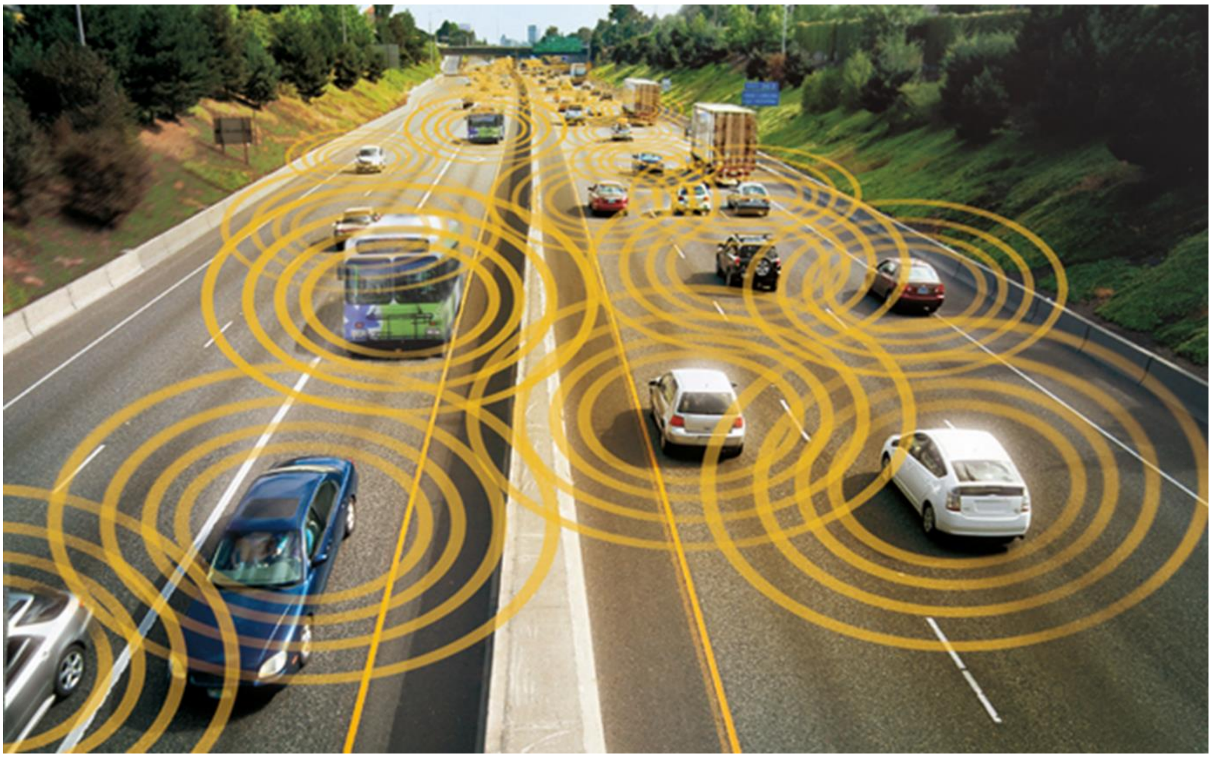
WAVE integration to V2X functionality (WV2X)

Diary Number: 2014-05572



Project within: FFI Vehicle Development

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FFI

Contents

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

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1. Executive summary

The WAVE integration to V2X functionality (WV2X) project commenced in January 2015 and terminated in December 2016. The project was originally planned to terminate in the end of September 2016 but it was prolonged according to a decision in the project's steering group in February 2016. All project objectives defined in the application were fulfilled and the project will contribute to achieving overall FFI objectives from a V2X perspective.

The WV2X project has produced valuable results and knowledge in the area of Vehicle-to Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication (together V2V and V2I are often called V2X – Vehicle-to-everything). The results include identification of proper requirements and verification methods, system design and implementation of a retrofit solution, implementation of a more long-term solution for future vehicles, and verification of these solutions in laboratory environment.

IEEE WAVE is the common name of the US set of protocol standards for C-ITS. In Europe, the corresponding set of standards, called ITS-G5, is defined by ETSI. Both WAVE and ITS-G5 are based on the IEEE 802.11p standard for the physical layer. Research on ITS-G5 is covered by the FFI WCAE project (diary number 2013-01285). The purpose of this WV2X project was to cover the US WAVE standard.

On December 13th, 2016 NHTSA announced a V2V Notice of Proposed Rulemaking (see section 5.3.2), based on WAVE, which indicates that the project partners (Volvo Cars, Actia Nordic AB and Kapsch TrafficCom AB) are well-prepared for future product and solutions development based on experience and knowledge gained in the WV2X project.

2. Background

When the FFI application was made, in 2014, the following was part of the background to the need for WAVE research [1]:

> The National Highway Traffic Safety Administration (NHTSA), a part of the U.S. Department of Transportation, announced in January 2014 that it will begin the regulatory proposal process for vehicle-to-vehicle communication technology for light vehicles. In the U.S., as well as in Europe, this technology will be an essential component in the next generation of automotive safety improvements. By exchanging safety data such as speed and location between nearby vehicles risks can be identified and provide drivers with warnings to avoid accidents.
> For example, the accident that took place on the E4 motorway at Tranarpsbron outside Östra Ljungby, Sweden, in January last year could potentially have been avoided or at least the damages could have been minimized if C-ITS already had been deployed in a fraction of the vehicles.
>
> Europe and U.S. have chosen different paths to the introduction of V2X technology in vehicles. Whereas Europe has chosen a path based on voluntary adoption to the standards in new generations of vehicles, US have chosen to go the regulatory path. In US, the introduction is driven by NHTSA and ultimately depending on the bill passing in the congress. In Europe the members of the Car-2-Car Communication Consortium (C2C-CC) is driving the introduction. With the declaration of intent from the U.S. Department of Transportation, it is clear that US will have regulatory requirements for V2X based on IEEE 802.11p and WAVE in vehicles in the 2018-2020 timeframe. In Europe the members of C2C-CC has signed a MoU to start the deployment in 2015. The race is on between the OEMs and there are requirements for V2X in upcoming vehicle models in both European and U.S. Both VCC and AB Volvo

have signed the Memorandum of Understanding (MoU) with the OEMs within C2C-CC and are active on the US market.

In Europe, the corresponding set of standards, called ITS-G5 and also based on IEEE 802.11p for the physical layer, is defined by ETSI. Research on ITS-G5 is covered by the FFI WCAE project (diary number 2013-01285), which started in 2013 [2]. The purpose of this WV2X project was to cover the US WAVE standard.

The figure below illustrates the protocol layers of ITS-G5 and WAVE.

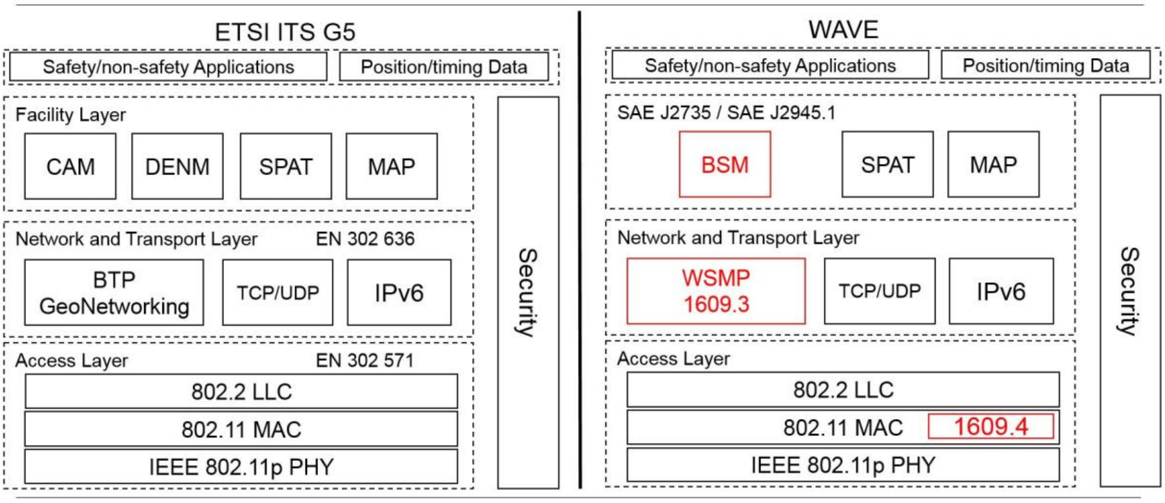

Figure 2.1: Comparison of ITS-G5 and WAVE protocols

Many protocols, including IEEE 802.11p at the physical layer, are used in both standards. Please refer to the appropriate ETSI, IETF, SAE and IEEE protocol standards for detailed descriptions of these protocols. The boxes in red color in the figure are specific to WAVE. These are:

- BSM (Basic Safety Message), SAE J2735/J2945.1 standards
- WSMP (WAVE Short Message Protocol), IEEE 1609.3 standard
- 1609.4 is the IEEE standard for WAVE – Multi-Channel Operation

3. Objectives

The project objectives as defined in the FFI application [1] remained unchanged during the course of the project.

The scope of the WV2X project was to evaluate and integrate the WAVE standard with the main objective to add this functionality to the functionality developed in another, already ongoing project, called Wireless Communication in Automotive Environment (WCAE). A number of supporting objectives were also defined [1]:

1. To identify the transfer function between customer needs and system level and from system level to component level for the WAVE technology.
2. Investigate the possibilities to integrate WAVE as a parallel protocol stack to ITS-G5 in the same hardware.
3. Specification and implementation of a common architecture for WAVE and ITS-G5.
4. Verification of WAVE in laboratory environment.

Comments at project conclusion:

1. Customer needs were broken down to system and lower level requirements, which are the deliverables from WP 1. A transfer function was identified and documented as a pathloss model for IEEE 802.11p [3].
2. The possibilities to integrate WAVE as a parallel protocol stack to ITS-G5 in the same hardware were investigated in the project.
3. A common architecture was specified and a dual stack solution, WAVE and ITS-G5, was implemented in the project. The implementation covers the same three use cases as for the WCAE project: Emergency Electronic Brake Light (EEBL), Stationary Vehicle Warning (SVW) and Green Light Optimal Speed Advisory (GLOSA).
4. The implemented solution was successfully verified in laboratory environment.

4. Project realization

The project was structured into the following work packages (WPs) [1][1]:

- WP 0: Project Management (VCC)
  - Based on monthly reports and meetings in the project team, meetings with the steering group at least before each reporting to VINNOVA, meetings within each WP, workshops and project seminars.
- WP 1: Requirements and Use Cases (VCC)
  - Specify requirements verification methods WAVE technology.
- WP 2A: WAVE System design and implementation for retrofit solution (Kapsch)
  - Develop a common V2X communication stack for both the ITS G5 and WAVE protocol stacks that runs on the same HW platform and is easily configurable.
- WP 2B: WAVE Implementation for future vehicles (Actia)
  - Implement support for V2X WAVE in the WCAE Node[2] .
- WP 3A: Verification of WAVE in laboratory environment retrofit solution (Kapsch)
  - Verify a common V2X communication stack for both the ITS G5 and WAVE protocol stacks that runs on the same HW platform and is easily configurable.
- WP 3B: Verification of WAVE in laboratory environment future vehicles (Actia)
  - Verify support for V2X WAVE in the WCAE Node.

[1] Main responsible partner for a WP within brackets.

[2] A prototype node developed by partner Actia in the FFI WCAE project for different research purposes.

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5. Results and deliverables

5.1 Delivery to FFI-goals

The project's contribution to FFI over-arching and sub-program targets/goals were defined as follows in the FFI application [1]:

Targets	**Contributions**	
	Defined	**Actual** (at project conclusion)
How well the project satisfies the targets defined within transport, energy and environmental policy	Improve	Potentially improved 1)
The ability of industry to operate knowledge-based production in Sweden in a competitive way	Strengthen	Strengthened
Contribute towards a vehicle industry in Sweden that continues to be competitive	Strengthen	Strengthened
Undertake development initiatives of relevance to industry	Improve	Improved
Lead to industrial technology and competence development	Improve	Improved
Contribute towards secure employment, growth and stronger R&D operations	Strengthen	Strengthened
Contribute towards actual improvements being made to production at participating companies	Strengthen	Potentially strengthened 1)
Strengthen research environments in selected, prioritized research areas in the field of production technology	Neutral	Neutral
Support environments for innovation and collaboration	Strengthen	Partially strengthened 2)
Strive to ensure that new knowledge is developed and implemented, and that existing knowledge is implemented in industrial applications	Strengthen	Potentially strengthened 1)
Rationalize the application of R&D results so that actual production improvements are implemented in participating companies	Neutral	Neutral
Improve the quality of technical production training	Neutral	Neutral
Reinforce collaboration between the vehicle industry on the one hand and the Swedish Road Administration, universities, colleges and research institutes on the other	Strengthen	Partially strengthened 2)
Strive to secure national supplies of competence and to establish R&D with competitive strength on an international level	Improve	Partially Improved 2)

Comments:

1) Will be determined when the project partners have eventually introduced WAVE-based products on the market.
2) The project consisted of three industry partners but through their contacts with universities and research institutes in adjacent research projects (e.g. Lund University and SP in the FFI WCAE project) the project partially contributed to this FFI goal.

5.2 Examples of Results

5.2.1 WP 1: Requirements and Use Cases

5.2.1.1 Activities Performed

The WP was led by VCC in cooperation with Kapsch and Actia AB. The major tasks were carried out by VCC, whereas the other partners helped in the review process. It concludes the use cases, detailed requirements for both the WAVE and the IEEE 802.11p standards from the physical layer to the facility layer in the OSI model.

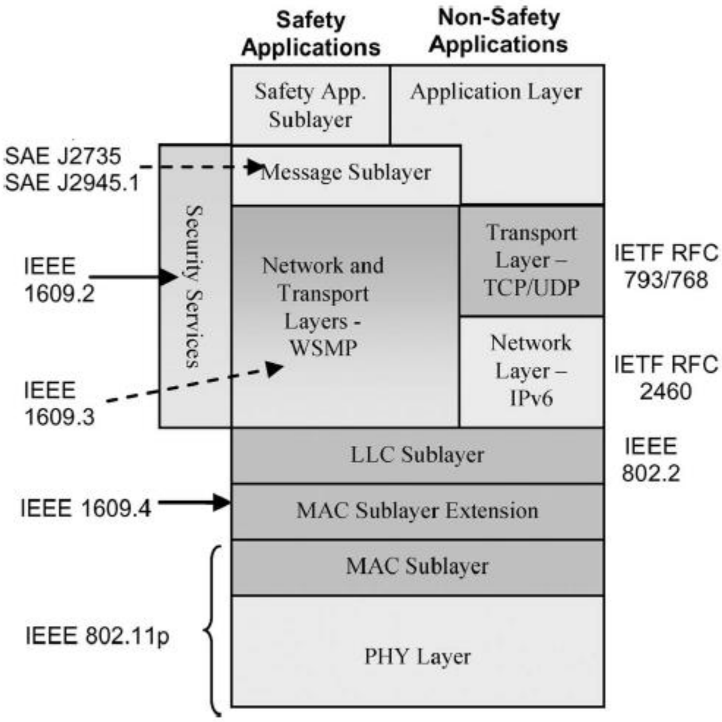

Figure 5.1: WAVE DSRC Architecture Overview [4]

Additionally, to test the requirements a set of design verification requirements was defined to elaborate how to validate the functionality of the hardware. Initially, much time was spent into studying and understanding the WAVE standard especially to identify how it is different from ETSI ITS G5, which is the standard used for the same purpose in the EU. Later on detailed requirements for US specific WAVE DSRC were written. The requirements for both the EU and US are presented in one document for simplicity, where a dedicated chapter addresses the requirements relevant to each standard, i.e., ETSI ITS G5 or WAVE, respectively.

5.2.1.2 Results

The results were documented in technical specifications [5-7]. These documents include the hardware specification (DPR), the software requirements (SWRS), and a first draft of the device level design verification methods (DVM). The DVM will be finalized later because certification tests are currently not provided in the WAVE standard.

5.2.1.3 Conclusions and future research

The WAVE standard is still not completely frozen. It has continuously been updated with some modifications here and there, so the plan is to closely follow the standardization process and keep on updating these requirements in an iterative manner.

5.2.2 WP 2A: WAVE System design and implementation for retrofit solution

5.2.2.1 Activities Performed

The activities performed include study of standards, primarily from SAE and IEEE standardizing WAVE, as well as architectural design, implementation and testing.

The goals with the activities were to find:

- A common abstraction of the Hardware, particularly the 5.9 GHz Radio.
- Isolate the differences between the standards.
- Investigate the possibility for common applications.
- Implement a solution.

On a high level V2X units share the same architecture, described below.

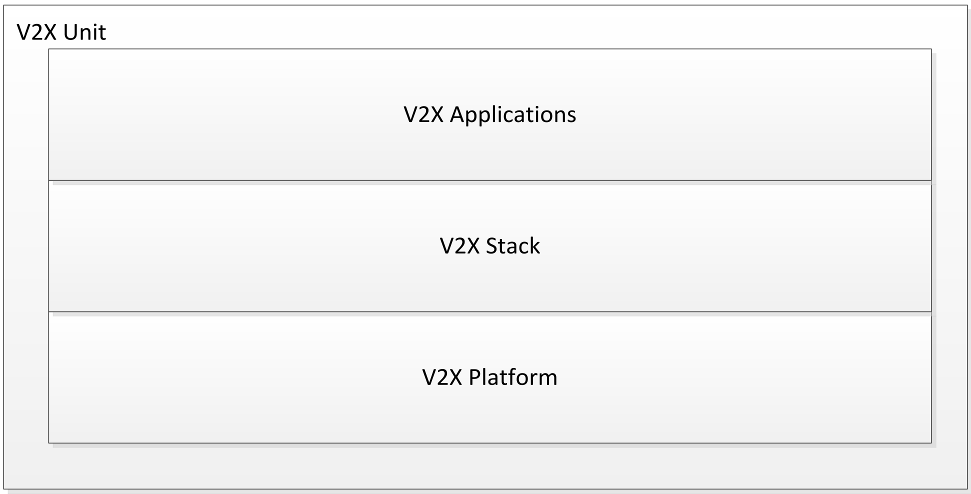

Figure 5.2: V2X overview

The following pictures show the main differences and commonalities between the V2X stacks for ITS-G5 and WAVE from a system design perspective:

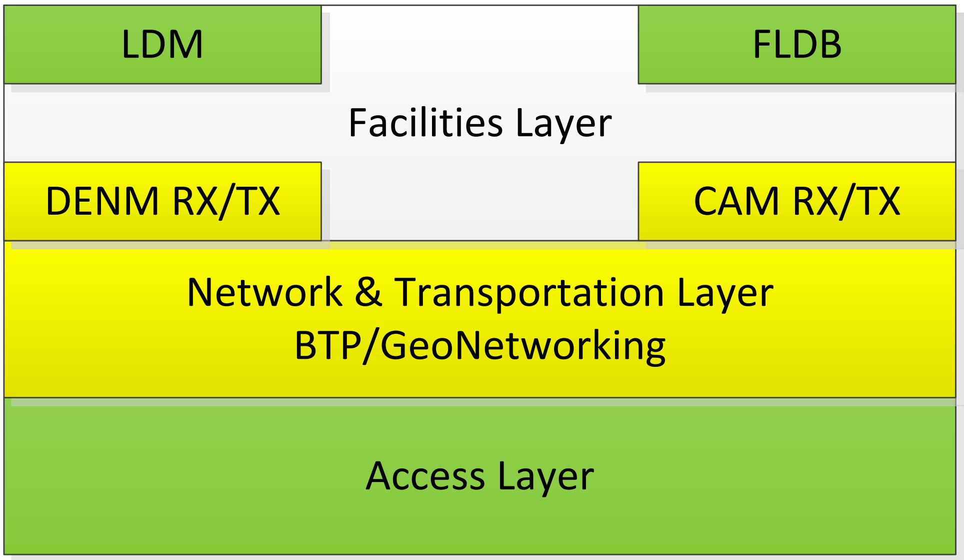

Figure 5.3: ITS-G5 Stack overview

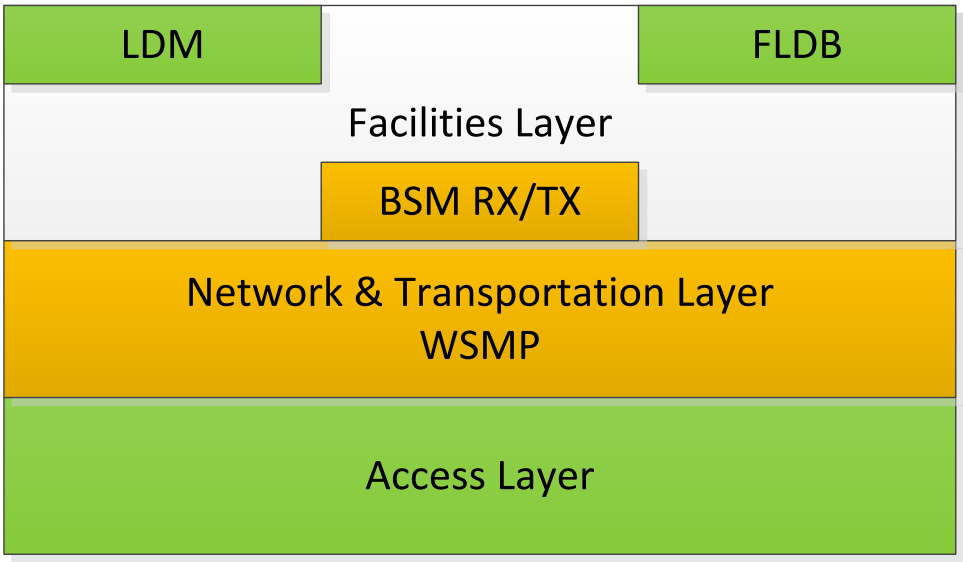

Figure 5.4: WAVE Stack overview

In the figures above, the green boxes indicate common parts of both protocol stacks, and yellow/orange boxes indicate the differences. The most important commonality is the Access Layer, i.e. the abstraction of the Radio and the lowest stack layers.

Switching between the two stacks is realized using a configuration parameter. The V2X unit needs to be reset in order for the new configuration to take effect.

The Kapsch solution using a common API towards the facilities layer above enables the same applications to run on both stacks. However, the common applications may only depend on data present in both CAMs and BSMs.

Implementation of the orange stack components in Figure 5.4 have been added and tested (see section 5.2.4). The solution was demonstrated and validated together with Actia for both WP 2A and WP 2B setup using the same V2X-applications as in the WCAE-demo.

5.2.2.2 Results

We have reached results in the work package on how to adjust the same stack for both protocols independent of hardware. Switching between ITS-G5 and WAVE is implemented and easily configured by a parameter. This is presented on an architectural level, designed, implemented and demonstrated.

5.2.2.3 Conclusions and future research

Conclusions are that it is possible to implement the two stack variants on the same radio hardware, and to some extent, run the same applications on top of the stack. Furthermore, it is also possible to keep both versions installed on the same equipment and by means of configuration choose the correct stack version according to the region of deployment.

Looking further into the security aspects would be a natural next step for research in this area. Even though it was not covered by the work package, assessment is that it would be feasible to use the same hardware for key management, signature calculation and signature verification. However, WAVE and ITS-G5 are going in different directions when it comes to certificate management.

Further proposals for future research are in the area of applications, both road safety and traffic efficiency.

5.2.3 WP 2B: WAVE Implementation for future vehicles

5.2.3.1 Activities Performed

Actia led the WP in cooperation with Kapsch and VCC. WV2X WP 2B is based on the Actia WCAE WP 2B Node in combination with Kapsch WCAE WP 2A V2X radio.

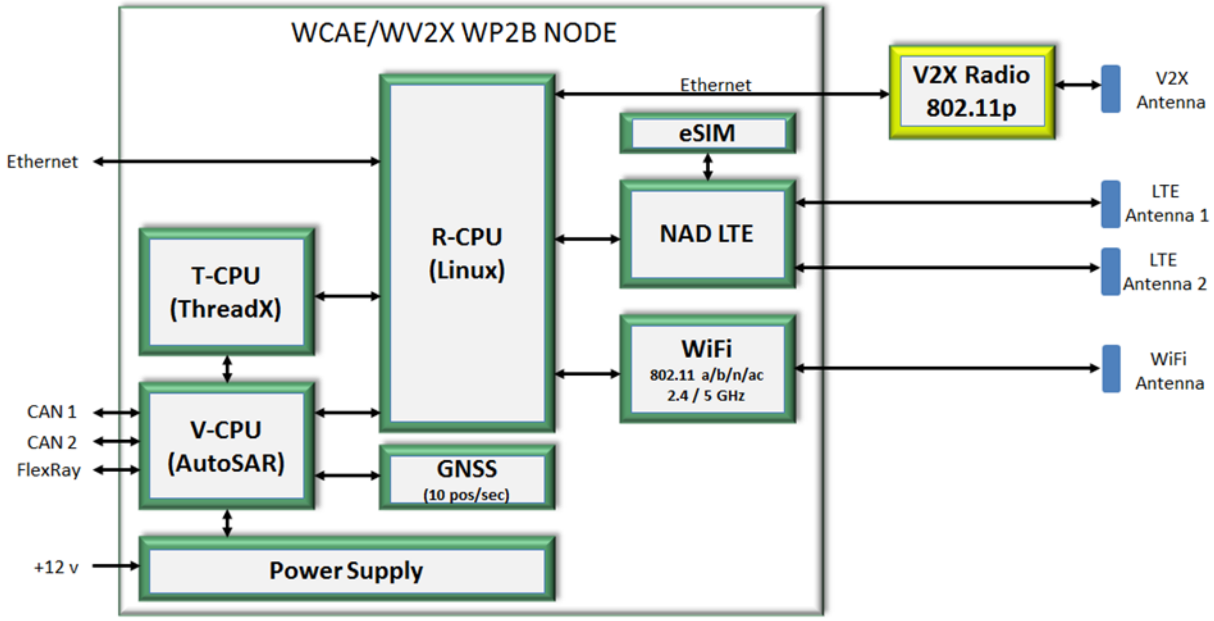

Figure 5.5: WP 2B High-level system architecture. Router-CPU (R-CPU) is the central component hosting the applications driving the main V2X applications

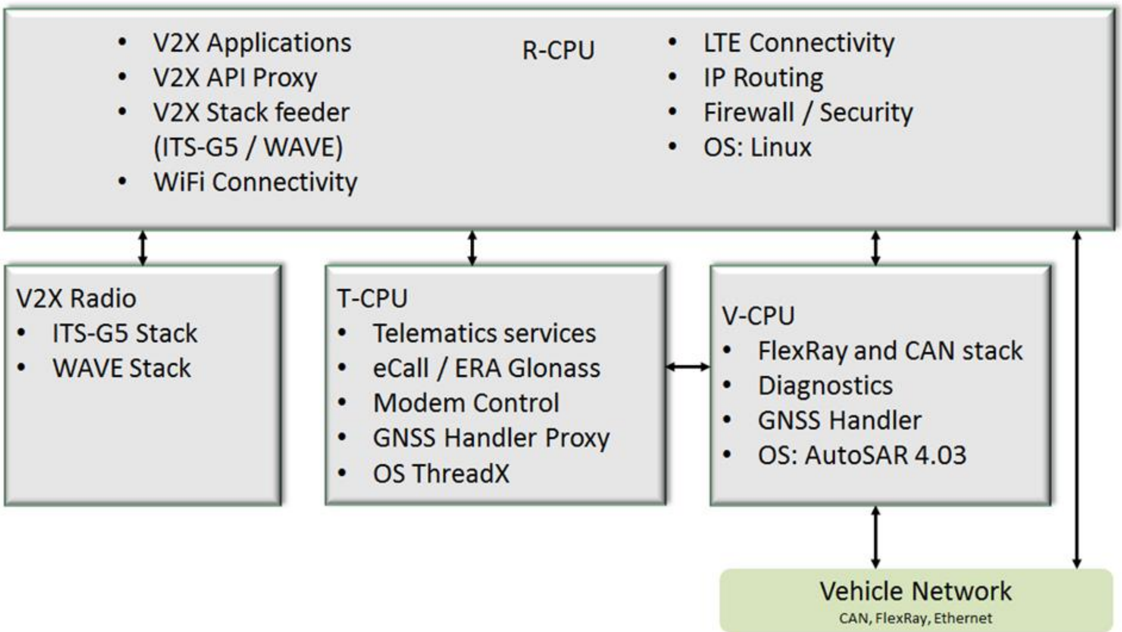

Figure 5.6: WP 2B Function partitioning. Vehicle signals are collected from the vehicle bus and used to populate the V2X messages. Received V2X messages are interpreted by the V2X applications and decoded data is distributed to the vehicle network for HMI display and future control algorithms.

Software adaptations were made in the WCAE WP 2B Node and WP 2A V2X radio in order to support WAVE .The following main SW adaptations were made:

- Applications were modified to work with the WAVE stack
- Radio module was configured to run the WAVE stack

As depictured in figure 5.5, the WCAE/WV2X node supports V2X communication through the external radio module. It can be configured for either WAVE or ITS-G5 communication. The node hosts a set of internal applications implementing V2X features such as emergency break warning. The V2X applications will change depending on configuration. As seen in figure 5.6, the radio module hosts the radio stack, and can be configured for either WAVE or ITS-G5 communication. The radio module is configured by the WCAE/WV2X node. It is possible to have an internal application dedicated to retrieve API requests from external nodes hosting their own V2X applications. The application can be designed to take input from any communication interface including CAN or Flexray. The applications collect information from both the V2X stacks and the vehicle, and once events are triggered, they are forwarded for notifying the user via the HMI. The V2X applications also populate the V2X messages to be sent out, through the V2X stack, over the V2X radio.

5.2.3.2 Results

The WCAE WP 2B node was equipped with software to support WAVE, resulting in the WV2X WP 2B node. The system architecture is documented in the system architecture description [8].

5.2.3.3 Conclusions and future research

In the current state of the standards, one single hardware variant is able to meet the needs for both ITS-G5 and WAVE communication requirements. The difference is possible to handle through software configuration. Further research is needed in the fields of vehicle networks at a larger scale, communication with applied security layers, size optimized modules, automotive safety compliant nodes and behavior of additional applications.

5.2.4 WP 3A & 3B: Verification of WAVE in laboratory environment

This section describes WP 3A (Verification of WAVE in laboratory environment retrofit solution) and WP 3B (Verification of WAVE in laboratory environment future vehicles).

5.2.4.1 Activities Performed

A joint test was performed together between WP 3A and 3B. The scope of the test was to validate interoperability of the solutions for the WAVE retrofit solution and the solution for future vehicles. This was tested by using a setup based on a Kapsch EVK and the Actia WCAE Node. The test also validated that the setups could switch from WAVE to ITS-G5 using a configuration parameter.

5.2.4.2 Results

An extract from the test report [9] illustrating the use of the WAVE WSMP messages being exchanged between the two setups can be seen in the figure below. It can be observed that it is the same two MAC-ids communicating in the two different configurations.

3146	327.553309	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3147	327.589129	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3148	327.662935	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3149	327.689173	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3150	327.739058	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3151	327.789953	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3152	327.857183	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3153	327.889163	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3154	327.952005	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3155	327.989168	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3156	328.034423	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3157	328.089306	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3158	328.139048	KapschAg_00:bb:4b	Broadcast	WSMP	193	WAVE Short Message Protocol IEEE P1609.3
3159	328.189336	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3160	328.247533	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3
3161	328.289059	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3162	328.345298	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3
3163	328.389283	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3164	328.461528	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3
3165	328.489370	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3166	328.537941	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3
3167	328.589305	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3168	328.654301	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3
3169	328.689293	KapschAg_00:ba:56	Broadcast	WSMP	72	WAVE Short Message Protocol IEEE P1609.3
3170	328.786856	KapschAg_00:bb:4b	Broadcast	WSMP	203	WAVE Short Message Protocol IEEE P1609.3

Figure 5.7: Extract from the Wireshark log displaying WAVE messages. Notice that two different MAC-ids are represented, both 00:ba:56 and 00:bb:4b.

The WAVE messages were able display a correct position in the HMI as seen in the figure 5.8. The locations are the same for both setups.

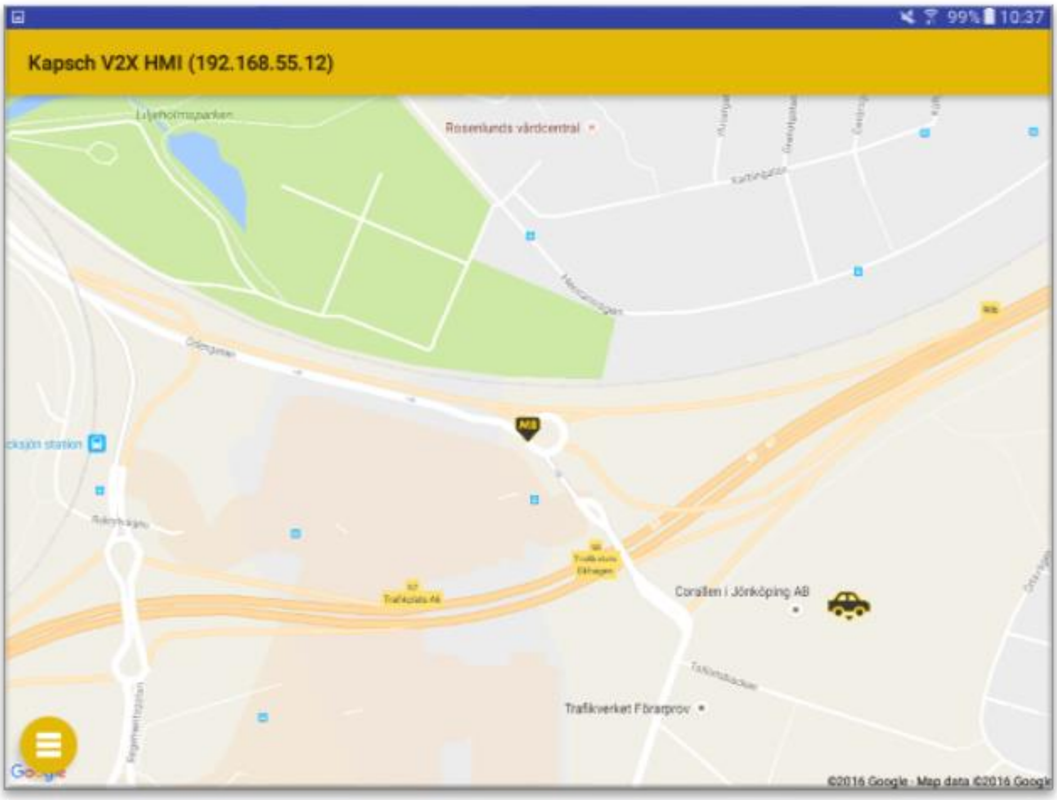

Figure 5.8: Print screen of the HMI with the two setups communicating over the WAVE protocol and able to display both the position of itself and the other setup.

5.2.4.3 Conclusions and future research

The WAVE retrofit solution and the WAVE solution for future vehicles are able to communicate using the WAVE-protocol with the same resulting positions as when communicating over the ITS-G5 protocol. Further, it is possible to reconfigure the two setups from WAVE to ITS-G5 using a configuration parameter in the web interface. Thus, it is possible to support both WAVE and ITS-G5 using a single hardware solution.

A next step in the research could be to make a joint test with a third party developed stack, from a party outside the WV2X project.

5.3 Legislation and Market Introduction Aspects

5.3.1 C-ITS in general

The potential of the cooperative intelligent transportation systems (C-ITS) technology has been identified globally. The major standardization and deployment efforts are ongoing especially in three regions the US, EU and Japan. For C-ITS, WAVE DSRC is adopted in North America and ETSI ITS G5 in the EU where both of them rely on IEEE 802.11p standard, based on IEEE 802.11 standard that defines the physical and MAC layers. FFI WCAE covers only the ITS G5 standard but not WAVE and that was the main reason to start FFI WV2X. Purpose of the project was to understand the standard, identify the differences from ITS G5 and then prepare a dedicated requirement document that can be used to enable WAVE technology for the cars.

It is a known fact that C-ITS will involve car-to-car (C2C), car-2-infrastructure (C2I), and car-to-device (C2D) communications and therefore it is collectively known as C2X communications. It may not only rely on 802.11p-based technology but several other access technologies, such as cellular LTE-V or LTE D2D, 5G or maybe Bluetooth Low Energy. In the last couple of years there has been enormous efforts to develop technology standards so that existing or new cellular network could be utilized as a complement to WAVE or ITS G5 for many different reasons, such as to achieve better security, cost and Quality of Service.

5.3.2 WAVE US breakthrough

Despite all the efforts to develop the technology standards, it is still unclear when and how the technology is going to be adopted. Therefore, US-department of transportation together with NHTSA for some years have been looking into all the possibilities that could be used as a basis to introduce C-ITS as a feature of public safety after it is mandated by the US government.

On December 13, 2016, finally a breakthrough occurred when NHTSA announced a V2V Notice of Proposed Rulemaking [10], based on WAVE, with the following text in the summary:

> "This document proposes to establish a new Federal Motor Vehicle Safety Standard (FMVSS), No. 150, to mandate vehicle-to-vehicle (V2V) communications for new light vehicles and to standardize the message and format of V2V transmissions. This will create an information environment in which vehicle and device manufacturers can create and implement applications to improve safety, mobility, and the environment. Without a mandate to require and standardize V2V communications, the agency believes that manufacturers will not be able to move forward in an efficient way and that a critical mass of equipped vehicles would take many years to develop, if ever. Implementation of the new standard will enable vehicle manufacturers to develop safety applications that employ V2V communications as an input, two of which are estimated to prevent hundreds of thousands of crashes and prevent over one thousand fatalities annually."

Press release and more information, including web links, see: https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The main mechanism for dissemination with the project partner organizations were the Project Seminars arranged in the project in cooperation between the FFI projects WV2X and WCAE.

The subsections below show the agendas and other relevant information for these seminars. The presentations were, like other results from the project, stored on the Project SharePoint site, administered by VCC and accessible for the other project partners.

6.1.1 WCAE/WV2X Seminar 2015-04-08

WCAE & WV2X Seminar – Agenda 2015-04-08

Time 09.30-15.00, Place: Volvo Car Corporation (VCC), Volvo Jakobs väg, Torslanda, Göteborg, Room: PVH5 "Hörsal B"
(First go to: PVH Reception, see attached map in Outlook Invitation)

09.30 Registration and Coffee/Tea

09.50 0) Welcome and Introduction – P-A Jörgner, Volvo Car Corporation (VCC) (10 min)

10.00 **1) From Active Safety Systems to Connected Automation**
Katrin Sjöberg, AB Volvo (30 min)

10.30 **2) Why 5.9 V2X?**
Adam Tengblad, Kapsch (20 min)

10.50 Break (Coffee/Tea) [20 min]

11.10 **3) Market Trends Toward the Deployment of C-ITS – Environment Scan Report**
Taimoor Abbas, VCC (30 min)

11.40 **4) What's left Before Deployment of C-ITS Can Start?**
Katrin Sjöberg, AB Volvo (20 min)

12.00 Lunch [1 h]

13.00 **5) WCAE WP1C Update – Initial RLOS Measurements on Car**
Jan Carlsson, SP (20 min)

13.20 **6) Vehicle-to-vehicle System Simulator**
Jan Carlsson, SP (20 min)

13.40 **7) Stress Test of Vehicular Communication Transceivers Using Software Defined Radio**
Carl Gustafson, Lund University (20 min)

14.00 Break (Coffee/Tea) [20 min]

14.20 **8) On Multilink Shadowing Effects in Measured V2V Channels on Highway**
Mikael Nilsson, VCC (20 min)

14.40 **9) Wireless Communication as part of Architecture for Autonomous Driving**
Kent Melin, VCC (20 min)

15.00 Thank You & The End – P-A Jörgner, VCC

Figure 6.1: Agenda WCAE/WV2X Seminar, April 2015

6.1.2 WCAE/WV2X Demonstration Days 2016-09-28/29

This event also included, in parallel, V2X test drives for the audience with two AB Volvo FH test trucks and two VCC XC90 test cars.

WCAE/WV2X Demonstration Days Seminar – Agenda 2016-09-28 (Day 1)

Time 09.30-15.10, Place: Volvo ATR Concept Studio at M1, Lindholmen, Göteborg

09.30	Registration and Coffee/Tea
09.50	**0) Welcome and Introduction** – P-A Jörgner, Magnus Olbäck, Mikael Nilsson [10 min]
10.00	**1) EU and US Standardization of c-ITS and Connected Automation** Katrin Sjöberg, AB Volvo [30 min]
10.30	**2) Channel characteristics for cooperative ITS and positioning** Fredrik Tufvesson, Lund University [30 min]
11.00	Break (Coffee/Tea) [20 min]
11.20	**3) Multiprobe Over-the-Air Test Setup for Cars: Introduction** Mikael Nilsson, Volvo Cars and Kristian Karlsson, SP [20 min]
11.40	**4) An ECU for wireless communication via 3G, LTE, Wi-Fi and V2X** Lennart Strandberg, ACTIA Nordic AB [20 min]
12.00	Lunch [1 h]
13.00	**5) ADAS and Cooperative Safety** Adam Tengblad, Kapsch TrafficCom AB [40 min]
13.40	**6) Autonomous Driving Cars in a Wireless Environment** Kent Melin, Volvo Cars [30 min]
14.10	Break (Coffee/Tea) [20 min]
14.30	**7) Mapping V2X Wireless Performance to System Specifications** Russ Whiton, AB Volvo [30 min]
15.00	**Wrap up** – P-A Jörgner, Volvo Cars
15.10	End

Figure 6.2: Agenda WCAE/WV2X Demonstration Days, September 2016 (Day 1)

WCAE/WV2X Demonstration Days Seminar – Agenda 2016-09-29 (Day 2)

Time 09.30-15.10, Place: Volvo ATR Concept Studio at M1, Lindholmen, Göteborg

09.30 Registration and Coffee/Tea

09.50 0) Welcome and Introduction – P-A Jörgner, Magnus Olbäck, Mikael Nilsson [10 min]

10.00 1) Channel Emulation Using Software Defined Radio (SDR)
Dimitrios Vlastaras, Lund University [20 min]

10.20 2) A Simulation framework for V2V Wireless Systems at 5.9 GHz
Carl Gustafson, Lund University [40 min]

11.00 Break (Coffee/Tea) [20 min]

11.20 3) Multiprobe Over-the-Air Test Setup for Cars: Introduction, Method & Results
Mikael Nilsson, Volvo Cars and Kristian Karlsson, SP [60 min]

12.20 Lunch [1 h]

13.20 4) A Measurement Based Multilink Shadowing Model for V2V Network Simulations of Highway Scenarios
Mikael Nilsson, Volvo Cars [30 min]

13.50 5) Simulations in the WCAE project
Edith Condo Neira, SP [20 min]

14.10 Break (Coffee/Tea) [20 min]

14.30 6) Measurement Methods & Tools – WiFi & LTE
Magnus Eek/Tai Huang, Volvo Cars [30 min]

15.00 Wrap up – P-A Jörgner, Volvo Cars

15.10 End

Figure 6.3: Agenda WCAE/WV2X Demonstration Days, September 2016 (Day 2)

The Demonstration Days seminar presentations can also be found on the public web site: www.wcae.se

6.2 Publications

As no research institute or academia was part of this project, no academic papers and similar publications were produced. However, numerous publications related to V2X, mainly focusing on ITS-G5 but partly also relevant for WAVE were produced in the adjacent project FFI WCAE [2].

7. Conclusions and future research

Conclusions and future research ideas are documented per WP in section 5.2 above. This chapter draws some general conclusions and identifies some future research ideas summarized for the whole WV2X project.

The three project partners have gained deeper understanding about the IEEE WAVE standard and the similarities and differences compared to ETSI ITS-G5.

The project has shown that it is feasible to produce common C-ITS specifications for WAVE and ITS-G5 (WP 1), to implement a prototype dual stack for retrofit solutions and future cars (WP 2A/2B) and to verify the prototype in a laboratory environment (WP 3A/3B).

For a long period it was unclear whether NHTSA would activate the process towards C-ITS legislation based on the WAVE standard but in December 2016 this happened, see section 5.3.2 [10]. This means that, thanks to the WV2X project, the project partners are well prepared for the continued development of WAVE-based products and solutions (in other projects).

To study the upcoming challenges and opportunities further research is needed. For example regarding the positioning and further development of WAVE and ITS-G5 (both based on IEEE 802.11p) with respect to C-ITS based on mobile networks (LTE and 5G), the application layer, and security.

8. Participating parties and contact persons

The following organizations were part of this project (listed below in alphabetical order with main contact persons):

- Actia Nordic AB: Lennart Strandberg, Andreas Bergvall
- Kapsch TrafficCom AB: Adam Tengblad, Maria Borgmark
- Volvo Car Corporation[3]: Hans Alminger, Taimoor Abbas, Per-Anders Jörgner

[3] Volvo Personvagnar AB

9. Annex

9.1 References

[1] FFI Application for Vehicle Development: WAVE integration to V2X functionality - WV2X; P-A Jörgner, VCC; Håkan Johansson, Kapsch; Lennart Strandberg, Actia; version C, 2015-01-29.
[2] FFI Application to Vehicle Development: Wireless Communication in Automotive Environment (WCAE), AnnSofie Ruuth VCC, 2014-06-13.
[3] M. Nilsson, C. Gustafson, T. Abbas, F. Tufvesson, “A Measurement Based Multilink Shadowing Model for V2V Network Simulations of Highway Scenarios”, IEEE Transactions on Vehicular Technology, July 2016.
[4] J. B. Kenney, "Dedicated Short-Range Communications (DSRC) Standards in the United States," in *Proceedings of the IEEE*, vol. 99, no. 7, pp. 1162-1182, July 2011.
[5] DPR C2X ITS-G5 and WAVE Physical and Datalink Layer, Taimoor Abbas, VCC, 2016.
[6] SWRS C2X ITS-G5 and WAVE Network to Facility Layer, Taimoor Abbas, VCC, 2016.
[7] DVM C2X ITS-G5 and WAVE Physical and Datalink Layer, Taimoor Abbas, VCC, 2016.
[8] WCAE_WV2X WP2B System Architecture Description 2.1, Lennart Strandberg, Actia, 2016.
[9] Test Report: WV2X WP3B WP3A Verification of WAVE in laboratory environment v1_0, Linus Conradson, Actia, 2016.
[10] DEPARTMENT OF TRANSPORTATION, National Highway Traffic Safety Administration, 49 CFR Part 571 [Docket No. NHTSA-2016-0126] RIN 2127-AL55, Federal Motor Vehicle Safety Standards; V2V Communications, December 2016.

9.2 Terminology

5G	5th Generation mobile networks
API	Application Programming Interface
BSM	Basic Safety Message
BTP	Basic Transport Protocol
C2C	Car-to-Car
C2D	Car-to-Device
C2I	Car-to-Infrastructure
C2X	Car-to-everything (car to other cars, infrastructure, etc.)
CAM	Cooperative Awareness Messages
C-ITS	Cooperative Intelligent Transport Systems
DENM	Decentralized Environmental Notification Messages
DPR	Design Pre-Requisites
DSRC	Dedicated Short-Range Communications
DVM	Design Verification Methods
EEBL	Emergency Electronic Brake Light
ETSI	European Telecommunications Standards Institute
FFI	*Fordonsstrategisk Forskning & Innovation*
FLDB	Facilities Layer Database
GLOSA	Green Light Optimal Speed Advisory
HMI	Human Machine Interface
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
ITS	Intelligent Transport Systems
ITS-G5	ETSI group responsible for ITS standardization
LDM	Local Dynamic Map

LLC	Logical Link Control
LTE	Long Term Evolution
MAC	Media Access Control
MoU	Memorandum of Understanding
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer (here automaker)
OSI	Open Systems Interconnect
PHY	Physical layer
RX	Receiver
SAE	Society of Automotive Engineers
SPAT	Signal Phase And Timing
SVW	Stationary Vehicle Warning
SWRS	Software Requirement Specification
TCP	Transmission Control Protocol
TX	Transmitter
UDP	User Datagram Protocol
US	United States
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-everything (vehicle to other vehicles, infrastructure, etc.)
VCC	Volvo Car Corporation
WAVE	Wireless Access in Vehicular Environments (IEEE 1609 family of standards)
WCAE	Wireless Communication in Automotive Environment
WSMP	WAVE Short Message Protocol
WV2X	WAVE integration to V2X functionality
WP	Work Package

9.3 Report Authors

Many people have provided input to this report and several authors have written different chapters and parts. Thus, the language can vary and we hope that the readers have patience with this. The list below shows the main author or authors of the different parts of the report.

Chapter/Section	Author/Authors
1, 2, 3, 4 & 5.1	P-A Jörgner, VCC
5.2.1	Taimoor Abbas, VCC
5.2.2	Maria Borgmark & Martin Krutzsch, Kapsch
5.2.3	Lennart Strandberg & Linus Conradson, Actia
5.2.4	Maria Borgmark & Martin Krutzsch, Kapsch; Lennart Strandberg & Linus Conradson, Actia
5.3	Taimoor Abbas & P-A Jörgner, VCC
6, 7, 8 & 9	P-A Jörgner, VCC