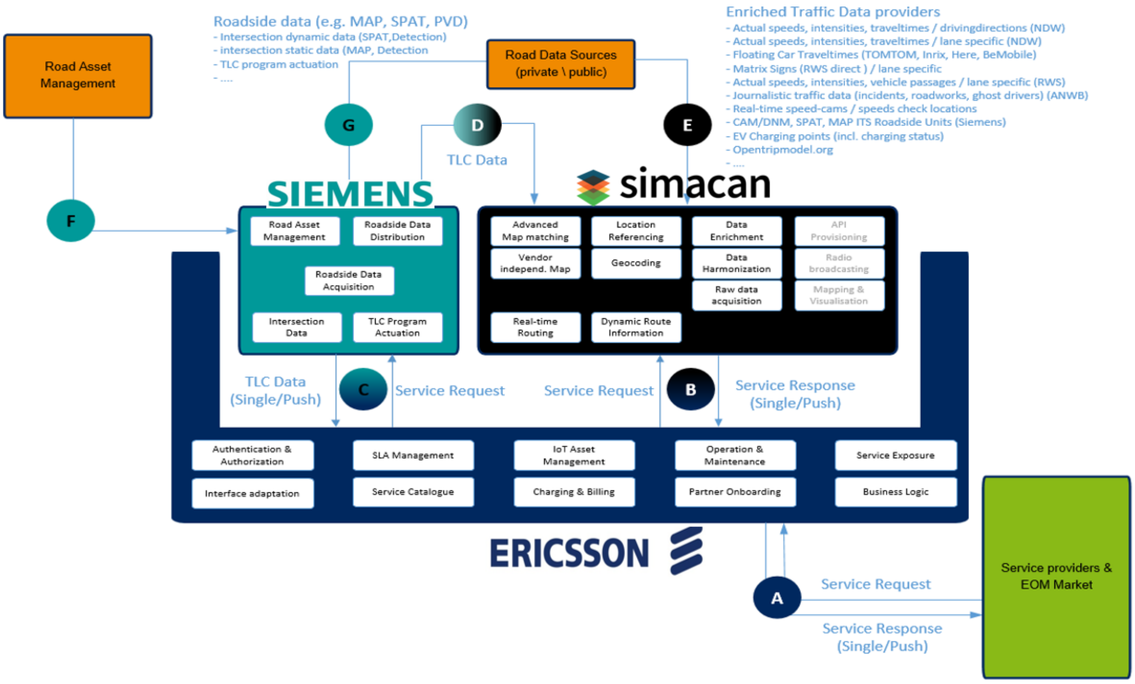


Figure 16 Beter Benutten solution with Connected Traffic Cloud functions

4.2.2 Interfaces

The Siemens and Simacan clouds provide road and traffic data information to the Ericsson Connected Traffic Cloud in a standardized format, from following sources:

- Public Data Sources: DATEX-II, TMC, Environmental data (weather), National Road Database (Dutch)
- Private Data sources: Floating Car Data, Variable Message Signs
- ITS Assets: SpaT / MAP (SAE J2735 / ISO TS 19091), Loop Data

Service Providers (Cluster 3) that shell deliver relevant info to their served vehicles (e.g. roadworks alerts or the maximum speed allowed on a road segment), will request specific services via the Ericsson Connected Traffic Cloud, using a Push/Pull interface (REST), or custom interfaces that are built specifically for the service providing party.

4.2.3 Use Cases

Following use-cases have been selected for the “Beter Benutten” initiative:

1. Maximum Speed
2. Road Works
3. Traffic Light Priority
4. Traffic Light “time-to-green”
5. Optimize Traffic Lights
6. Parking Information

As an example, Figure 17 depicts a message-flow for the “Maximum Speed” use-case.

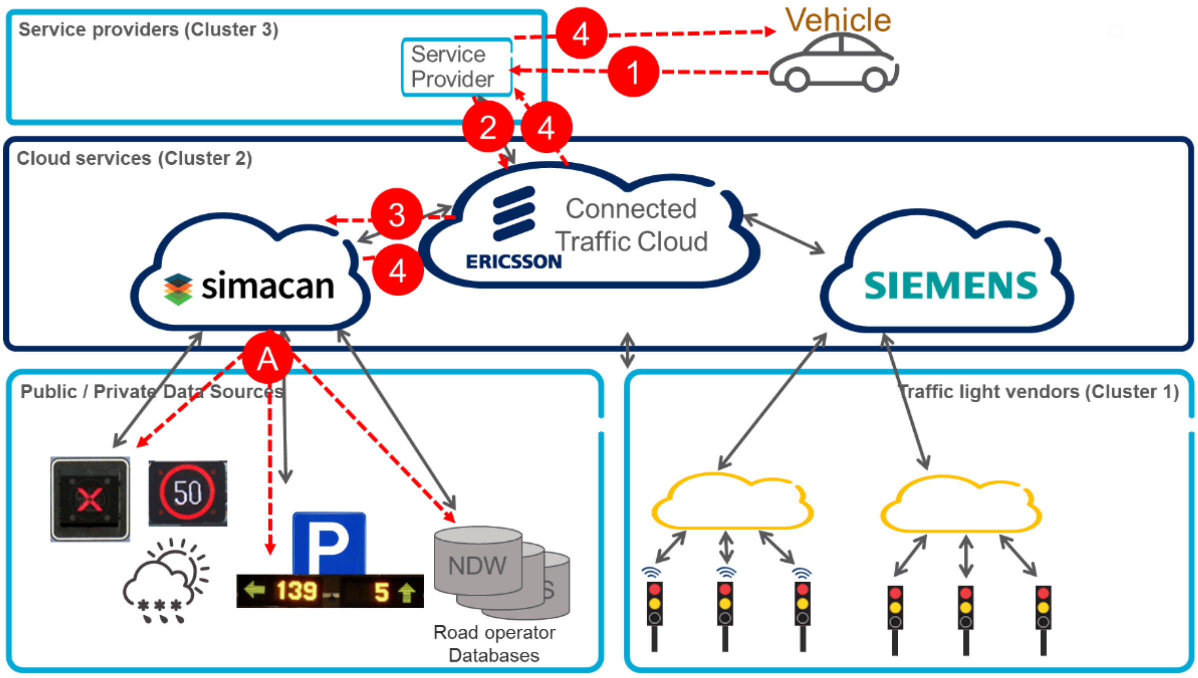


Figure 17 “Maximum Speed” Use Case data flow

The information flow is as follows:

(A) The GIS platform builds a digital model of the road-network (initially based on the national road database), continuously updating the model with information received from several sources (DATEX-II, Variable Message Signs, Road Traffic warnings), keeping a digital model of the road network with the active maximum speed on each stretch of road.

(1) A vehicle, driving on a specific road, sends its location to its service provider with a request for the current maximum speed.

(2) The service provider connects to the “Beter Benutten” solution, sending the location of the vehicle, and requesting the current maximum speed.

(3) The Ericsson CTC authorizes the requests, optionally monetizes it, and then sends the request to the GIS system (Simacan).

(4) Simacan maps the location to a stretch of road, and returns the current maximum speed on that stretch of road to the vehicle.

4.3 NordicWay-I

The main objective of the NordicWay project [6] was to test and demonstrate the interoperability of C-ITS (Cooperative ITS) services both for passenger and freight traffic, and to provide a comparable user experience in the four engaging countries (Finland, Sweden, Norway, Denmark). It was the first large-scale pilot demonstrating the technical feasibility of probe data collection and C-ITS service delivery using cellular communication (3G and LTE/4G). The Cooperative services demonstrated within the NordicWay-I project correspond to the Safety Related Traffic Information (SRTI), i.e. they aim to increase the awareness of drivers in dangerous situations.

4.3.1 Architecture

The NordicWay architecture builds on the following elements:

- cloud-to-cloud communication for the communication between the different service providers and Traffic Data providers involved.
- a NordicWay Interchange Node (Figure 19) is the key element to assure interoperability. The server allows different service providers and traffic data providers to communicate with each other
- cellular technologies for the transmission of SRTI messages with low latency, complemented with Infrastructure-to-Vehicle communication based on ITS-G5 for specific use cases

Figure 18 below provides high-level view of the NordicWay-I architecture approach.

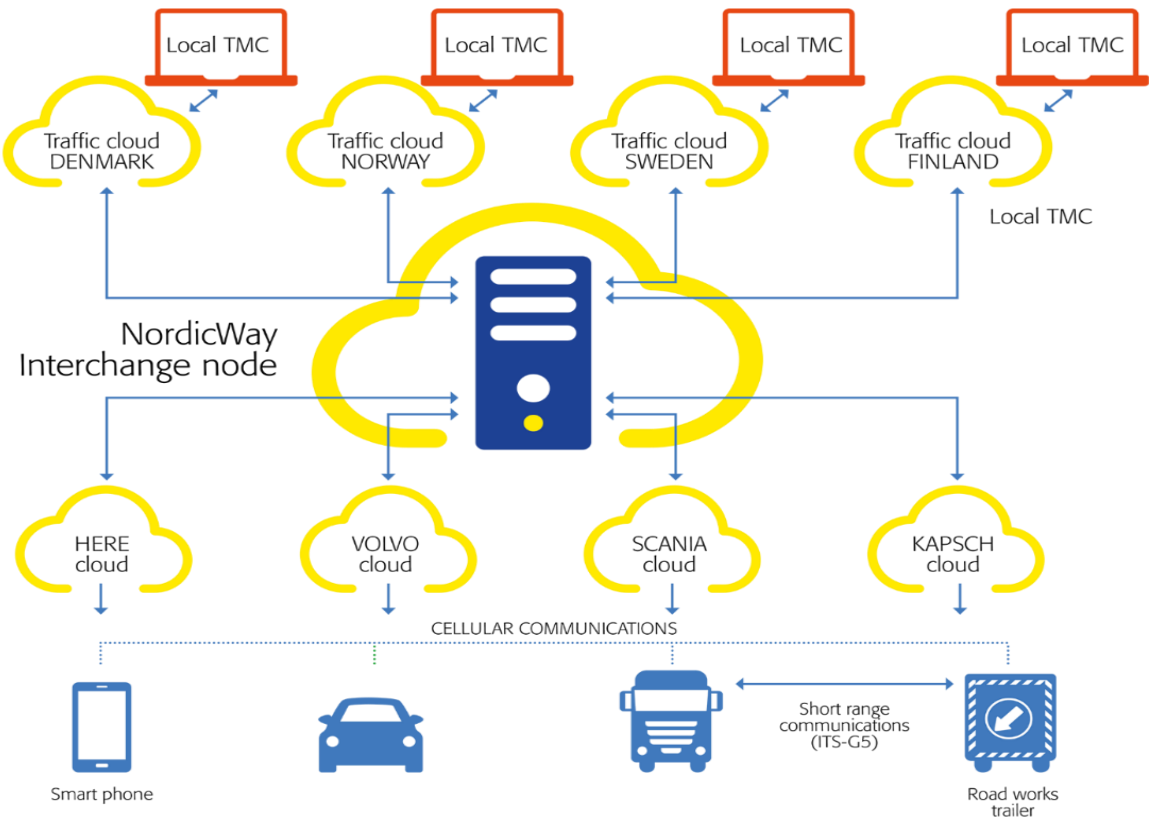


Figure 18 NordicWay-I High Level Architecture

4.3.2 Interfaces

The key component in the NordicWay architecture is the NordicWay Interchange Node (Figure 19).

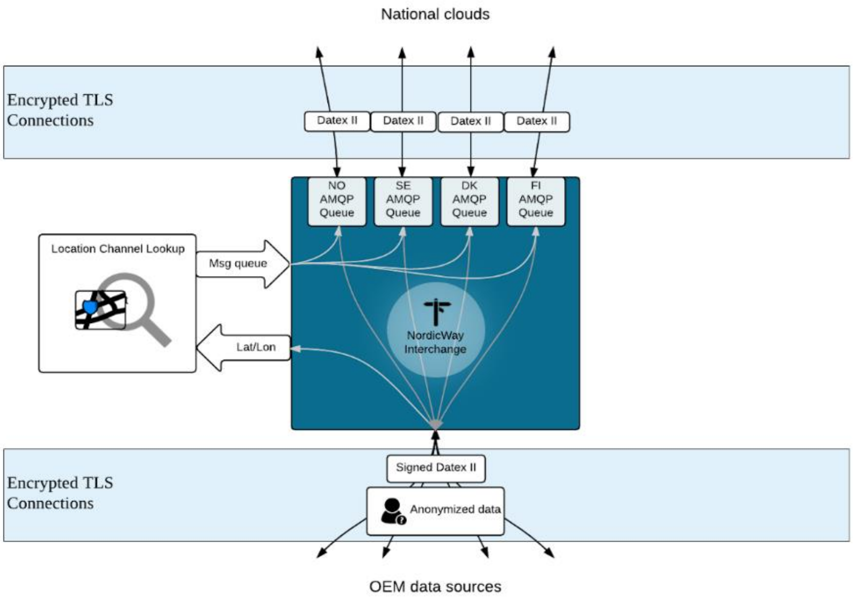


Figure 19 NordicWay Interchange Node queues and messages routing

The Interchange Node is based on open source Advanced Messaging Queuing Protocol AMQP. Key features and capabilities of AMQP are outlined in Figure 20 below.

AMQP in a nutshell from: https://www.amqp.org/about/what

AMQP is the Internet Protocol for Business Messaging

The Advanced Message Queuing Protocol (AMQP) is an open standard for passing business messages between applications or organizations. It connects systems, feeds business processes with the information they need and reliably transmits onward the instructions that achieve their goals.

Key Capabilities

AMQP connects across:

- Organizations – applications in different organizations
- Technologies – applications on different platforms
- Time – systems don't need to be available simultaneously
- Space – reliably operate at a distance, or over poor networks

Business Case

The main reasons an enterprise will chose AMQP over proprietary alternatives are:

- Realize the savings commoditization brings; remove vendor lock-in
- Connect applications on different platforms; choose the right platform for the job
- Connect to business partners using a full featured open standard; remove technical barriers to trade
- Position for innovations built upon the foundation of AMQP

Key Features

AMQP was designed with the following main characteristics as goals:

- Security
- Reliability
- Interoperability
- Standard
- Open

Bottom Line

The capable, commoditized, multi-vendor communications ecosystem which AMQP enables creates opportunities for commerce and innovation which can transform the way business is done on the Internet, and in the Cloud.

Figure 20 AMQP in nutshell

The AMQP-based Interchange Node is a publish-subscribe message queue system that routes messages between the OEM clouds (shown as south-bound in the Figure 18 and National Traffic Clouds (Traffic Management Centers, shown as north-bound in Figure 18). The messages that are coming to Interchange Node are sorted in queues (see Figure 19 above) based on the AMQP message header containing geographical position, origin of data, and type of data. In NordicWay-I, the chosen type of data or the data container format is DATEX-II.

Each party connected to Interchange Node can be a producer and/or consumer of messages, based on their subscription mode. Subscriptions are set up manually upon agreement with the party’s stakeholders. Queues as well as message filtering methods for specific queues are configurable. In NordicWay-I, the queues are sorted by country. However, there are also border areas between Norway - Sweden and Denmark – Sweden, that are of interest for Traffic Management in both countries, so those areas shall become available/forwarded to both counties, irrespectively of a given country code. In this way, the national Traffic Management Center can also “look” a little over the national border.

In a future commercial implementation, Ericsson foresee a “federated network” of Interchange Nodes, which is further detailed in the CloudKonkret Consulting Report [1].

Furthermore, the Interchange Node is also becoming part of Ericsson Connected Traffic Cloud, which is an open, transport industry-specific service platform that provides industrial grade security, data protection, Quality of Service, charging and billing, partner onboarding etc. As shown in Figure 21 below, the Interchange Node is complemented by Connected Traffic Cloud generic enabling functions (depicted in dark blue) and Interfaces described in chapter 3.2.1, providing a secure, scalable and customizable end-to-end solution.

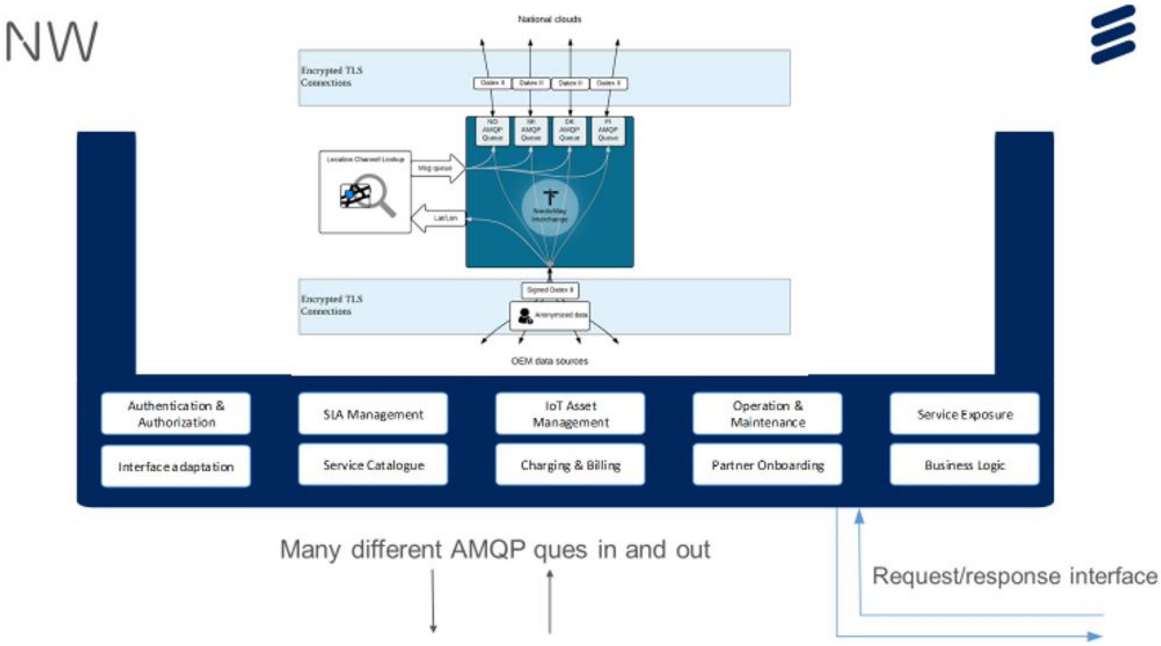


Figure 21 NordicWay Interchange Node as part of Ericsson Connected Traffic Cloud

For more details about interfaces, communication technologies and message format please refer to the NordicWay System Design document [6].

4.3.3 Use Cases

The NordicWay-I use-cases focus on the delivery of following Safety Related Transport Information (SRTI) with low latency to vehicle drivers:

1. **Road authority informs about exceptional weather conditions**

   In case of fog, heavy rain or heavy wind, the national TMC cloud publishes SRTI message to the Interchange Node, which transfers it to the subscribed OEMs clouds, that forward the messages to the connected vehicles which are near the event.

2. **Vehicle detects slippery road**

   Volvo vehicle passing the slippery spot sends sensor data to OEM cloud (e.g. from Volvo Cars) that informs other OEM-registered vehicles that are in the vicinity. The OEM cloud also publishes the message to the Interchange Node for forwarding to a local TMC cloud.

3. **Smart phone user informs on object on the road**

   A driver with a phone passing by a dangerous event, e.g. accident or low visibility on the road, sends a waring message to the OEM cloud / HERE that informs other OEM-registered vehicles that are in the vicinity. The OEM cloud also publishes the message to the Interchange Node for forwarding to local TMC cloud.

4. **Trailer warns about roadworks**

   Activated roadworks trailer transmits message to Provider's backend (e.g. a Kapsch Trafficcom backend), which publishes the message to the Interchange Node for forwarding to subscribed clouds, which transmit the message to vehicles approaching the roadworks. The trailer transmits roadworks warning message to approaching Scania vehicles via ITS-G5.

This film illustrates the use cases: https://youtu.be/gTrrl4ymvyc.

Following Figure 22 shows that hybrid communication was utilized in NordicWay-I for demonstration of use cases.

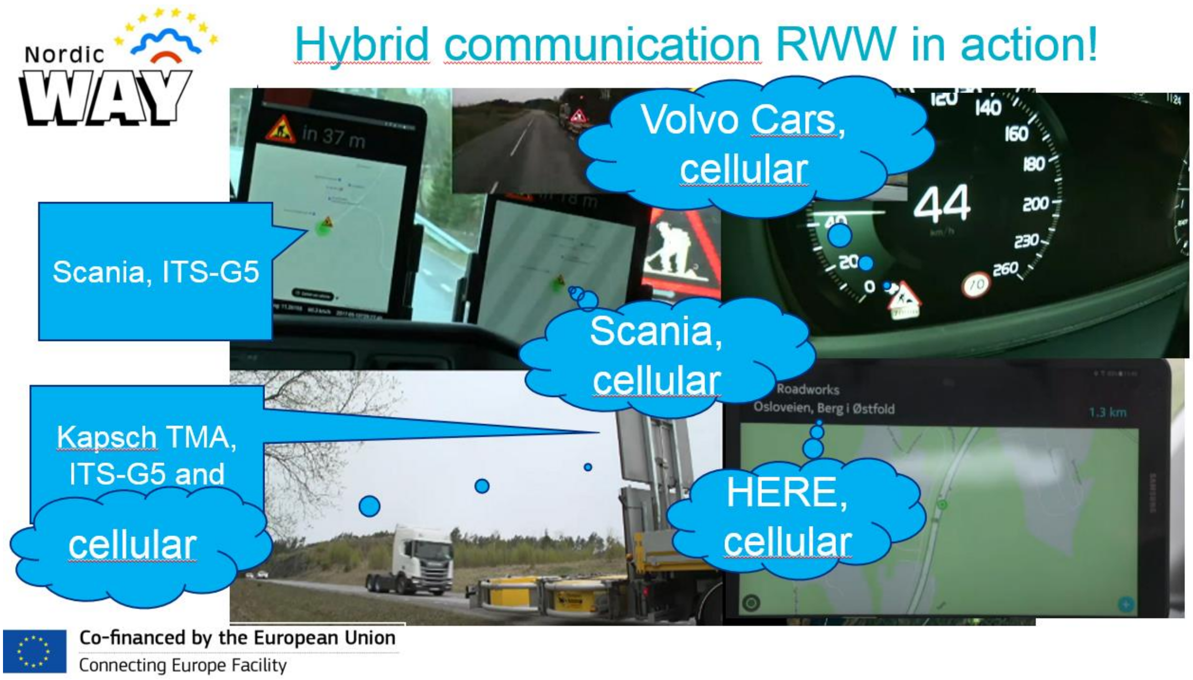


Figure 22 Hybrid communication in NordicWay-I

4.3.4 Next steps

More performance measurements will be made, and statistics gathered during Q3 2017. During Q3 and Q4 2017 the final NordicWay-I report will be written with conclusions and recommendations.

4.4 NordicWay-II

The Innovation and Networks Executive Agency (INEA) has approved the NordicWay-II project and funding in June 2017. During Q3 and Q4 2017, the consortium led by the Norwegian Public Road Administration will negotiate the grant agreement with INEA. The description below is based on the project application, but the exact content of the project (including partners and use cases) will be determined during the grant agreement process. Project execution will start in January 2018.

4.4.1 Architecture – High Level Approach

As described in Chapter 4.3, the NordicWay-I project has established a unique architecture and eco-system, enabling a cross-border cellular/hybrid C-ITS pilot with demonstration of V2V and V2I communication and core Safety Related Traffic Information (SRTI) services. The Nordic countries have decided to further develop their C-ITS cooperation through extended joint pilot activities in a NordicWay-II project.

The key innovation in NordicWay-I, the Interchange Node for linking the clouds of OEMs, service operators, and road authorities (see Figure 18), has demonstrated an elegant and efficient solution for interoperability. By using DATEX-II messages and geo-localized message distribution through the Interchange AMQP server, all messages are standardized and the system is functioning seamless regardless to borders and jurisdictions. Therefore, the Nordicway-II project will reuse the architecture of NordicWay-I and further enhance its key element, the Interchange Node, with additional features and functionalites such as federation capabilities.

Even though the exact scope of Use Cases in NordicWay-II is not yet determined in detail, it will focus on Day 1 and day 1,5 C-ITS services as defined by the C-ITS Platform and further exploit hybrid communication.

The Swedish pilot will contribute to the project with a particular focus on C-ITS in urban areas (nodes) and the interfaces between urban and interurban networks, and towards other transport modes (intermodal nodes).

The Norwegian pilot will focus on Bottleneck management in arctic conditions.

The Finnish pilot will focus on Cooperative and automated driving pilots.

The Danish road authority will participate in the horizontal activities in NordicWay-II, and supply data to the NordicWay Interchange network in order to reach a critical mass of data to make this platform a viable data source for large scale projects.

5 ASFINAG CLOUDKONKRET PROTOTYPE

The ASFINAG CloudKonkret prototype combines key elements of NordicWay-I, DriveSweden, Camino, and the Geo-location Messaging concepts with some country-specifics to demonstrate two typical Use Cases that can be implemented as cloud services in future. For general overview of NordicWay-I, DriveSweden and Camino please refer to previous Chapters 4.3, 4.1.1 and 3.2.3 respectively.

In case of the NordicWay-I system blueprint, the Kapsch Cloud provides information about the roadworks in Sweden, and the Swedish Road Authority Trafikverket subscribes to this information in order to get the information pushed via a NordicWay Interchange Node to its TMC. In difference to this blueprint, and in case of the CloudKonkrete Proof of Concept, ASFINAG collects the roadworks information from roadworks trailers on Austrian roads and publishes this information to a reference traffic cloud. Similarly, ASFINAG collects traffic-relevant data from many other sources such as cameras, sensors, etc. and then further refines and enriches this data in the Traffic Management Center and internal processes, which results in various directives and information for drivers such as speed limits, road hazards, traffic congestion and similar.

The CloudKonkret project and prototype aim to investigate and demonstrate how a Road Operator such as ASFINAG can utilize cloud services to seamlessly share traffic information with various other Operators, OEMs and Service Providers clouds, despite some country or operational specifics. In the CloudKonkret prototype, ASFINAG publishes traffic-relevant information to a reference cloud instance that serves as entry point to an intelligent messages routing network to other clouds and thereby as enabler for services provisioning to back-end connected vehicles. Such a cloud setup has the following advantages:

- It facilitates the interoperability of C-ITS (cooperative ITS) and the exchange of information cross-border and cross-organizational, with a method that is commonly accepted by all parties and not restricted to a specific partnership or implementation

- It also means that Road Authorities such as ASFINAG, or OEMs can establish and maintain a single commonly agreed interface to the reference cloud to send and receive traffic data regardless of physical location, administrative boundaries and organizational specifics.
- Last but not least, it enables services to be offered to end-users in real-time, independent of the vehicle or the end-user equipment (smart phone, in-car app, …) and independent of country, language or communication medium.

The next chapters provide a high-level overview of the CloudKonkret PoC architecture and the systems involved, the interfaces and the technologies used. This is followed by an overview of the implemented use cases that exemplify the delivery of ASFINAG safety-related traffic information via the reference cloud to potentially affected connected vehicles.

5.1 Architecture

ASFINAG CloudKonkret prototype architecture is based on the cloud infrastructure elements that are being developed as part of NordicWay, DriveSweden and Camino concepts.

Same as other Road Authorities Clouds in NordicWay, ASFINAG CONTENT System connects to NordicWay Interchange Node which is a key element in the NordicWay concept and broker that routes the traffic messages published by “producer” system to the output or “consumer” system, based on predefined selection criteria, such as the message type and message geo-location.

As shown in the Figure 23 below, in the CloudKonkret prototype, ASFINAG system acts as “producer” that publishes Roadworks Warning (RWW) and Traffic Management Plan (TMP) DATEX-II messages to NordicWay Interchange Node. Upon reception, Interchange Node will route all messages with “producer” ASFINAG, which have geo coordinates that belong to Austria, to the “consumer” system Ericsson CTC (Connected Traffic Cloud).

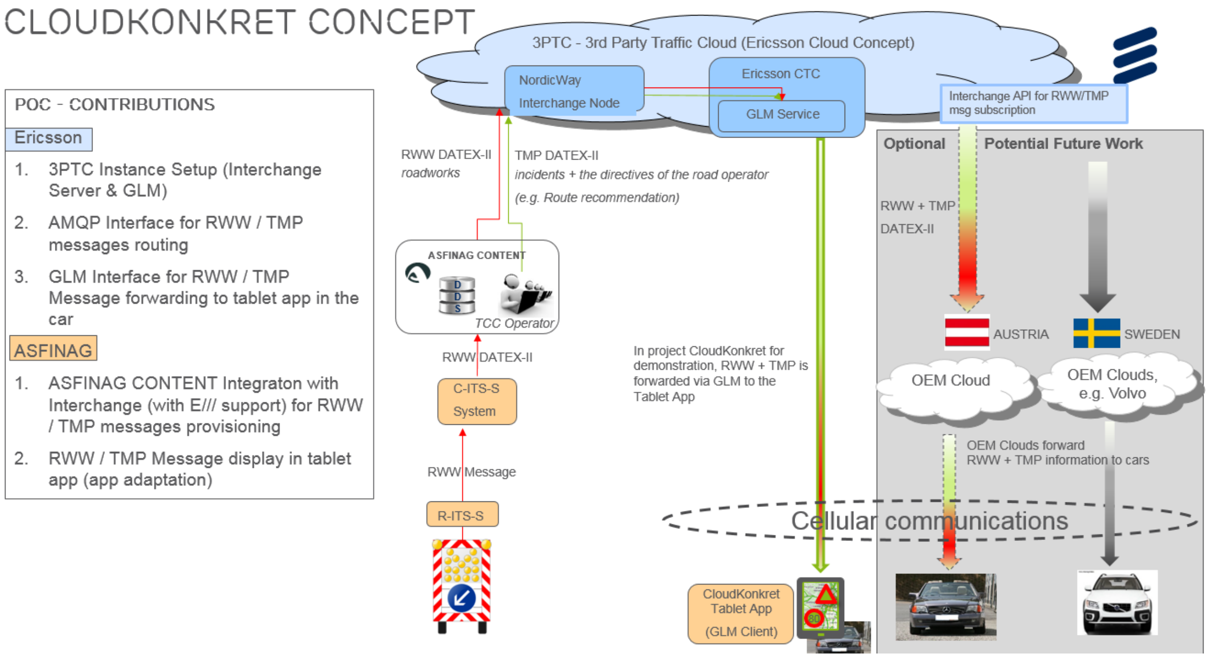


Figure 23 CloudKonkret High Level Architecture

In case of the CloudKonkret PoC, the Ericsson CTC is parsing incoming messages to create individual RWW and TMP records, which in turn will then be forwarded to the GLM Service (3.2.2), used also in Camino project (see 3.2.3). GLM Service consists of server and client-side application.

The GLM Server provides the following functionality:

- It contains map with the tile grid and messages relevance radius
- In the demo setting, (only!) the GLM Server knows the position of vehicles by the GLM Client app (Android app on the mobile device or tablet), because the client is constantly sending its GPS position to the GLM Server. In a real operation setting, a position update will only be send when leaving a virtual grid area and the boundaries of a new grid tile need to be received. This “privacy-by-design principle” is perfectly matching with the upcoming EU regulation for data privacy protection [18].
- It recognizes which car is in the relevance area for the specific warning (for ex. roadworks warning) and sends respective message to the GLM Client app to notify the driver in advance

For example, if ASFINAG has pushed the RWW message to the Interchange Node, containing a situation record for road construction works on the road A2 Süd Autobahn, that message will be forwarded by the Interchange Node to an Ericsson CTC, then parsed and pushed to the GLM Server. As soon as the vehicle approaches this road section, the GLM client app in the vehicle will receive the roadworks notification from the GLM Server and the client map will display respective "!" road hazard icon, as can be seen in Figure 24 GLM Client Map below.

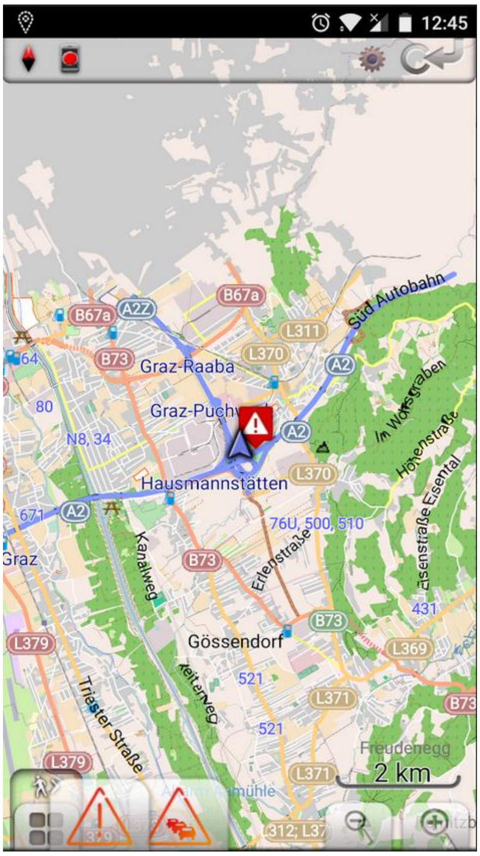


Figure 24 GLM Client Map

5.2 Interfaces

The CloudKonkret prototype implements the following interfaces, as shown in Figure 25 below.

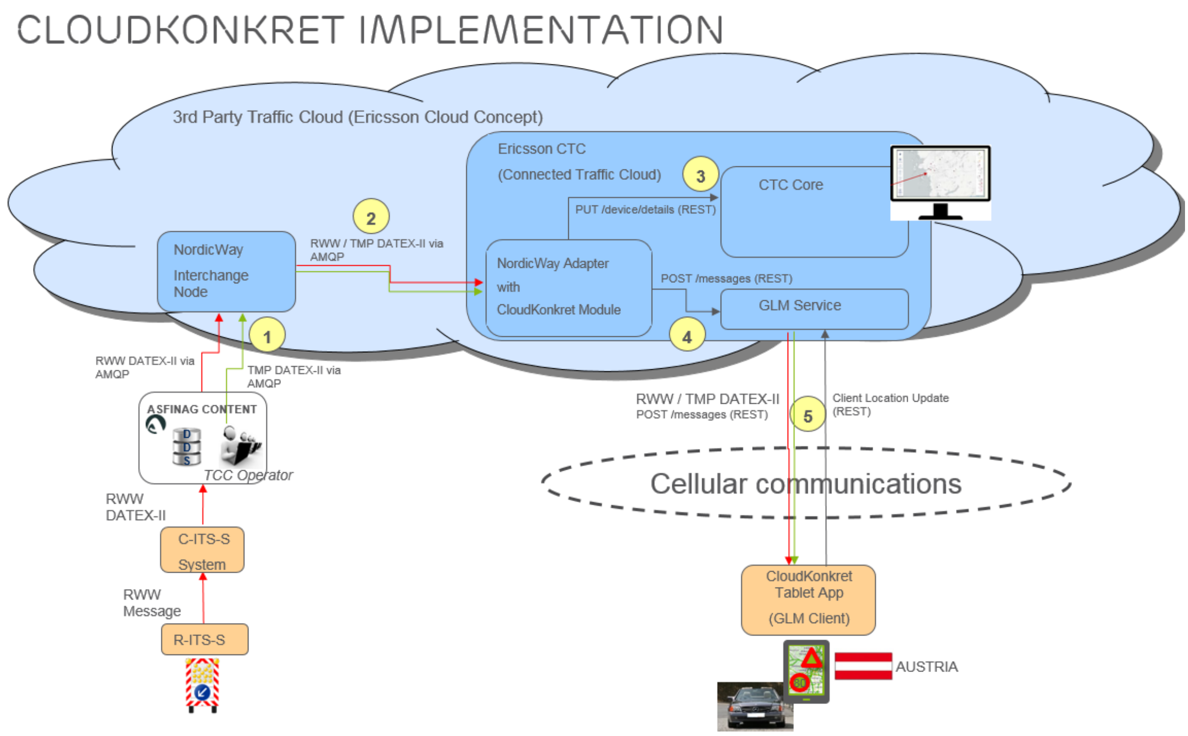


Figure 25 CloudKonkret Interfaces

(1) ASFINAG CONTENT -> Interchange Node

The Interchange Node utilizes the publish-subscribe AMQP (v1.0) queuing protocol for distributing messages between connected actors, which can be data producers, consumers or both. In the CloudKonkret prototype, ASFINAG CONTENT is serving the role of a traffic data producer.

Same as other NordicWay-I producers, ASFINAG implemented AMQP producer client that connects to AMQP server URL via SSL and then sends RWW and TMP messages (with AMQP header and DATEX-II body) to the NordicWay Interchange “onboard” queue. “Onboard” queue is used by all data producers in NordicWay-I for sending messages to the Interchange, hence the ASFINAG prototype, that uses the standard queue and protocol, complies with the NordicWay-I setup.

For the integration details including AMQP client specification, user, certificates etc. please refer to [3].

(2) Interchange Node -> Ericsson CTC (NordicWay Adapter)

As shown in Figure 26 below, the Interchange Node is configured with a new receiving queue “AT AMQP Queue” specifically for the CloudKonkret prototype. For all incoming messages, the Interchange Node performs an AMQP header check and a geo-location lookup, so all ASFINAG messages that satisfy the criteria (the AMQP header contains parameters such as who=”ASFINAG” and lat/lon coordinates that match Austria) will end up in “AT AMQP Queue” and will be pushed to the Ericsson CTC component. The Ericsson CTC implements a NordicWay adapter that acts as AMQP consumer client. The NordicWay adapter strips AMQP headers from the messages and parses the remaining DATEX-II messages into individual situation record messages.

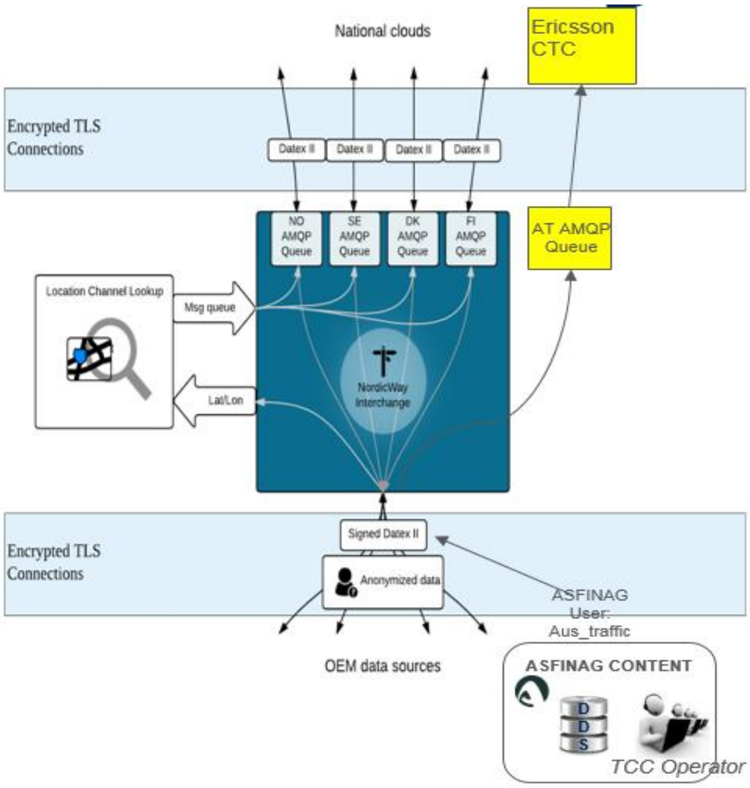


Figure 26 NordicWay Interchange Data Sources and Queues

(3) NordicWay Adapter -> Ericsson CTC Core

The NordicWay adapter sends each individual RWW and TMP situation record to the CTC Core component, using the CTC REST Interface method PUT /device/details. In this way, all RWW / TMP records are also stored in CTC database and become displayed in the CTC Traffic Operations Map, as shown in Figure 27.

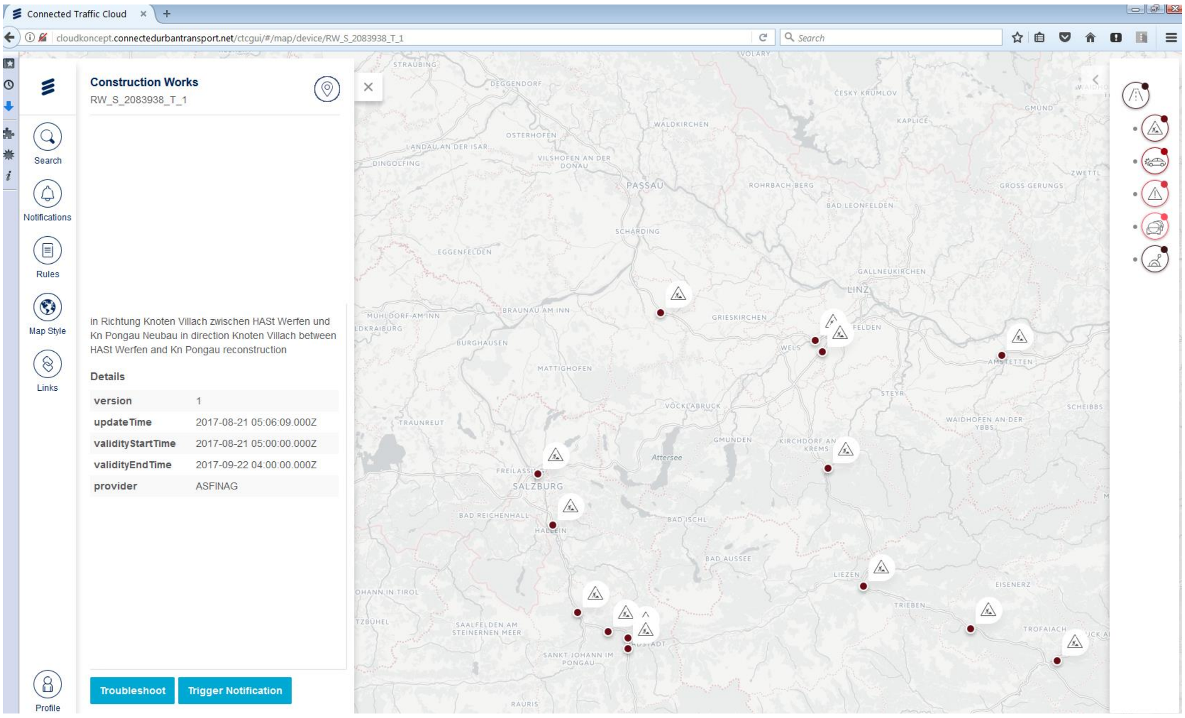


Figure 27 Ericsson CTC Map

(4) NordicWay Adapter -> GLM Service

The NordicWay adapter also sends each individual RWW and TMP situation record to the GLM Service component using the GLM REST Interface method POST /messages.

The GLM Service consists of a server and client-side applications. The GLM Server operates on an overlay-map that divides a geographical area into virtual map tiles. The server holds information about the location of the clients on a per-tile granularity. The GLM Server exposes above-mentioned northbound REST Interface, through which messages are received from NordicWay adapter, and map them to a certain geographic area-tile. The GLM Server exposes also a southbound REST Interface that gives the client the possibility to report its current position to the server. The latter is used for demo purposes to “track a vehicle in real-time” and thereby mistreating the GLM build-in privacy-by-design methodology.

(5) GLM Server <-> GLM Client App

The GLM Client app is an Android application that consists of two parts:

- glm-client-android.apk app - contains connectivity settings, tile handling, location update and server messages handling

- OsmAnd.apk app – provides a client-side GUI that consists of a map and a device navigation services that can be used either in real-time mode or in a simulation mode for demo purposes.

The GLM Server provides a southbound REST Interface (POST /messages) that GLM Client is using to send its current position to the GLM Server. In turn, the client receives the corners of the square/tile it is currently located in. Once the vehicle with the GLM Client moves outside this square, the client will send its new location to the GLM Server. This procedure is called Location Update.

The GLM Client exposes an interface to the GLM Server over which it can receive RWW & TMP messages that are relevant in the area, the client is currently located in. Those messages will be displayed along the route the vehicle with the GLM client is driving on, as shown in Figure 28 below.

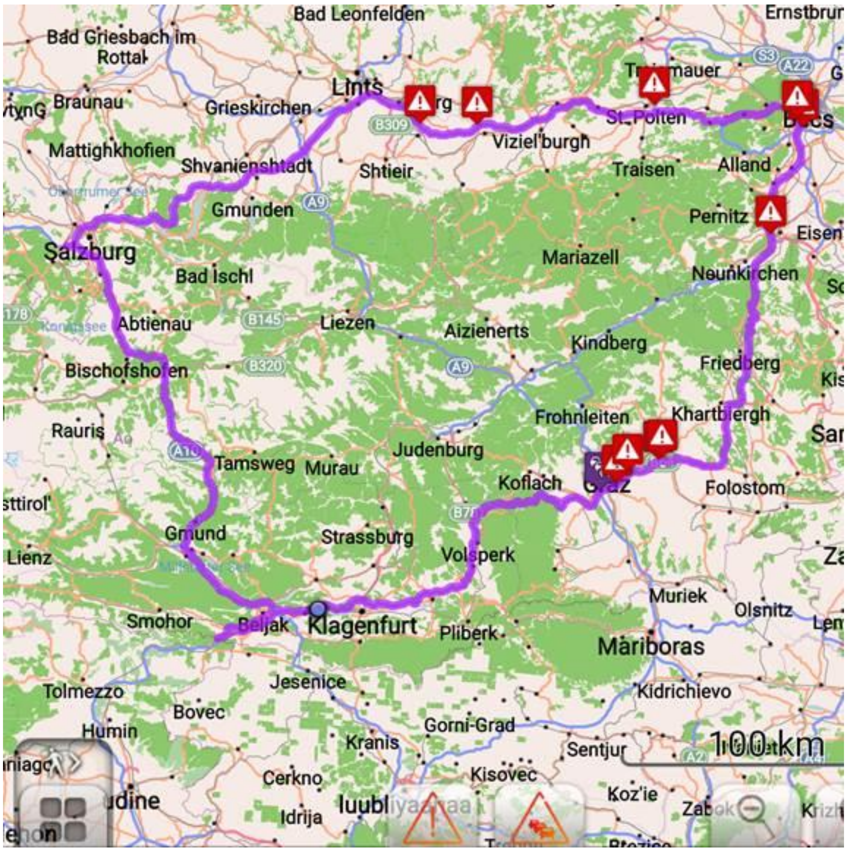


Figure 28 GLM Client Map on the Android Device

5.3 Use Cases

ASFINAG aims to provide its customers with highly secure and highly available roads network by actively managing all traffic disturbances and instantly informing drivers, by providing traffic information directly to connected vehicles. This in turn increases driving safety and efficiency. Among various cooperative services, such as display of important traffic signs in the vehicle (e.g. speed limit sign), dangerous situations, traffic jam warnings, roadworks warnings, routing recommendation, travel info, expected travel time and so on, two specific services were chosen for the CloudKonkret prototype:

- Roadworks Warning (RWW)
- Traffic Management Plan (TMP)

RWW and TMP are representative messages types, since the way they are created and handled could serve as a blueprint for handling the majority of other message types/services, that would potentially be provided from the ASFINAG Systems to a reference traffic cloud. More specifically:

- The Roadworks Warning (RWW) message represents all messages that can be provided unchanged as a cloud service. Namely, RWW DATEX-II message that originates from a roadworks trailer itself, passes through ASFINAG systems without any change, and get delivered as such to a reference cloud.
- The Traffic Management Plan (TMP) message represents all messages that are a result of certain Traffic Management Center decisions based on existing traffic-relevant information. Such a DATEX-II message is therefore created ad-hoc in TMC. A typical example is an alternative routing advice for drivers, that TMC personnel would issue/trigger to a reference cloud in case of specific traffic conditions such as traffic jam on specific road.

By implementing and demonstrating those two representative Use-Cases, the CloudKonkret PoC aims to validate the suggested cloud architecture and to provide guidance for implementing and operating similar cloud services.

5.3.1 Use Case RWW – Roadworks Warning

An overview of the RWW Use Case is given in the data flow diagram in Figure 29, followed by a detailed steps description.

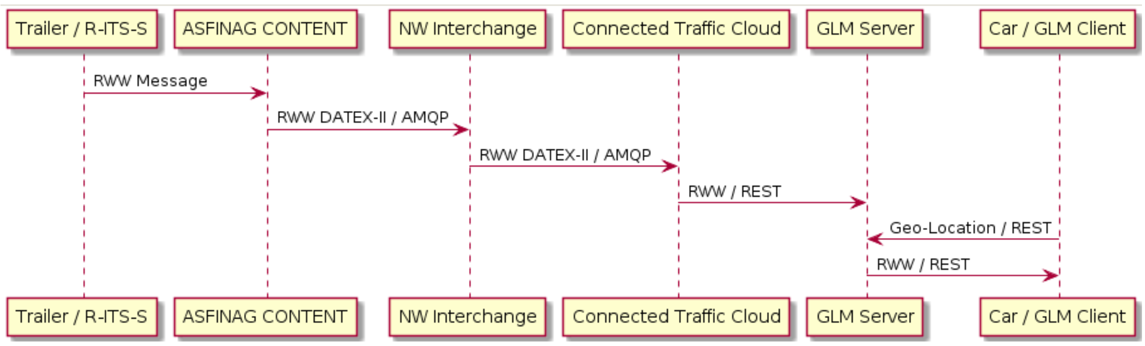


Figure 29 RWW Sequence Diagram

1) A Roadside ITS Station (R-ITS-S), that is deployed on roadworks vehicles / trailers, transmits current roadworks information to the ASFINAG Traffic Control Center (TCC). The TCC collects all road works information from all R-ITS-S stations and this results in a comprehensive RWW message, containing all currently active roadworks. This message is generated and provided by DDS, ASFINAG's central traffic data hub system, and from there to ASFINAG CONTENT for external distribution (see Figure 30).

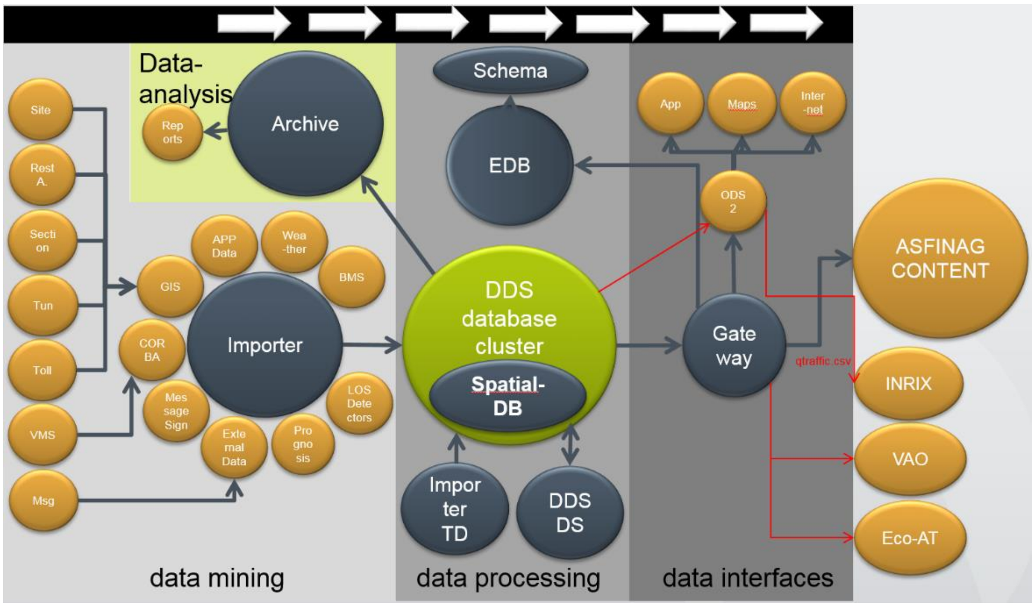


Figure 30: ASFINAG Content Management System (status 2016)

2) The ASFINAG CONTENT system sends RWW DATEX-II messages via an AMQP protocol to a reference cloud i.e. NordicWay Interchange Node

3) The NordicWay Interchange Node routes the RWW DATEX-II message to the ASFINAG's AT queue, based on geo-location information specified in the AMQP message

4) Message from AT queue is pushed automatically to Connected Traffic Cloud, where it is processed and provided to the GLM Server

5) The GLM Server receives a vehicle's (GLM Client) location information and based on that, forwards the RWW alert to all affected vehicles that are within 1km proximity of the roadworks area. Note that the location update is set periodical for demo purposed only. In a real production GLM deployment, the location update and hence the communication between the GLM server and the client will be kept to a bare minimum i.e. will be done only in case of a vehicle is changing from one virtual grid tile to another.

Each RWW message consists of multiple situations and each situation can have one or more situation records that can be of following types: ConstructionWorks and MaintenanceWorks. Those situationRecord types can have subtypes (<constructionWorkType> and <roadMaintenanceTyp> respectively) as follows:

- ConstructionWorks:
  - constructionWork
  - roadImprovementOrUpgrading
  - roadWideningWork

- MaintenanceWorks
  - grassCuttingWork
  - maintenanceWork
  - other
  - repairWork
  - resurfacingWork
  - roadMarkingWork

In the CloudKonkret prototype, a comprehensive RWW message gets split into individual roadworks records, where each situationRecord is mapped to an RWW event, regardless of type/subtype. Hence, each situationRecord will be represented with its own RWW icon/alert in a CTC GIS map, and each individual RWW event (if relevant) will be forwarded to the GLM Client for becoming displayed at the client map.

Besides RWW type and subtype, each situationRecord in the RWW message contains also following data:

- roadworks id (DATEX-II element <situationRecord> with attribute “id”)
- roadworks start time and end time (DATEX-II elements <validityTimeSpecification> and <overallStartTime> / <overallEndTime>)
- roadworks start and end position (DATEX-II element <linearByCoordinates> that contains <start> / <end> latitude and longitude)
- roadworks comment (DATEX-II elements <generalPublicComment> and <comment>)

In case of moving roadworks or changes in roadworks start/end time, ASFINAG would send updated data in the RWW message update cycle. In the CloudKonkret prototype, *an RWW message, with all currently active roadworks situations, is sent by ASFINAG every minute*. This is however not recommended, as it does not apply real-time situation updates and because it is not scalable. For further details regarding this and other recommendations, based on learnings of CloudKonkret PoC, please refer to Chapter 6.

Above-mentioned RWW situationRecord data will be displayed in a CTC GIS map, as shown in Figure 27, and will be used for alerting the GLM client in the vehicle about relevant roadworks in proximity, as shown in Figure 28.

For sample cases of RWW messages, used in the CloudKonkret prototype, please refer to [4].

5.3.2 Use Case TMP – Traffic Management Plan

An overview of the TMP Use Case is given in the data flow diagram in Figure 31, followed by a detailed step by step description below.

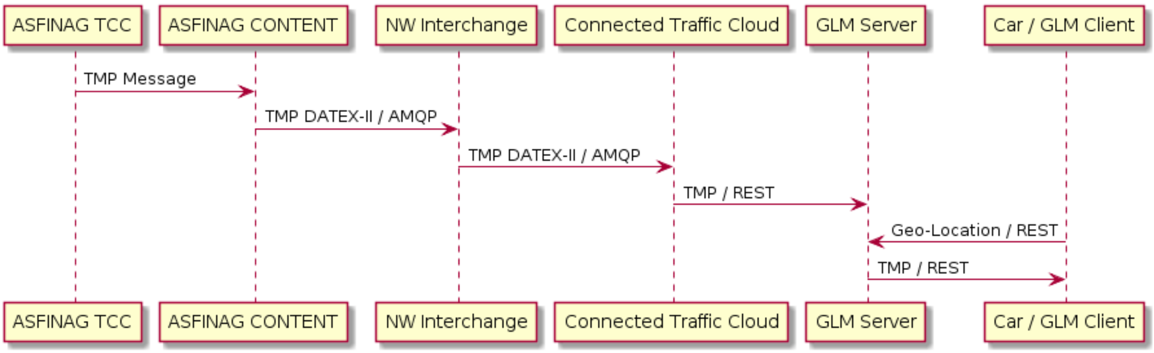


Figure 31 TMP Sequence Diagram

1) Based on the available traffic and roads information, an Operator in the ASFINAG Traffic Control Center (TCC) initiates a TMP message (e.g. routing advice due to road closure), which in turn is provided to the DDS, ASFINAG's central traffic data hub system, and from there to the ASFINAG CONTENT for external distribution (see Figure 30)

2) The ASFINAG CONTENT system sends TMP DATEX-II messages via the AMQP protocol to a reference cloud, i.e. NordicWay Interchange Node

3) The NordicWay Interchange Node routes the TMP DATEX-II message to the ASFINAG's AT queue, based on geo-location information specified in the AMQP message

4) The message from the AT queue is pushed automatically to a Connected Traffic Cloud, where it is processed and provided to the GLM Server

5) The GLM Server receives a vehicle's (GLM Client) location and based on the area the vehicle is in a TMP alert will be pushed to all affected vehicles that are within 1km proximity of that TMP event

Each TMP message consists of a single situation, which has just one situationRecord of type GeneralNetworkManagement that contains the following data:

- TMP id (DATEX-II element <situationRecord> with attribute "id")
- TMP start time and end time (DATEX-II elements <validityTimeSpecification> and <overallStartTime> / <overallEndTime>)

- TMP route start position (DATEX-II element <pointByCoordinates> that contains location <latitude> and <longitude>)

In case of changes in TMP start/end time and location, ASFINAG would send updated data in the TMP message update cycle. *In CloudKonkret current prototype, active TMP message(s) are sent by ASFINAG every minute.* This is however not recommended, as it does not apply real-time situation update and is not scalable. For further details regarding this and other recommendations, based on the learnings from the CloudKonkret PoC, please refer to Chapter 6.

Same as with RWW, the above-mentioned TMP situationRecord data is used for a display in the CTC GIS map (Figure 27) and for sending route advice to the GLM client in the vehicle, when being within the proximity of the closed road.

For a sample TMP message used in the CloudKonkret PoC, please refer to [5].

5.4 Test Cases and Results

For the CloudKonkret PoC, a test system setup with the following components has been prepared, based on the architecture described in 5.1.

- An AMQP-Producer client – deployed at ASFINAG
- The NordicWay Interchange Node – deployed at Ericsson for NordicWay-I project
- A Connected Traffic Cloud instance for ASFINAG, with a NordicWay adapter and the GLM service – deployed at Ericsson for the CloudKonkret PoC
- GLM Clients – deployed on ASFINAG Tablets

The use-cases described in 5.3 have been tested with above-mentioned test setup, in order to demonstrate that the cloud services concept works in practice.

Following test cases have been executed:

1. **Secure RWW / TMP messages transfer**

Sending of RWW / TMP messages via AMQPS (AMQP via SSL) using provided user and certificate has been successfully tested

2. **RWW / TMP messages reception in the NordicWay Interchange Node**

   Reception of RWW / TMP messages and routing to the ASFINAG-dedicated queue is successfully tested with the NordicWay Interchange

3. **RWW / TMP messages processing in Ericsson CTC / GLM Server**

   RWW / TMP messages parsing in the CTC, and forwarding and further processing in the GLM Server is successfully tested. RWW / TMP icons display in the CTC and GLM Server Map is successfully tested

4. **Display of RWW / TMP alerts in the GLM client**

   RWW / TMP alerts display in the GLM client map has been successfully tested using both GPS driving simulation and driving in car with the GLM Client.

5. **RWW / TMP messages life cycle handling**

   ASFINAG-initiated RWW / TMP messages updates handling in Ericsson cloud systems is successfully tested. Display of updated messages in the GLM client is successfully tested.

   RWW / TMP expired messages removal in Ericsson cloud systems is successfully tested. Removal of expired alerts in the GLM client is successfully tested.

   RWW situationRecords deletions in ASFINAG system and respective deletions in Ericsson cloud systems are successfully tested. Deleted roadworks alerts are not displayed in the GLM client anymore.

Note that deleting ad-hoc roadworks situations information in the ASFINAG system, lead to removal of the respective records from the RWW message which were sent to Interchange Node without update of the record <validityTimeSpecification>. This is not recommended as it may lead to the inconsistent display of information at the operator map in a Connected Traffic Cloud. The preferred way of doing it, would be to update of the <overallEndTime> in <validityTimeSpecification> to the current date/time, which would lead to immediate record expiration and hence removal from all systems in the PoC in reliable way.

6. RWW messages reception and processing - Latency test

The RWW message processing and transfer time between the prototype components was measured based on timestamps in log entries, as shown in the Figure 32. The measurement was done for a single roadworks situation.

Interchange Adapter (Received message #7 originating from [ASFINAG])	2017-09-19T09:47:13.248Z
Interchange Adapter (Message send to CTC)	2017-09-19T09:47:14.189Z
Interchange Adapter (Success response to CTC)	2017-09-19T09:47:15.081Z
Interchange Adapter (Message send to GLM)	2017-09-19T09:47:15.081Z
Interchange Adapter (Response from GLM)	2017-09-19T09:47:15.082Z

AVIS BE (create timestamp of message)	2017-09-05 13:29:49.740
DDS GW Façade (notification received from UpdateService)	2017-09-05 13:30:27,832
DDS GW Facade (data loaded and cached)	2017-09-05 13:30:29,863
DDS GW Facade (sent notification to CM)	2017-09-05 13:30:29,863
DDS GW CM (received notification from Facade)	2017-09-05 13:30:29,863
DDS GW CM (fetched data from Facade)	2017-09-05 13:30:30,019
DDS GW CM (created Datex2)	2017-09-05 13:30:30,019
DDS GW CM (started AMQP upload)	2017-09-05 13:31:10,988
DDS GW CM (AMQP upload finished)	2017-09-05 13:31:11,332

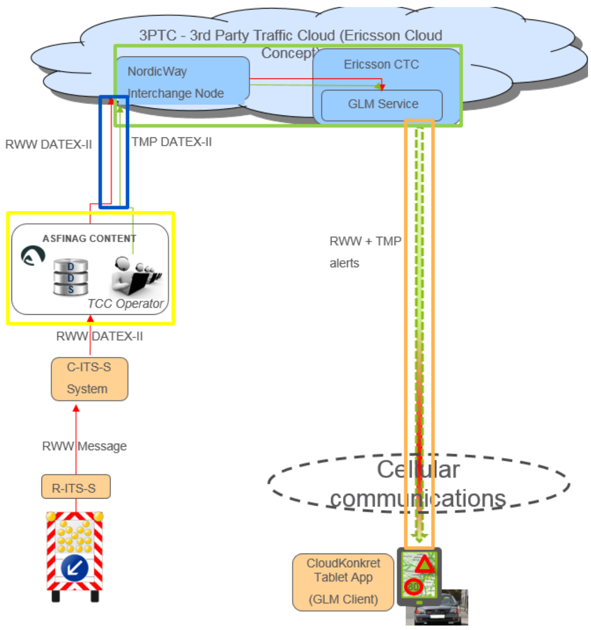


Figure 32 Performance measurements

The message processing within the ASFINAG systems, which is yellow-highlighted in Figure 32, took approximately **1 min 20 sec**.

The AMQP message upload from ASFINAG AMQP Producer to the Interchange Node, which is blue-highlighted in Figure 32, took approximately **0,34 sec**.

The message processing upon reception at the Interchange Node and until the alert became available at the GLM Server, which is green-highlighted in Figure 32, took **2,579 sec**.[6]

The message transfer from the GLM Server to the client (orange-highlighted in Figure 32, was not measured in CloudKonkret PoC, since the measurements were already available from projects such as CoCar (3G/HSPA **< 0,3 sec**) and CoCarX (4G/LTE **< 0,05 sec**). For more details on these projects see Figure 4 and [17].

7. **RWW / TMP messages reception - Load test**

   RWW / TMP messages updates are uploaded by ASFINAG in **cycles of 1 min.** No delays or instability of the Interchange Node has been observed during 3 months of testing time.

6 CLOUDKONKRET FINDINGS, RECOMMENDATIONS AND POTENTIAL FUTURE WORK

The CloudKonkret proof-of-concept efforts have led to a number of findings, insights and confirmations. The latter are leading to recommendations and to potential PoC extensions. This section provides now a corresponding summary.

Committing to a PoC work item always means committing to a bulk of work, with most often unexpected complications, changing its scope during its development, and much more time and effort than initially anticipated. The CloudKonkret PoC has been no exception in this respect.

This in turn means that every party involved has to have a clear upfront understanding on the rational before committing and executing a PoC effort:

- Is it to test the feasibility of a certain technology aspect (which aspect is it exactly)?
- Is it to test the feasibility of a certain use case and of potential customer feedback on that use case?

[6] Note that the 2,5 sec. latency for message processing within the Ericsson CloudKonkret Proof of Concept prototype is likely to cut down in a commercial operation deployment and with optimized end-to-end latency characteristics. Testing the performance characteristics of a commercial configuration was out of scope for the CloudKonkret PoC.

- Is it to inform the public about traffic management perspectives with a live demo proof point?
- Is it to discover some operational implications when turning a certain PoC concept into a 24/7 operational deployment?
- Or is it for some other reason (which)?

After having gained great clarity, one shall review any potential 3rd party relationships or dependencies that may hinder, prevent, or delay the successful execution and the conclusion of the PoC effort. Furthermore, a change process shall be agreed as well as a viable procedure to compensate for additional cost and efforts which results as consequences of a change request decision and its execution.

6.1 Findings

The CloudKonkret efforts have revealed different sorts of findings.

The clarifying discussions on scope and nature of the pre-committed PoC, and thereby on the ambition of the PoC (during the project execution time) have resulted in a late start of the implementation work. This in turn has led to delays in the project execution, to a project period prolongation, and eventually to the successful conclusion of the project in October 2017.

The customer ambition of providing an operational reference instance that can mirror a multi-party eco-system architecture with incremental builds had to be scaled down to a feasible number of third party dependencies and to a PoC architecture that compensated for implied restrictions. Despite big efforts by ASFINAG and Ericsson it was not possible to get car manufacturers or other system suppliers (in non-project membership) to commit to adding their commercial or pre-commercial platforms to the CloudKonkret reference design.

This meant that the “test vehicle demonstrations” had to be emulated by a connected tablet application.

Fortunately, the CloudKonkret team, under Ericsson leadership, managed to draw big on insights, reference prototypes and cloud execution environments from the NordicWay-I project [7] and from the Drive Sweden Innovation system platform [8]. In fact, the CloudKonkret PoC links to the live test systems of these Scandinavian research and development projects.

The technical end-to-end latency studies, performed by CloudKonkret and documented in 5.4, have in parts re-confirmed some of the observations made in the Camino research project [10] and during its prototype design: “Real-time” perceptions in a human context is much different to “real-time behavior” when transforming a system landscape towards the vision of a fully automated road traffic monitoring and information processing environment, with direct end-to-end driving advice to itemized individual and fully automated vehicles.

The human perception of real-time, with delay-figures in a few minutes order, is likely acceptable. Correspondingly, a system architecture design with database pulling every minute or so might be an appropriate design principle. The same holds for full-state date record transfers, with every message pull and every data retrieval capturing the full status information, leaving it to the receiver to filter according to its context and to its information desire (Figure 32).

In fact, such an architecture design and such status posting principles is required as well in an automated multi-party eco-system scenario in which organizations and service providers can join ad-hoc and demand an automated boot-strap procedure or a resilience method to get in sync with the current traffic management status and with physical realities.

In cases of direct vehicle control and for individualized and per-vehicle contextualized driving advice, or road traffic information, the end-to-end latency has to be in a fraction of a second. Message content has to be stripped down to what matters to the situation that a particular (fully automated) vehicle is in. This in turn requires a consistent end-to-end event-driven and push-only data information processing system. Including the road traffic management operation arm of the message processing, validation, and delivery part. This in turn leads to the technical recommendation 6.2.2.

6.2 Recommendations

Every proof of concept, as the name suggests, can only proof a specific aspect and thereby will be far off from any commercial or 24/7 operation structure. Experiences have shown that step-by-step incremental additions to PoCs will likely end in big and complexity patch work structures than in a viable operational blueprint. Going further towards a system-of-systems operational structure, in a fully automated data processing and vehicle operations world, it is recommended to:

6.2.1 Implement the full set of Interface Groups (outlined in 3.2.1)

The Ericsson IoT/CTC Architecture, for example, includes a complete set of services and functions that allow both service providers and partners to manage service offerings and let end-users or business partners discover and purchase new applications, services, and digital content. Furthermore, it facilitates the dynamic onboarding of content- and services providers and of 3rd party system functions. This level of automation and flexibility in turn assumes that the full set of software interfaces are being implemented (see 3.2.1).

6.2.2 Add a real-time and event-driven IT-structure to the ASFINAG TMC design

Complement the ASFINAG internal TMC architecture (see Figure 30) with a fully automated and real-time event processing structure, able to deliver end-to-end short messages in a per-vehicle context in fractions of a second. Such a real-time delivery structure shall feed the existing TMC design. Two groups of external communication methods shall be supported: Pull-based, for boot-strap and resilience purposes. And push-based, for driving-advice, automated vehicle control and real-time data capturing (see 5.4 and [10]). The latter is a “must-have” capability for guiding and for active steering of fully automated vehicles. The reader may study the recommendations given at the CloudKonkret Consulting Report [1] for further details and for a broader rational.

6.2.3 Introduce DevOps methodologies for TMC transformation projects

In order to allow for rapid intake of software modules resulting from mature innovation and transformation projects, it is recommended to introduce the DevOps[7] development, testing, and operation approach, together with a cloud staging structure. The DevOps principles would break the year-long procurement procedures for ordering, delivering and integrating smaller or bigger parts of the TMC operations environment and it would provide a natural transition path from R&D projects to live operation.

6.3 Potential future work

Next to the principal recommendations in 6.2 and particularly in Chapter 5.3 of the CloudKonkret Consulting Report [1], a number of smaller extensions could be considered:

- Enhance the CloudKonkret PoC with additional use cases, such as publishing other traffic messages than RWW or TMP to a cloud interchange network.
- Add traffic-relevant alerts, e.g. roadworks from other countries, for example from Sweden, to the CloudKonkret CTC map and to the GIS of the GLM-Client apps.
- Fix a number of shortcomings in the CloudKonkret PoC interactions with the ASFINAG TMC system:
    - Situation record deletion without updating validity period is not recommended, as mentioned in test case 5 in 5.4.
    - TMP/RWW is currently pushed in min cycle – not updated in real-time (refer to 5.3)
    - Consider that OEMs wants to keep control of the information received & displayed in the car, hence there is no option to have direct and uncontrolled communication to a car. This in turn has architecture implications on the complete eco-system. Launch corresponding study projects to seek for supporting system solutions.

[7] DevOps explained: https://en.wikipedia.org/wiki/DevOps ; https://www.versionone.com/devops-101/what-is-devops/

- In the world of fully automated vehicle fleets, new tasks for supporting those fleets and supporting OEMs with AD-Advice enabled vehicles provide an evolution perspective to a connected road operation center. Launch studies on how such scenarios could be supported in an Austrian context.

- Investigate joint ASFINAG & Ericsson concept demonstrations and ITS community education opportunities. I.e. joint participation at fairs, exhibitions, and conferences.