Technical Report **IDE09120**, December 2009

Report on Collaboration between CVIS and CERES in the Project Vehicle Alert System (VAS)

Katrin Bilstrup, Annette Böhm, Kristoffer Lidström,
Magnus Jonsson, Tony Larsson and Elisabeth Uhlemann

School of Information Science, Computer and
Electrical Engineering,
Halmstad University, Box 823,
SE-30118 Halmstad, Sweden

Report on the Collaboration between CVIS and CERES in the Project Vehicle Alert System (VAS)

Katrin Bilstrup, Annette Böhm, Kristoffer Lidström, Magnus Jonsson, Tony Larsson and Elisabeth Uhlemann
CERES – Centre for Research on Embedded Systems
Halmstad University, Halmstad, Sweden
{katrin.sjoberg, annette.bohm, kristoffer.lidstrom, magnus.jonsson, tony.larsson, elisabeth.uhlemann}@hh.se

Abstract – In March 2007 an agreement was made for interchange of experiences between CVIS and the Centre for Research on Embedded Systems (CERES) at Halmstad University in Sweden. The majority of the work relating to this collaboration has been conducted within the CERES project Vehicle Alert System (VAS), aiming to use vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications to provide different types of warning messages. The main focus of the VAS project is on communication and in particular the lower layers of the communication stack are investigated. VAS involves academic researchers from Halmstad University as well as researchers from Volvo Technology, SP Technical Research Institute of Sweden and the company Free2move. This report presents the results of the VAS project, its publications, and other issues of interest both to the CVIS consortium as well as a broader scope.

I. Introduction

There exist a plethora of applications based on vehicular communications intended for intelligent transport systems (ITS) which roughly can be divided into one of three groups; *traffic safety*, *traffic efficiency*, and *value-added services*. Due to the challenging requirements imposed on the wireless communication by traffic safety applications, these have been the focus of the VAS project [1], [11]. The introduction of different wireless access technologies enabling cooperative ITS systems plays a vital role in the development of proactive traffic safety systems. It enables vehicles to exchange data that help both the vehicle itself and its driver to correctly assess the current traffic situation and its potential hazards. Information is shared between vehicles through inter-vehicle communication, either vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I), with the latter involving an entity called road side unit (RSU). Reduction of fatalities and financial loss due to traffic accidents is a common goal of all traffic safety applications.

In VAS, communication issues derived from traffic safety applications are tackled on two layers of the ISO OSI communication stack – application and data link. When considering the European ITS communications architecture for cooperative systems published by COMeSafety, Fig.1, VAS deals with the layers “ITS Facilities” and “ITS Access Technologies”. The data link layer together with the physical layer from the OSI stack is termed “ITS Access Technologies” in the COMeSafety report and most of the algorithms developed in the project would be used as “ITS Facilities”. Also note that the data traffic models derived from the local dynamic map (LDM) in the ITS Facilities layer have been used to evaluate the performance of the considered ITS Access Technologies.

At the application layer, the system must handle communicated kinematic data observations from vehicles in dependable and scalable ways. The information is used to make a vehicle aware about the traffic situation and potential accident risks. Specific sub-goals have been (*i*) to develop a system architecture that takes into account the roles of infrastructure versus vehicles as carriers, interpreters and goal driven controllers of information, (*ii*) find methods for modeling, prioritizing and handling situational information and decision making in a scalable way, even in overloaded situations, (*iii*) enable cooperation between autonomous nodes with multiple, possibly conflicting, control goals.

This work was funded in part by the Knowledge Foundation, www.kks.se.

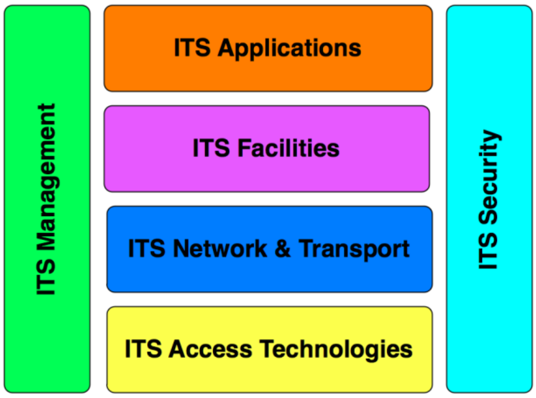

Figure 1: Reference Protocol Stack of an ITS Station

ITS safety applications rely on the timely and reliably delivery of data and the medium access control (MAC) algorithm is a key component to achieve this. Therefore, the MAC method in the data link layer has been scrutinized from different aspects. The MAC algorithm is responsible for deciding who has the right to transmit next on the shared communication channel – if channel access is not granted in a timely manner, cooperation cannot be achieved. To further complicate the problem, the high mobility of nodes implies requirements on the MAC protocol to be scalable. In addition, the cooperative awareness messages (CAM) derived form the LDM, requires channel access to be fair. This means that scheduling of messages must be done according to their particular level of importance and timing requirements. Specific sub-goals have been: (*i*) develop and evaluate MAC methods for V2X communication supporting the strict timing requirements of traffic safety applications, (*ii*) develop protocols for fast connection setup and handover to support the instant delivery of critical data, (*iii*) increase the reliability in special scenarios such as highway entrances with support from RSUs.

In Section II the chosen application scenarios for the VAS project are outlined, and the specific research activities and results are presented in Section III. Section IV describes how the CVIS platform has been used within VAS. Finally, the report ends with conclusions and outlook in Section V.

II. Application Scenarios

Three application scenarios have been chosen as a starting point for the research conducted in VAS – *emergency vehicle routing*, *merge assistance* and *pedestrian crossing warning*. They all have different properties and requirements. In the *emergency vehicle routing* scenario, Fig. 2, the aim is to create a “green wave” for emergency vehicles using both V2V and V2I communication. The knowledge horizon for the emergency vehicle could be extended through proactive warning messages and a path for the vehicle can be cleared in time. The vehicle queries the infrastructure for suitable routes to its destination as well as for traffic signal preemption.

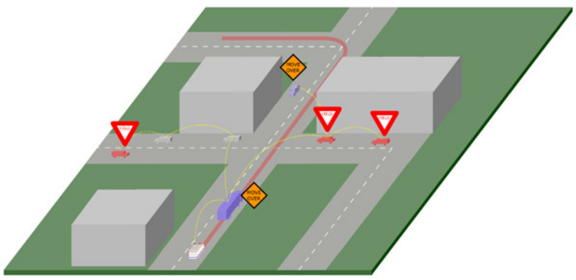

Figure 2. Vehicles and infrastructure cooperate to create a "green wave" for the ambulance.

In Fig. 3. the second scenario *merge assistance* is depicted, aiming to increase safety and efficiency at highway on-ramps. A highway entrance might be a given spot for installing RSUs, especially in difficult environments (e.g., bad visibility, many roads crossing). Through this RSU, the communication between vehicles can be better controlled and traffic safety applications can be prioritized and scheduled side by side with e.g., traffic efficiency data.

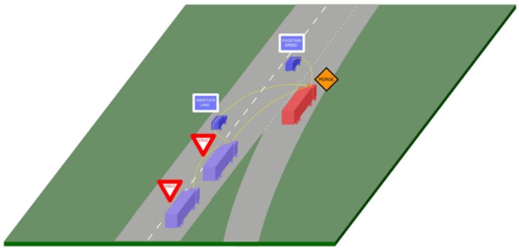

Figure 3. A truck merging onto the highway cooperates for a safer and smoother maneuver.

The *pedestrian crossing warning* scenario, Fig. 4, employs mainly V2I communication to warn the driver that pedestrians are located on, or near the crossing. Crosswalk signaling infrastructure can also benefit from interaction with vehicles. If a vehicle is unable to stop in time, for example due to road conditions or driver inattention, the crosswalk signaling system could delay giving the "walk" signal or alert pedestrians. At unguarded crossings, detectors could alert drivers that there are pedestrians waiting to cross.

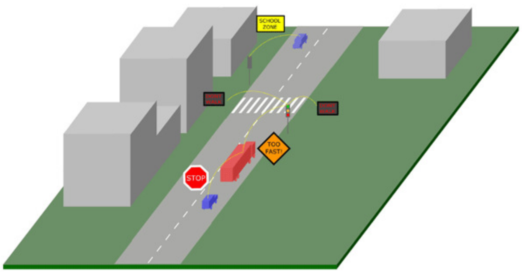

Figure 4. Vehicles and infrastructure cooperate to create a safer situation at a pedestrian crossing.

III. Research Activities and Results

To identify problems and challenges within the area of cooperative systems, we have made several state-of-the-art surveys and pre-studies in the form of master thesis works ([2], [3], [4]) and white papers or technical reports ([5], [6], [28]). Further, we have several publications in scientific journals and conference proceedings relevant for academic research in the ITS area ([7]-[8], [10], [14]-[18], [23]) as well as eight contributions to the World Congress on ITS in 2007 ([11]), 2008 ([19]-[22]) and 2009 ([32]-[34]). In addition we have made contributions to ongoing standardization activities ([26]-[27]) and presented our work to spread information about CVIS and research on cooperative systems ([9], [12]-[13], [24]-[26], [29], [35]-[36]). We have also developed an application based on the *pedestrian crossing warning* scenario, using the CVIS platform [33]. Finally, three licentiate theses conclude the work ([30], [31], [37]). Please, contact any of the authors listed if you have questions or comments. Below is an overview of our most important contributions.

We were invited both by C2C-CC (the PHY/MAC/NET and the Simulation Working Groups) and by ETSI TC ITS to present parts of our research. Due to this, Halmstad University decided to become a member of ETSI to be able to follow the standardization activities within the V2X field more closely. The purpose of the membership is to be able to use the most recent information about traffic safety applications, e.g., different settings for CAMs and DEMNs, in performance evaluations of different technological building blocks.

Application layer

Traffic accidents account for nearly 40,000 fatalities each year in the European Union and reducing this number relies on the successful coordination between several stakeholders in the traffic domain. ITS, a marriage between information, communication and transportation technologies, is a promising platform for coordination between car manufacturers, infrastructure operators and policy makers. Cooperative safety systems inherit the stringent reliability requirements of traditional non-cooperative safety systems while at the same time being subject to the unreliable characteristics of a distributed system linked by wireless communication.

Application and middleware strategies for reliably providing traffic safety applications over the wireless channel have been the focus of the application layer work within the VAS project. Cooperative safety using V2X communication enables warning systems to take into account more detailed and longer range information than previously possible. Due to the increased prediction horizon tactical concepts such as traffic rules and driver intentions must be modelled in addition to short term kinematics traditionally used in driver alert systems. Utilizing the FOAM and POMA frameworks and components we proposed a cooperative warning system that models such concepts using artificial potential fields taking into account multiple route-choice hypotheses. The proposed system was also implemented on the CVIS platform and subsequently used as an experimental platform to evaluate the feasibility of using the history of route-choice estimates as an indicator of unpredictable driver behaviour.

Additional investigations into strategies for reliable VANET applications using the CVIS platform are planned. A middleware service that provides site-specific communication quality predictions based on continuous measurements made by vehicles in the network is one such strategy for which we intend to provide a reference implementation based on the CVIS platform.

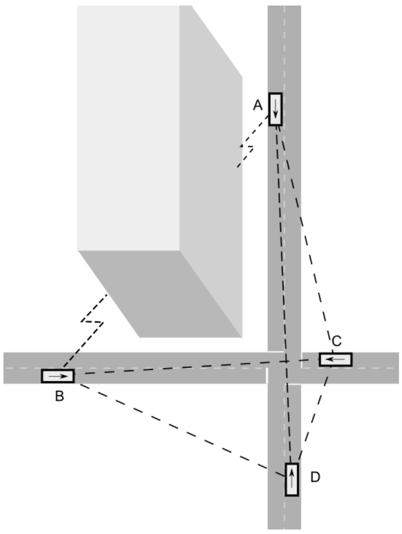

Figure 5. Comparing world-view discrepancies, the link failure between node A and B can be detected.

Medium Access Control

Many traffic safety applications will rely on vehicle *ad hoc* networks (VANET) implying a distributed network with direct communication between vehicles. This means that the VANET does not contain any access points or base stations regulating the data traffic. Currently, there is only one standard supporting communication in a VANET, namely the upcoming IEEE 802.11p (to be ratified in June 2010). The MAC scheme used by IEEE 802.11p is based on carrier sense multiple access (CSMA). The 802.11p is one part of the proposed protocol stack from IEEE called wireless access in vehicular environment (WAVE) and it specifies a physical layer and MAC scheme see Fig. 6. The WAVE stack has support for the TCP/IP suite and it has its own network and transport layer protocol called WAVE short message protocol (WSMP). The WAVE stack consists of IEEE 1609.1 (application layer), IEEE 1609.2 (security), IEEE 1609.3 (transport and network), IEEE 1609.4 (channel usage) and IEEE 802.11p (physical and MAC).

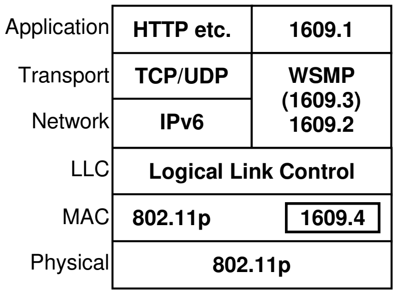

Figure 6. Overview of the WAVE protocol stack proposed by IEEE.

All scenarios described in Section II can use 802.11p, i.e., direct V2X communications. Note that in IEEE 802.11p all nodes are peers rather than one master and several slaves. A RSU can be installed using 802.11p, but the difference between a vehicle and a RSU appears only at the application layer. From the point of view of the MAC layer the RSU behaves like a stationary vehicle. In additions, some traffic safety applications requiring longer range, in the order of several kilometers, will call for other wireless access technologies, such as GSM/UMTS/LTE. In other situations, more than one access technology is needed and it may be necessary to complement the VANET with another wireless access technologies. The focus in the VAS project has, however, been on a VANET using IEEE 802.11p for direct V2X communications.

A VANET must self-organize and provide channel access in a distributed manner with support for all nodes within radio range. Therefore, the MAC procedure must be decentralized to fit the *ad hoc* structure. In addition, the MAC method needs to cope with rapid topology changes, i.e., nodes entering and leaving the network, as well as overloaded situations in terms of increased number of nodes and/or increased amount of data traffic injected without collapsing.

The MAC method CSMA used in IEEE 802.11p is a contention based MAC algorithm designed with reliability in mind and as such does not consider delay aspects. In CSMA, each node initiates a transmission by listening to the channel, i.e., performs a carrier sense operation during a predetermined listening/sensing period. If the sensing is successful, i.e., no channel activity is detected, the node transmits directly. If the channel is occupied or becomes occupied during the sensing period, the node must perform a backoff procedure, i.e., the node has to defer its access a randomized time period. When the network load increases, nodes do not know how long it will take before they are allowed to transmit, i.e., the maximum delay is not known. Due to this traffic safety applications will not be supported satisfactorily since they require timely delivery of data packets to function properly. We have therefore two proposals to overcome the delay problem – one for V2X communications involving changing the MAC layer in the standard and another one that does not require changing the standards, but instead needs a RSU for V2I communications.

In [16] it was shown that nodes using CSMA of 802.11p suffered from unbounded channel access delay and multiple consecutive packet drops when the network load increased. This illustrates that CSMA has problems with predictability and fairness, especially when periodic positioning messages are used. For the V2X scenario we therefore propose to replace the current MAC algorithm with a self-organizing time division multiple access (STDMA) scheme. The benefit of this is that all vehicles, regardless of how many, always are granted access to the channel, i.e., the maximum delay is upper bounded. STDMA is therefore fair and predictable because everyone is granted timely channel access, and these properties remain even during heavily loaded periods. STDMA is in commercial use in the shipping industry in a LDM system called Automatic Identification System (AIS) aiming for collision avoidance among ships. The drawback with STDMA is that the time slotted scheme requires strict synchronization between nodes, through a global navigation satellite system (GNSS). Further, the self-organizing mechanism requires periodic position messages to be present in the system. However, if CAMs are used, the periodic position messages are already in place and the GNSS can be achieved through the GPS.

Instead of replacing the MAC method, we propose to introduce an additional protocol on top of 802.11p providing a deterministic polling-based MAC scheme. This guarantees timely delivery of packets for traffic safety applications – but requires a RSU. The static or semi-static access point on the road side (i.e., RSU) coordinates the vehicles' access to the communication medium by polling them for data according to a schedule based on earliest deadline first (EDF) principle. It is thereby possible to provide real-time support such that the RSU can guarantee collision-free channel access within its transmission range. Part of the bandwidth remains unchanged and best effort services like ongoing V2V applications can continue. We enhance our MAC solution by introducing a prioritization mechanism based on vehicle positions and the overall road traffic density, Fig. 7. This further improves the throughput of both real-time and best effort data traffic by focusing the communication resources to the most hazardous areas of the road infrastructure. The MAC concept (with and without position-based prioritization) is evaluated based on a realistic task set from a V2I merge assistance scenario. We even target connection setup, associating a passing vehicle to an RSU, and handover between widely spaced RSUs. Position data is utilized to proactively forward connection setup information from RSU to RSU. Hereby, a vehicle is already integrated into the communication schedule of our MAC protocol when it arrives at the next RSU, eliminating the handover delays and further supporting the timely delivery of traffic safety application data.

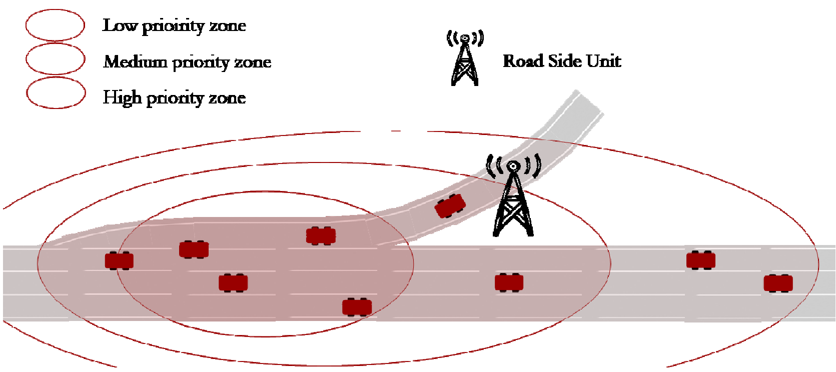

Figure 7. Position-based data traffic prioritization.

This part of the VAS project connects to a related project funded by the Swedish Road Administration (Vägverket), focusing on a vehicle warning system to warn about approaching vehicles on the sparsely trafficked road network based on vehicle-vehicle and vehicle-infrastructure communication.

IV. CVIS Platform

The current version of the CVIS platform has great potential as a research platform since it is largely based on well-known non-proprietary components. The platform, popularized, will contribute in a major way to the development of VANET systems also outside the CVIS project since it will provide a common frame of reference, enabling experiment reproducibility. It is our view that a community-based approach is necessary to enable widespread adoption and uptake of the CVIS application development platform. Additionally, the platform is not only a good research tool within disparate research groups, but can also act as a common denominator for ensuring that systems and solutions developed in different institutions are compatible. The potential for the platform to be used in events such as the Grand Cooperative Driving Challenge (GCDC) organised by the Dutch organisation TNO is thus also great.

The VAS project developed an application on the platform to act as a demonstrator of the research carried out within the project. The *pedestrian crossing warning* scenario in Fig. 3 served as a staring point. The application was demonstrated during the World Congress on ITS in Stockholm, September 2009, where it at the same time was a finalist in the CVIS application innovation contest and ended up being chosen as the winning application by congress delegates.

V. Conclusions and Outlook

The last years have been very exciting due to the frantic activity all around the world within cooperative systems. The VAS project was launched in December 2005 and its results have already received much attention. The CVIS platform will be used for future research at Halmstad University, e.g., for more application development as well as real life measurements. The work started around the MAC scheme of 802.11p will be subject to further research and the collaborations with ETSI TC ITS will continue.

We have identified three topics of particular importance for the deployment of cooperative systems:

Sensor Fusion for Congestion Control: The control loop that is using the communicated data consists of four steps: observation, evaluation, decision and action. The received data typically corresponds to an observation. However, the communicated messages could either be raw data (observation) or some level of refined data (evaluation) or even the actual action of another vehicle. The latter is likely to require a *higher penetration rate* such that decisions are made based on the same information. However, transmitting processed data is likely to required *less bandwidth*. Therefore, when penetration increases, more and more processed data could be transmitted to compensate for the increase in required collective bandwidth.

Autonomy versus Reliability: An issue that greatly influences the communication requirements of traffic safety applications is the selected level of autonomy. The more reliable the communication system is, the higher autonomy can be given to the application, i.e., "Inform – Warn – Advice – Guide – Steer". *If the reliability is too low for some types of road scenarios, the level of autonomy could be temporarily reduced*, e.g., from guide and advice to warn and inform.

Performance Measures: The communicator requirements of traffic safety applications differ notably from those of most existing applications relying on wireless communications. Therefore, *existing performance measures need to be redefined* to suite the new communication requirements. For example, data collisions and throughput are often not relevant and further not easily defined in a broadcast vehicular *ad hoc* network. The throughput instead depends on which and how many nodes that needs to receive the message in the first place. Therefore, deadline miss ratio and number of consecutive packet losses may be more relevant performance measures.

Traffic safety applications using vehicular networks thus need to be designed and evaluated by application software developers and communication experts jointly, not only when defining the communication requirements, but also when implementing, evaluating and using the vehicular networks since the communicator requirements differ notably from those of most existing applications relying on wireless communications.

Publications Produced within the Project

[1] VAS project homepage: http://ceres.hh.se/vas

[2] I. Khalil and M. Morsi, *Collaborating Vehicles for In-creased Traffic Safety*, Master's Thesis, Technical Report IDE0617, Halmstad University, Jan. 2006.

[3] Z. Iqbal, *Self-Organizing Wireless Sensor Networks for Inter-Vehicle Communication*, Master's Thesis, Halmstad University, Technical Report, IDE0635, Mar. 2006.

[4] P. Lerchbaumer and A. Ochoa, *Test Environment Design for Wireless Vehicle Communications*, Master's Thesis, Technical Report IDE0710, Halmstad University, Jan. 2007.

[5] K. Bilstrup, "A survey regarding wireless communication standards intended for a high-speed vehicle environment," Technical Report IDE0712, Halmstad University, Sweden, February 2007.

[6] A. Böhm, "State-of-the-art on network layer aspects for inter-vehicle communication," Technical Report IDE0748, Halmstad University, Sweden, June 2007.

[7] K. Lidström, T. Larsson and L. Strandén, "Safety consideration for cooperating vehicles using wireless communication," in *Proc. of the 5th IEEE Int. Conf. on Industrial Informatics*, Vienna, Austria, July 2007.

[8] P. Lerchbaumer, A. Ochoa, and E. Uhlemann, "Test environment design for wireless vehicle communications," in *Proc. of the 66th IEEE Vehicular technology Conference*, Baltimore, MD, Sept. 2007, pp. 2214-2218.

[9] K. Bilstrup, E. Uhlemann, E. Ström, and U. Bilstrup, "Medium access control schemes intended for vehicle communication," presented at *3rd COST2100 Meeting*, TD(07)369, Duisburg, Germany, Sept. 2007.

[10] K. Lidström and T. Larsson, "Cooperative communication disturbance detection in vehicle safety systems," *Proc. 10th IEEE International. Conf. on Intelligent Transportation Systems (ITSC'07)*, Seattle, Washington, USA, Sept. 2007, pp. 522-527.

[11] K. Bilstrup, A. Böhm, K. Lidström, M. Jonsson, T. Larsson, L. Strandén, and H. Zakizadeh, "Vehicle alert system," in *Proc. of the 14th World Congress on Intelligent Transport Systems (ITS)*, Beijing, China, Oct. 2007.

[12] K. Bilstrup, "Vehicular Communication Standards," invited speaker to the annual *Telematics Valley Conference*, Göteborg, Sweden, Nov. 2007.

[13] E. Uhlemann "Samverkande Fordon" seminar serie Fordonselektronik i Västsverige, Lindholmen Science Park, November 2007. Arranged by Volvo Cars, Volvo 3P, Mecel, QRtech, and LSP.

[14] A. Böhm and M. Jonsson, "Position-Based Forwarding Techniques for Vehicular Ad-Hoc Networks", *Proc. of the 5th Swedish National Computer Networking Workshop (SNCNW)*, Karlskrona, Sweden, April 2008.

[15] K. Lidström "Cooperative Safety Based on Shared Conventions", YEAR Competition, Safety Pillar, at the *2nd European Road Transport Reseach Arena (TRA 2008)*, Ljubljana, Slovenia, April 21-24, 2008.

[16] K. Bilstrup, E. Uhlemann, E. G. Ström and U. Bilstrup, "Evaluation of the IEEE 802.11p MAC method for vehicle-to-vehicle communication," in *Proc. of the 67th IEEE Vehicular Technology Conference*, Calgary, Canada, Sept. 2008, pp. 1-5.

[17] A. Böhm and M. Jonsson, “Supporting real-time data traffic in safety-critical vehicle-to-infrastructure communication,” in *Proc. IEEE Conf. on Local Computer Networks*, Montreal, Canada, Oct. 2008.

[18] K. Lidström and T. Larsson, "Model-based Estimation of Driver Intentions Using Particle Filtering", in *Proc. IEEE Conference on Intelligent Transportation Systems (ITSC 08)*, Beijing, China, Oct. 2008.

[19] K. Bilstrup, E. Uhlemann and E. G. Ström, “Medium access control in vehicular networks based on the upcoming IEEE 802.11p standard,” in *Proc. of the 15th World Congress on Intelligent Transport Systems (ITS)*, New York, NY, Nov. 2008.

[20] A. Böhm and M. Jonsson, “Real-time communication in infrastructurebased safety-critical information exchange,” in *Proc. of the 15th World Congress on Intelligent Transport System*, New York, US, Nov. 2008.

[21] M. Morsi Mahmod, I. Khalil, and E. Uhlemann, “Wireless strategies for future and emerging ITS applications,” in *Proc. of the 15th World Congress on Intelligent Transport Systems (ITS)*, New York, NY, Nov. 2008.

[22] L. Strandén, E. Uhlemann and E. G. Ström, “State-of-the-art survey of wireless communication vehicle projects,” in *Proc. of the 15th World Congress on Intelligent Transport Systems (ITS)*, New York, NY, Nov. 2008.

[23] K. Bilstrup, E. Uhlemann, E.G. Ström and U. Bilstrup, “On the ability of the 802.11p MAC method and STDMA to support real-time vehicle-to-vehicle communication,” in *EURASIP Journal on Wireless Communications and Networking*, vol. 2009, Article ID 902414, 13 pages, 2009, doi: 10.1155/2009/902414.

[24] K. Bilstrup, "Vehicular communication standards - DSRC, CALM M5, WAVE and 802.11p," presented at a SAFER Seminar, Gothenburg, Sweden, January 2009.

[25] E. Uhlemann “Communication Requirements for Traffic Safety Applications” presented as part of a *SAFER seminar on Wireless Communications for Traffic Safety*, Lindholmen Science Park, Jan. 2009.

[26] E. Uhlemann and K. Bilstrup “Predictable medium access control in vehicular ad hoc networks”, invited talk at the ETSI TC ITS WG4 standardization meeting, Sophia Antipolis, France, Jan. 2009.

[27] K. Bilstrup, E. Uhlemann, E. G. Ström and U. Bilstrup, “Does the 802.11p MAC method provide predictable support for low delay communications?,” presented at the *1st ETSI TC ITS Workshop*, Sophia Antipolis, France, Feb 2009.

[28] A. Böhm and M. Jonsson, “Handover in 802.11 based delay sensitive vehicle-to-infrastructure communication,” Technical Report IDE0924, Halmstad University, Sweden, March 2009.

[29] E. Uhlemann, “Cooperating Vehicles for Increased Traffic Safety”, invited speaker as part of Master’s course *Seminars in Wireless Systems*, Royal Institute of Technology, Stockholm, Sweden, March 2009.

[30] K. Lidström, *On Strategies for Reliable Traffic Safety Services in Vehicular Networks*, Licentiate thesis, Halmstad University, Apr. 2009.

[31] A. Böhm, *Real-Time Communication Support for Cooperative Traffic Safety Applications*, Licentiate thesis, Halmstad University, May 2009.

[32] K. Bilstrup, E. Uhlemann, E. G. Ström and U. Bilstrup, “IEEE 802.11p and its ability to support a predictable channel assess,” in *Proc. of the 16th World Congress on Intelligent Transport Systems (ITS)*, Stockholm, Sweden, Sept. 2009.

[33] K. Lidström and T. Larsson, "Act normal: using uncertainty about driver intentions as a warning criterion", in *Proc.16th World Congress on Intelligent Transport System (ITS)*, Stockholm, Sweden, Sept. 2009.

[34] E. Uhlemann and N. Nygren, “Cooperative systems for traffic safety: Will existing wireless access technologies meet the communications requirements?,” in *Proc. 16th World Congress on Intelligent Transport Systems (ITS)*, Stockholm, Sweden, Sept. 2009.

[35] K. Sjöberg Bilstrup, E. Uhlemann, and E. Ström, "Performance of IEEE 802.11p and STDMA for vehicular cooperative awareness applications," presented at *9th COST2100 Meeting* , TD(09)938, Vienna, Austria, Sept. 2009.

[36] E. Uhlemann, ”Bilar som pratar med varandra gör trafiken säkrare” in the TV-program *Vetenskapslandet* on the channel *Kunskapskanalen*, September 20, 2009 at 20.30. Available at YouTube: http://www.youtube.com/watch?v=Nk6uFtb2Nms

[37] K. Sjöberg Bilstrup, *Predictable and Scalable Medium Access Control in Vehicular Ad Hoc Networks*, thesis to be presented for the degree of licentiate, Chalmers University of Technology, Dec. 16, 2009.