NordicWay

System Design

Sub-Activity 1.2 & 1.3, Milestone 10

Version: 1.0

Date: 3 November 2016

Document Information

Authors

Name	Organisation
Johan Scholliers	VTT

Distribution

Date	Version	Dissemination

Preface

The NordicWay project will test and demonstrate interoperability of C-ITS (cooperative ITS) of services both for passenger and freight traffic, piloting continuous services offering an equivalent user experience in the whole network. NordicWay is a real-life deployment pilot, which will facilitate a wider deployment in the Nordic countries and in Europe in the next phase.

The main purpose of this deliverable « System Design » is to give a high-level overview of the NordicWay system and services, and to describe the technology options in the design of the system.

Chapter 1 gives an overview of the system, and a high-level overview of the architecture, and the NordicWay Interchange Server, which is the key element in the NordicWay concept.

Chapter 2 gives an overview of the different use cases in the NordicWay project. The services in NordicWay relate to the delivery of Safety Related Transport Information with low latency. Events are detected by vehicle sensors or reported by users, and transferred via the NordicWay Interchange Server to the actors which have registered to the events.

Chapter 3 gives an overview of the technologies used in NordicWay. This includes both cellular and ITS-G5 communications, the DATEX and C-ITS message protocols, and the AMQP message protocol.

.

List of Abbreviations

AMQP	Advanced Message Queuing Protocol
CAM	Cooperative Awareness Message
C-ITS	Cooperative ITS
DENM	Decentralised Environmental Notification Message
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
ITS	Intelligent Transport System
ITS-G5	Cooperative car to car/infrastructure communication standard operating in the 5.9 GHz band
IVI	In-Vehicle Information
LTE	Long Term Evolution
OEM	Original Equipment Manufacturer
RSU	Road Side Unit
SPaT	Signal Phase and Timing
SRTI	Safety Related Traffic Information
SSL	Secure Sockets Layer
TLS	Transport Layer Security
TMC	Traffic Management Centre
V2X	Vehicle-to-Anything (X=V : Vehicle ; X=I : Infrastructure)

Table Of Contents

1. System overview

This document gives a general overview of the NordicWay system.

1.1. Background

The main objective of the NordicWay project is to test and demonstrate interoperability of C-ITS (cooperative ITS) of services both for passenger and freight traffic, piloting continuous services offering an equivalent user experience in the four countries involved (Finland, Sweden, Norway, Denmark). It is the first large-scale pilot demonstrating the technical feasibility and as a proof-of-concept of probe data collection and C-ITS service delivery using cellular communication (3G and LTE/4G). NordicWay is a real-life deployment pilot, which will facilitate a wider deployment in the Nordic countries and in Europe in the next phase.

The Cooperative services demonstrated within the NordicWay project aim to increase the awareness of drivers in dangerous situations. The services correspond to the Safety Related Traffic Information (SRTI), which should, according to priority action c of the directive 2010/40/EU of the European Commission, be provided to road users free of charge.

1.2. Interoperability

Implementing interoperability in NordicWay means facilitating the exchange of information cross-border and cross-organizational, with a method that is not restricted to the partnership of NordicWay. It means the capacity of a car / driver to send and receive data and make use of services provided, regardless of physical location, administrative boundaries and organizational domicile, and the capacity of organizations to exchange information regardless of distance, language and type of organization.

Hence, interoperability in the NordicWay is realized at three levels:

- similar services are offered to end-users independent of the car or the end-user equipment. Users with a smart phone, will be able to receive the same services as users with a device integrated in their vehicles.
- the same service to end-users will be offered independent of the country. When crossing the borders, users will receive the same type of information on both sides of the border. Traffic management centers in different countries will be able to get the same information provided by service providers.
- the same services will be offered independent of the communication medium. Users with a device using cellular information will receive the same information as users with a ITS-G5 equipped device.

1.3. NordicWay concept

The NordicWay project 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 Server is the key element to assure interoperability. The server allows different service providers and traffic data providers to communicate with each other. One of the functions included in the Interchange Server is geolocation, i.e. extracting the country (or region) from the message, so that messages can be routed to e.g. the Traffic cloud of relevance.
- cellular technologies for the transmission of SRTI messages with low latency, complemented with Infrastructure-to-Vehicle communication based on ITS-G5 for specific use cases.

Figure 1 shows the NordicWay concept architecture :

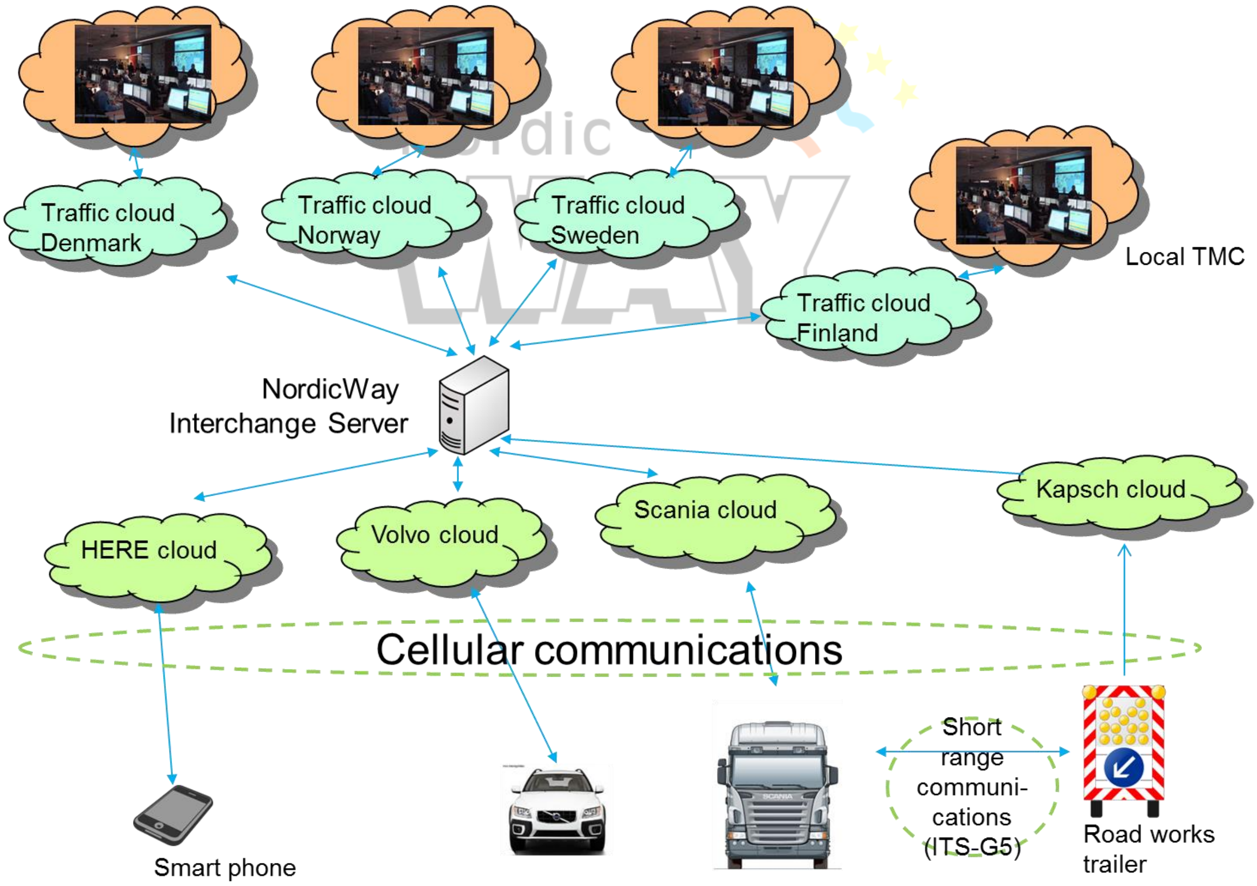

Figure 1. Overview of the NordicWay system

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

The key element in the NordicWay concept is the Interchange Server. The NordicWay Interchange Server is a broker, which directs the messages published by the different actors to actors, based on predefined selection criteria, such as the type and location of the event in the messages. The NordicWay Interchange Server has a geo-lookup functionality, which determines the country based on location information in the message.

2. Use cases

2.1. Overview of the services in NordicWay

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

The services include both

- cooperative hazardous location warning. Drivers are warned of the following events :
  - animal, people, obstacles, debris on the road
  - unprotected accident area
  - reduced visibility
- cooperative weather and slippery road warning. The driver is warned of a slippery road or of exceptional weather onditions (e.g. fog, heary rain, heavy wind).

Probe vehicle data, i.e. the collection of data from vehicles directly from sensor data, is used to support the services mentioned above.

The following sections will describe the NordicWay use cases.

2.2. Road authority informs about inclement weather

This use case consists of the following steps :

1. The TMC issues a Safety Related Transport Information message.
2. This message is published on the Interchange Server.
3. The message is then transferred to the service providers, who have registered for these messages.
4. The service providers then forward the message to the vehicles which are near the event.

2.3. Vehicle detects slippery road

This use case consists of the following steps :

1. A vehicle arrives at a slippery spot and sends sensor data to the OEM cloud.
2. The OEM cloud validates the data and :
   a. publishes a message on the Interchange Server. The message is transferred through the Interchange Server to the actors which have

registered to these messages. This includes the traffic cloud of relevance, and the message is validated at the traffic cloud and sent to the local TMC.

   b. the message is sent to other vehicles, registered at the OEM cloud, which are near the slippery spot.

2.4. Smart phone user informs on object on the road

This use case consists of the following steps :

1. A driver with a smart phone notices a dangerous event (e.g. animal at the road, accident, low visibility) and sends a warning message.
2. The service provide cloud validates the data and :
   a. publishes a message on the Interchange Server. The message is transferred through the Interchange Server to the actors which have registered to these messages. This includes the traffic cloud of relevance, and the message is validated at the traffic cloud and sent to the local TMC.
   b. the message is sent to other vehicles, registered at the service provider cloud, which are near the slippery spot.

2.5. Trailer warns about roadworks

This use case, demonstrated in Sweden, has the following steps :

1. A roadworks trailer is activated. The trailer starts transmitting ITS-G5 messages to vehicles approaching the roadworks.
2. The message is also sent to the provider's cloud.
3. The message is also published on the Interchange Server, from where it is transferred to actors, who have registered for this message.
4. The actors transmit the message to vehicles approaching the roadworks.

3. Technologies

3.1. Connected Vehicles and Drivers

3.1.1. Connected and Cooperative Vehicles

There are different definitions circulating for « connected vehicles ». Spaanderman et al. a distinction between cooperative and connected services [1]: “The so-called Connected services are mainly located in the information spectrum and rely on a back office for their information sources and thus 3/4/5G. Co-operative services are based on communications directly between vehicles and thus rely on ITS-G5. ». This approach is also used in this report :

- connected vehicles/ drivers are connected to the internet over a cellular connection. During the last years OEMs have developed connected vehicle tools, through which vehicle drivers are provided with additional services. In 2015, about 50% of cars globally sold is connected (either by embedded, tethered or smartphone integration) [5]. The vehicles and smart phone are continuously connected to a cloud, provided by a service provider. A vehicle is continuously connected to an OEM cloud, a smartphone to a service provider cloud. The driver is hence always connected to a single operator. This connection takes care of, among others, security and privacy related issues, using industrial standard tools and agreements.
- cooperative vehicles vehicles use short range communcations to exchange information with other road users and infrastructure nearby.

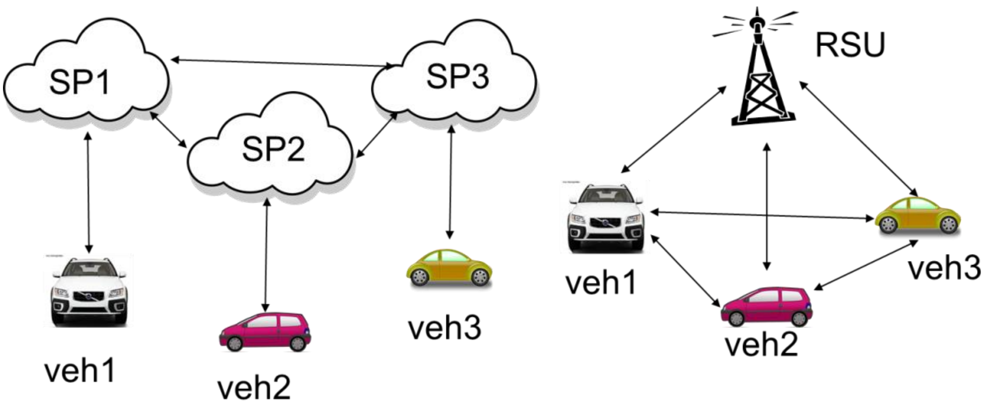

Figure 2 : Cloud based communication versus V2X short range communication

The two approaches complete each other. The main differences between the two approaches:

- Cloud-based communications have longer latencies than ITS-G5 based communications. The latencies are due to the delays in the air interface, processing in the clouds and inter-cloud communications. The latencies measured in the proof-of-concept tests of NordicWay in Espoo in August 2015 indicated latencies from 1 to 4 seconds, dependent on the paths followed by the message flow [3]. This is within the limits set for similar cooperative applications, such as informing conceptual speeds to drivers (ISO/TS 17426). As cellular communications evolve, the latencies will decrease significantly, with 5G as target 1 ms air interface delays and 5 ms end-to-end latency [2].

- Location based networking: the range of ITS-G5 is limited by physical laws. In cloud-based communications, the service provider needs to keep track of the location of all vehicles. This requires a geomessaging functionality, in order to communicate with the vehicles in a designated region [4].
- Broadcast versus unicast. In ITS-G5 networks messages on events are broadcasted at a high frequency (1-10 Hz) in order to assure receipt by passing vehicles. In cloud-based communications messages on events have to be sent only once and acknowledged.
- Vehicle status messages. In ITS-G5 networks, CAM messages are sent at high frequency in order to allow other vehicles to make a local dynamic map and assess the risk of conflicts with nearby road users. In cloud based communications transfer of CAM messages may lead to network overload (ETSI TR 102 962). The services addressed by the NordicWay project are not safety-critical and no local dynamic map is required. Vehicle sensor data are transferred in proprietary formats, optimised by the service providers, to the clouds.
- In cloud based communications the end user is only in contact with the service provider. Security in cloud-based communications is under the responsibility of the service provider and is based on proven industry solutions. In ITS-G5, for security the guidelines of the C-ITS Platform should be taken into account.
- Privacy in cloud-based communications is handled on agreements between the end user and the service provider. When transferring information to other clouds, no privacy related information is transferred and generally only aggregated data is transmitted. In ITS-G5 networks, the privacy is based on the guidelines of the C-ITS platform.

3.1.2. Smartphones

Smartphones have become ubiquitous devices, with a vast amount of applications and including sensors such as gps and accelerometers. Regarding operating systems, Android is global market leader with 82.8%, followed by Apple iOS 13.9% and Windows Phone with 2.6% [6].

Smartphones brought in the vehicle, and apps run on the smartphone can – if supported – be shown on the dashboard display and audio brought to the car's speakers. MirrorLink, created by the Car Connectivity Consortium, a non-profit organization of automakers, smartphone vendors and aftermarket car electronics providers, is the leading technology and is OS- and OEM-agnostic [8]. ETSI explores adopting Mirrorlink as an ETSI Technical Specification [7]. The Car Connectivity Consortium has issued application requirements for certification of applications for use while driving. These specifications have been taken into account when developing the HMI for NordicWay smartphone applications, in order to assure that use of the application is safe when driving.

3.2. Communications

3.2.1. ITS-G5 COMMUNICATIONS

Information between vehicles and between vehicles and road side units can be exchanged either using short range communications in the 5.9 GHz band, based on IEEE 802.11p. IEEE 802.11p is an amendment to the IEEE 802.11 standard, allowing adding wireless access in vehicular environments. In Europe, ITS-G5 protocols, which are standardized by ETSI, run on top of the IEEE 802.11p standard and support the GeoNetworking protocol for V2V and V2I communications.

ITS-G5 offers low latency, in the order of 1 ms for vehicle-to-vehicle communications. ITS-G5 is currently technical feasible, but there are still some hurdles to be taken before deployment, such as handling security and privacy. These aspects are under discussion in the C-ITS Platform [9], and are planned to be finalised by mid 2016, and potentially incorporated in a delegated act under the ITS Directive 2010/40/EU on C-ITS

3.2.2. CELLULAR COMMUNICATIONS

3.2.2.1. FROM 3G TO 4G, AND IN THE FUTURE TO 5G

New generations of cellular standars appear approximately every tenth year, and each generation is characterised by new frequency bands, higher data rates and non-backward compatible transmission technology. The first 3G networks were introduced in 1998 and fourth generation networks in 2008. LTE (Long Term Evolution) is often branded as 4G technolgogy, but the first releases did not fully comply with the 4G requirements. LTE is widely available in Scandinavia. The successor of LTE is LTE-Advanced, standardised as 3GPP Release 10, which shares the same frequency bands as LTE, is currently being deployed.

Future developments will lead to higher data rates and lower latency and new functionalities. 5G technologies will complement current cellular systems. V2X communications will be part of 5G from 3GPP Release 14 onwards, and are currently being specified. Vehicles will be able to communicate with other vehicles through network base stations, or directly vehicle-to-vehicle communications using Proximity Services (ProSe). [2] Other technologies which are standardised by 3GPP include NB-IoT

(Narrow-Band IoT), which is a Low Power Wide Area (LPWA) technology, which can be deployed in GSM and LTE spectrum, and is specially designed for the Internet of Thing s (IoT), which handle sall amounts of infrequent two-way data, securely and reliably. NB-IoT provides very low power consumption, excellent penetration coverage and low component cost. 5G is envisaged to provide latencies of 1 ms for the air interface in ProSe mode and of 5 ms when using communication through network base stations [2]

3.2.2.2. GEOMESSAGING IN CELLULAR NETWORKS

Geomessaging is the functionality to deliver messages to all subscribed participants inside a specific geographical area. In cellular networks this can be accomplished through unicast or broadcast transmissions (eMBMS). Broadcast is however not supported by all cellular networks. In order to perform unicast geomessaging, the provider has to be able to select the participants based on their location. Therefore, information on the location information of each single user in the area is required. The vehicles either send regularly their status (location, speed and other sensor data) to the provider, or use is made of network-based positioning. The CONVERGE project [4] assessed different potential options for geomessaging : (1) geolocation server located at the Mobile Network Operator ; (2) geolocation messaging server as a separate service provider ; (3) geolocation messaging located at each service provider. CONVERGE designed a solution as a combination of options (1) and (2), with a geiolocation messaging server at the Mobile Network Oprator and a geolocation messaging proxy at the CONVERGE C2X Systems network, providing an abstraction layer to service providers [11]. However, in the NordicWay project, where the user is always connected to a single service provider, option (3) is used, hence every service provider should have its own geomessaging functionality.

3.3. Message formats

3.3.1. DATEX II

The DATEX standard was developed for information exchange between traffic management centres, traffic information centres and service providers and constitutes the reference for traffic information. DATEX II is six-part Standard (CEN 16157),, maintained by CEN Technical Committee 278, CEN/TC278, (Road Transport and Traffic Telematics). The first three Parts of the CEN DATEX II series deal with: the modelling methodology (Part 1), Location referencing (Part 2) and the DATEX publication for traffic information messages (called Situation publication) as Part 3. The version of DATEX II that had been used for this standard has been created out of the version 2.0 of the DATEX II specifications.

The DATEX II versions currently most widely in use are 2.2 and 2.3. DATEX II 2.3 contains extensions regarding location referening (OpenLR) and SRTI markup, allowing it to label DATEX II messages as safety related according to the Commission Delegated Regulation (EU) No 886/2013 'with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to user [13].

DATEX II specifies both a data model and exchange mechanisms. DATEX II delivers a “Level A data model”, and allows extensions to the model to implement additional concepts and attributes. In Level B extensions, a limited set of wll-defined UML mechanisms can be applied, allowing standard level A compliant systems to process publications generated from an extended model. A registration process ofr level B model extensions is available, and when a consensus achieves a major degree of consensus it can become a candidate to be absorbed in a new version of the format DATEX II level A.

Level C implementations allow to implement additional concpets, but are not interoperable with level A compliant systems, but use common modelling rules and exchange mechanisms [13].

DATEX II offers both “supplier push” and “client pull” modes for information exchange. The pull mode is the mode which is most widely used. In client pull, two implementation profiles are implemented, using HTTP/1.1 protocol or via web services over HTTP. For supplier push, one platform has been defined over web services over HTTP [13].

In the NordicWay project, DATEX II version 2.3 data model is used, with “supplier push” mode to guarantee low latencies. The standard DATEX II exchange mechanisms are not used, instead message queuing over AMQP is used.

3.3.2. C-ITS MESSSAGES

ETSI and ISO have defined different messages for transmission of information over C-ITS, from which the most important are :

- **Cooperative Awareness message (CAM, ETSI EN 302 637-2).** This message is broadcasted by vehicles at high frequency (1-10+ Hz) and contains vehicle position, speed, heading…., allowing recipients to make a local dynamic map from approaching vehicles and assess potential risks. This message is not exploited in the NordicWay services, which are basicly awareness messages and not safety critical. The CAM message is optimised for ITS-G5 and is not optimised for mobile communications, where it can result in network overload [12].
- **Decentralised Environmental Notification Message (DENM, ETSI EN 302 637-3)**. This is an event based message to enable ITS stations to generate a warning such as a road hazard warning. The standard is optimised for ITS-G5. The NordicWay project uses the payload of DENM messages to communicate between smart phones and the service provider cloud.
- **In-Vehicle Information message sets :** ISO/TS 19321:2015 specifies the in-vehicle information (IVI) data structures that are required by different ITS services for exchanging information between ITS Stations, such as ISO/TS 17425 (In-vehicle presenation of external road and traffic related data) and

ISO/TS 17426 (Contextual speeds). IVI messages transmit information qualitied by road operators, and are coherent with the information that would be displayed on a road sign or VMS. These messages are not used in NordicWay.

- Messages related to signalised intersections (ISO TS 19091) : Signal Phase and Timing (SPaT) and Intersection topology (MAP). These I2V messages provide information on signalised intersections, allowing applications such as GLOSA. They are not used in NordicWay.Message queuing

3.3.3. MESSAGE QUEUING PROTOCOL : AMQP

The **Advanced Message Queuing Protocol** (AMQP) provides a platform-agnostic method for ensuring information is safely transported between applications, among organizations, within mobile infrastructures, and across the Cloud. AMQP defines a binary wire-level protocol, that allows for the reliable exchange of business messages between different actors.

The defining features of AMQP are message orientation, queuing, routing (including point-to-point and publish-and-subscribe), reliability and security. AMQP mandates the behavior of the messaging provider and client to the extent that implementations from different vendors are interoperable. AMQP provides flow controlled, [1]message-oriented communication with message-delivery guarantees (Wikipedia).

Two major versions of AMQP are in use: AMQP 0-9-1 and AMQP 1.0. AMQP 1.0 has been approved as an OASIS standard in 2012 and as an ISO/IEC 19464 international standard in 2014.

There are distinct differences between the way AMQP 0-9-1 and AMQP 1.0 works. Up to AMQP 0-9-1, AMQP standardasiation focused on client to broker wire level protocol and broker messaging capabilities. The AMQP 0-9-1 specification has commands for creating and managing exchanges, queues and bindings. AMQP 1.0 is a much more narrow standard and only defines the network wire-level protocol for the exchange of messages between two endpoints. Hence, several functionalities from AMQP 0-9-1, such as the generation of queues by clients, are not available in the standard AMQP 1.0.

AMQP1.0 supports both brokers and brokerless architectures.

A broker supporting AMQP 1.0 entails (1) taking responsibility for messages on behalf of the clients; (2) acting as a transaction resource, and possibly transaction co-ordinator and (3) routing and distribution messages. Broker can also have additional functionalities.

Using publish-subscribe messaging consumers can subscribe to specific queues.

The NordicWay project uses AMQP 1.0 for the transfer of messages between different actors. The NordicWay Interchange Server acts as a broker, and directs the messages to the consumers based on predefined selection criteria. An additional functionality of the broker is geo-lookup, based on location information in the messages.

3.3.4. Security protocol : TLS

TLS (Transport Layer Security) is the successor of SSL (Secure Sockets Layer), and is a cryptographic protocol that provides communications security over a computer network. Symmetric cryptography is used to encrypt the data transmitted. The keys for the symmetric encryption are generated uniquely for each connection and are based on a shared secret negotiated at the start of the session. The identity of the communicating partners can be authenticated using public-key cryptography. For this purpose, a digital certificate, issued by a trusted party, is used.

NordicWay uses the TLS 1.2 protocol for securing the messages transferred between the different clouds through the Interchange Server.

References

[1] P. Spaanderman, W. Broeders, R. van den Dries, Overview of standards for first deployment of C-ITS, Version 1.0, 19.11.2014

[2] 5G Automotive Vision, October 2015, https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf

[3] Kauvo, K., Koskinen, S., 2015. Technical Assessment of NordicWay Coop Demonstration, VTT Research Report, VTT-R-04147-15

[4] CONVERGE, Deliverable D3, Functional Requirements and Architecture Options, 2013

[5] GSMA, Connected Car Forecast: Global Connected Car Market to Grow Threefold Within Five Years, February 2013, http://www.gsma.com/connectedliving/wp-content/uploads/2013/06/cl_ma_forecast_06_13.pdf

[6] IDC, Smartphone OS Market Share, 2015 Q2, http://www.idc.com/prodserv/smartphone-os-market-share.jsp

[7] The Car Connectivity Consortium and ETSI Sign Co-operation Agreement, 18.11.2015, http://www.etsi.org/news-events/news/1028-2015-11-news-the-car-connectivity-consortium-and-etsi-sign-co-operation-agreement

[8] Car Connectivity Consortium, http://carconnectivity.org/developers/apps

[9] C-ITS Plaftorm, Final Report, January 2016.

[10] Draft work programme Second phase C-ITS platform, v0.1, 2016

[11] CONVERGE, Deliverable D4.3, Architecture of the Car2X Systems Network, 2015

[12] ETSI TR 102 962 V1.1.1 (2012-02), Intelligent Transport Systems (ITS); Framework for Public Mobile Networks in Cooperative ITS (C-ITS)

[13] DATEX II v2.2 User Guide, 31 May 2013

[14] AMQP 1.0 Discussion Paper, Broker Behaviour, 29.6.2010, http://www.rabbitmq.com/wp-uploads/2010/11/amqp-broker-prototype.pdf