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Workshop Report: Wireless Vehicular Communications

On 20 November 2013, the IEEE Vehicular Technology Society sponsored a workshop on wireless vehicular communications organized by the Centre for Research on Embedded Systems at Halmstad University in Sweden. It attracted some 45 participants both from industry and academia. The workshop featured an invited speaker, Prof. Falko Dressler from the University of Innsbruck, Austria, and presentations by researchers from Lund University, Chalmers University of Technology, the Vienna University of Technology, Volvo Group Trucks Technology (GTT), and Halmstad University in Sweden—all on the topic of wireless vehicular communications.

Workshop Contents

The workshop started with a presentation given by the invited speaker Falko Dressler from the University of Innsbruck, Austria, "Supporting Safety at Intersections and in Road Trains: Protocol Engineering for IVC" (Figure 1). In his talk, the need for a new generation of IVC protocols was discussed. With the standardization of the IEEE Wireless Access in Vehicular Environments protocol stack, the vehicular networking community has converged to a common understanding of data dissemination schemes, which already have high potentials

FIGURE 1 Falko Dressler from the University of Innsbruck, was the invited speaker with his talk "Supporting Safety at Intersections and in Road Trains: Protocol Engineering for IVC." (Photo courtesy of Falko Dressler.)

for many applications. Yet, vehicular networks are much more dynamic than originally considered. Radio signal fading and shadowing effects need to be considered in the entire design process, as well as the strong need for low-latency communication, fairness, and robustness. In the main part of the talk, examples and basic building blocks for such a new IVC protocol were presented. Starting with the adaptive traffic beacon (ATB) approach, which supports the exchange of delay-sensitive traffic information in a wide range of scenarios, several concepts that help in designing fully decentralized congestion-aware protocols were discussed. ATB has been designed to be adaptive in two dimensions: first, the beacon interval is adapted dynamically to the network load, and second, the protocol can dynamically make use of available infrastructure elements. This concept has now been taken over by the European Telecommunications Standards Institute standardization, where the new approach is

FIGURE 2 Falko Dressler highlighted the benefits and drawbacks of DCC for platooning applications. (Photo courtesy of Falko Dressler.)

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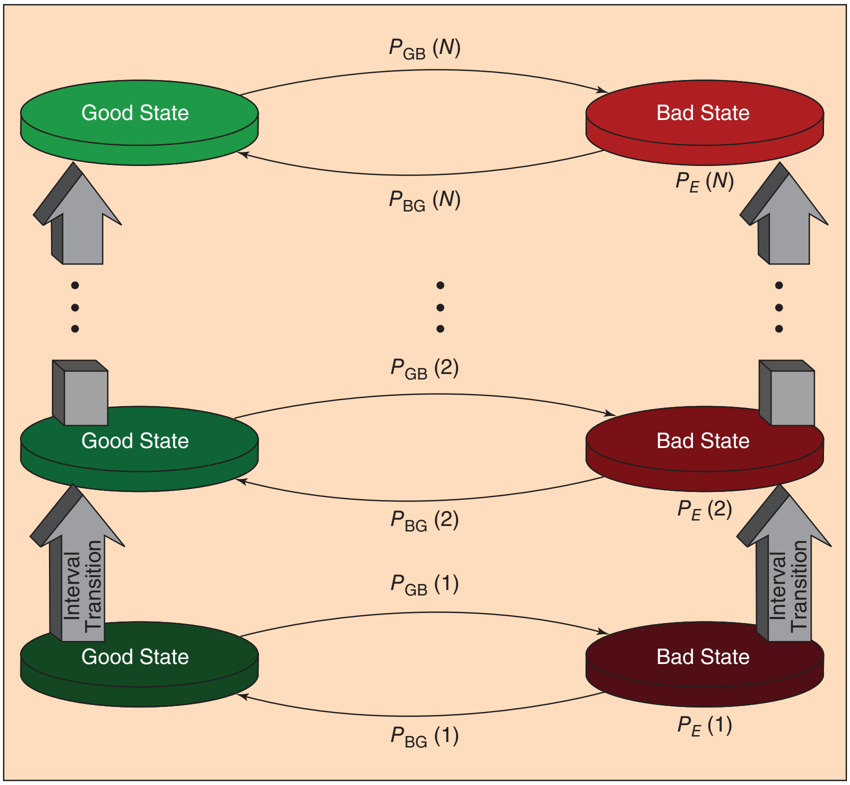

FIGURE 3 A schematic representation of the range-dependent modified Gilbert model. (Image courtesy of Veronika Shivaldova.)

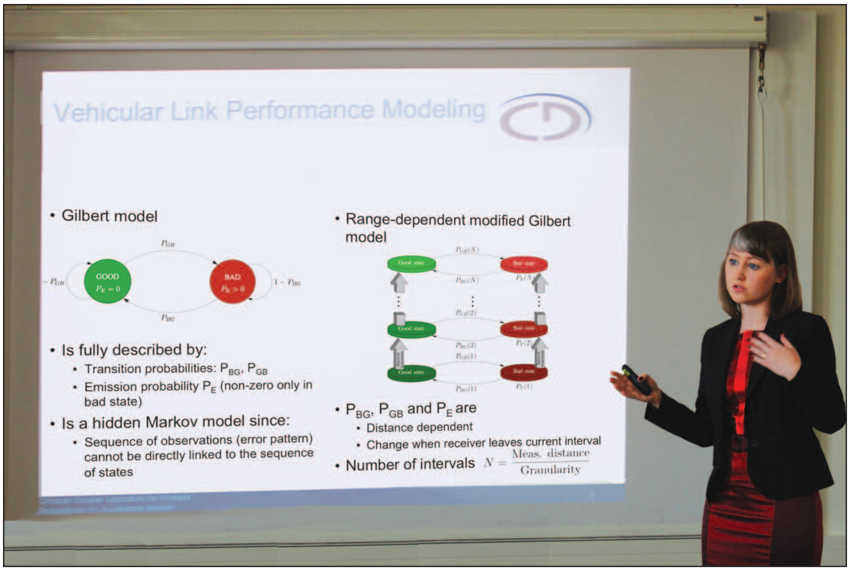

FIGURE 4 Veronika Shivaldova introduced a hidden Markov model-based concept for statistical modeling of vehicular link performance. (Photo courtesy of Veronika Shivaldova.)

called *decentralized congestion control* (*DCC*). Putting two application examples into the focus of the discussion, namely intersection warning systems and platooning, it was noted that careful congestion control might be counterproductive for hard safety applications (Figure 2). The discussion was finished off by suggesting possible solutions based on the new and way more aggressively reacting dynamic beacon approach. This concept considers the dynamics caused through signal shadowing by buildings and other vehicles. The optimization goal is again to make full use of the wireless channel but prevent overload situations, i.e., collisions that reduce the performance of the transmissions.

FIGURE 5 Erik Ström explored the pros and cons of using a larger channel spacing than 10 MHz for V2X communication based on the IEEE 802.11 OFDM physical layer. (Photo courtesy of Elisabeth Uhlemann.)

Veronika Shivaldova from the Vienna University of Technology gave a presentation on "Statistical Modeling of Vehicular Link Performance." Link performance models are designed to provide an accurate, but not too complex, physical layer representation for system- and link-level simulators. In this context, a range-dependent modified Gilbert model for generating realistic error patterns for various vehicular environments was proposed. This model is an extension of a simple two-state hidden Markov model introduced by Gilbert. As shown in Figure 3, the model is fully described by only three parameters: the transition probability from the bad state to the good state, P_{BG}, the transition probability from the good state to the bad state, P_{GB}, and the probability of an error P_E in the bad state. However, the parameters of the model are distance dependent and change as soon as a vehicle leaves a certain distance segment. In conclusion, Shivaldova emphasized the influence of various modeling aspects and elaborated on the potential applications of statistical performance models in the

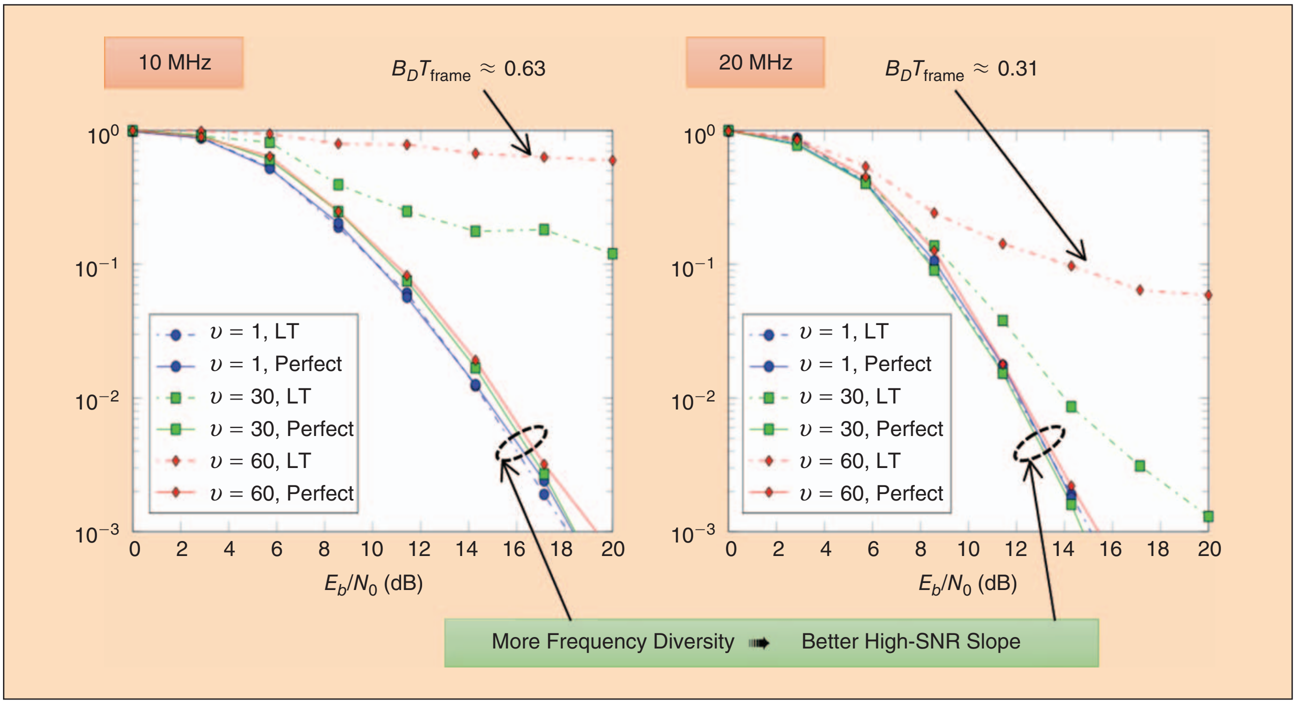

FIGURE 6 Erik Ström presented computer simulations indicating that a 20-MHz V2X system will outperform a 10-MHz V2X system. (Image courtesy of Erik Ström.)

context of intelligent transportation system simulators (Figure 4).

Next, Erik Ström from Chalmers University of Technology gave a talk "On 20-MHz Channel Spacing for V2X Communication Based on 802.11 OFDM." In his talk, Ström explored the pros and cons of using a channel spacing larger than 10 MHz for vehicle-to-infrastructure (V2X) communication based on the IEEE 802.11 orthogonal frequency-division multiplexing (OFDM) physical layer (Figure 5). The main advantage of shifting to 20-MHz channel spacing is reduced congestion, which will reduce, or even eliminate, the need for congestion control algorithms. He showed that the basic OFDM design rules are indeed satisfied for 20-MHz

FIGURE 7 Fredrik Tufvesson presented a solution that can be used to motivate the early adopters to install a V2V communication system even when there are no other vehicles to communicate with. (Photo courtesy of Fredrik Tufvesson.)

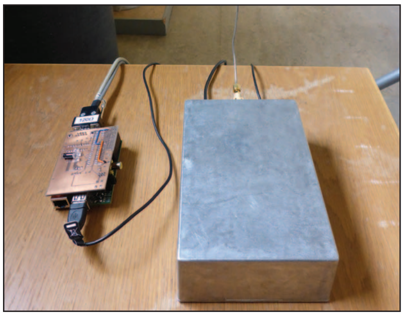

FIGURE 8 Researchers from Lund University have designed a device that monitors and positions oncoming traffic in an intersection. (Photo courtesy of Dimitrios Vlastaras.)

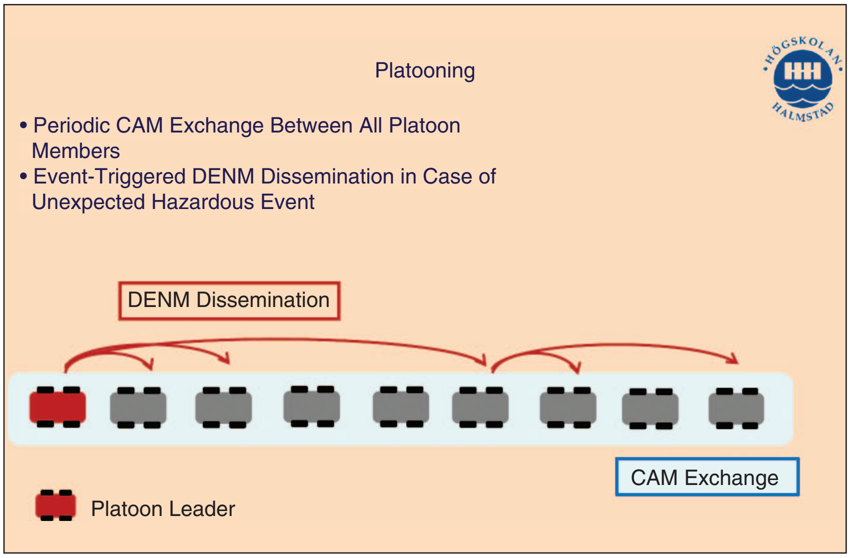

FIGURE 9 Vehicle platooning puts high requirements on the exchange of periodic status updates and the dissemination of event-based warning messages. (Image courtesy of Annette Böhm.)

FIGURE 10 Annette Böhm discussed the requirements on the medium-access control layer imposed by platooning applications. (Photo courtesy of Tony Maunsell.)

FIGURE 12 Erik Nordin presented the European Union-funded project Safe Road Trains for the Environment (SARTRE) where Volvo was implementing a prototype platooning system. (Photo courtesy of the SARTRE project http://www.sartre-project.eu/.)

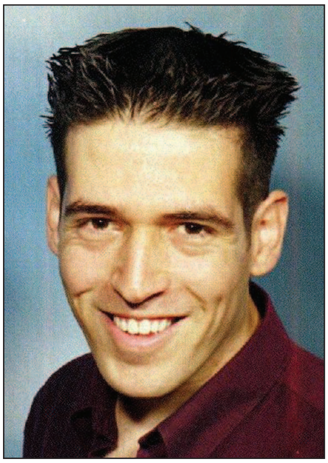

FIGURE 11 Elad Michael Schiller from Chalmers University of Technology presented a self-stabilizing TDMA algorithm for wireless ad-hoc networks, which works even without external references. (Photo courtesy of Elad Michael Schiller.)

channel spacing as well and presented computer simulations indicating that a 20-MHz system will outperform a 10-MHz system (Figure 6).

Fredrik Tufvesson from Lund University gave a talk titled "Universal Medium Range Radar and IEEE 802.11p Modem Solution for Integrated Traffic Safety" (Figure 7), describing a test platform to solve the chicken-and-egg problem in vehicle-to-vehicle (V2V) communication: how can we motivate the early adopters to install a V2V communication system when there are no other vehicles to communicate with? The researchers from Lund University have designed a device that monitors and positions oncoming traffic in an intersection (Figure 8). If the device notices that the oncoming vehicles did not transmit position messages, it does so on their behalf, pretending that the messages came from the respective vehicles themselves. The system has been tested with successful results and could easily be deployed in a few critical intersections in a city to motivate early adopters and provide increased safety for, e.g., emergency vehicles.

Following this, Annette Böhm from Halmstad University addressed the topic of "Medium Access Control for Delay-Sensitive Platooning Applications." Platooning of trucks is an emerging research topic, as it has been shown that keeping a minimum intervehicle distance results in considerably reduced fuel consumption. This, however, puts high requirements on the timeliness and reliability of the underlying exchange of control messages between platoon members, i.e., the exchange of periodic status updates and the dissemination of event-based warning messages (Figure 9). The recently adopted European profile of IEEE 802.11p employs a random medium-access protocol over a common control channel, which may result in excessive delays during high network loads. In her talk, Böhm compared the performance of standard compliant interplatoon communication to a proposal that instead uses a dedicated service channel for platooning applications (Figure 10). Service channels typically have less strict requirements on send rates, data traffic types, and medium-access methods. The proposed service channel solution is therefore able to combine a random-access phase with a centralized, scheduled access phase. This enables timely channel access for periodic control messages between neighboring platoon members while still providing reasonable dissemination delays for warning messages throughout the platoon.

Next, Elad Michael Schiller from Chalmers University of Technology presented a self-stabilizing time division multiple access (TDMA) algorithm for wireless ad-hoc networks without external references such as a global positioning system (Figure 11). TDMA is a method for sharing communication media. In wireless communications, TDMA algorithms often divide the radio time into time slots of uniform size, ξ, and combine them into frames of uniform size, τ. Elad Michael Schiller considered TDMA algorithms that allocate at least one timeslot in every frame to every node. Given a maximal node degree, δ, and no access to external references for collision detection, time, or position, he considered the problem of collision-free self-stabilizing TDMA algorithms that use a constant frame size. His work demonstrates that this problem has no solution when the frame size is $\tau < \max\{2\delta, \chi_2\}$, where χ_2 is the chromatic number for distance-2 vertex coloring. As a complement to this lower bound, he focused on proving the existence of collision-free, self-stabilizing TDMA algorithms that use a constant frame size of τ. He considered basic settings (no hardware support for collision detection and no prior clock synchronization) and the collision of concurrent transmissions from transmitters that are at most two hops apart. He and his coauthors use simulations to show convergence even with computation time uncertainties.

Finally, Erik Nordin from Volvo GTT gave a talk titled: "Platooning Using IEEE 802.11p." Platooning, or road trains, has great potential for improving safety and energy efficiency in road traffic. Complementary to in-vehicle sensors, e.g., radars and cameras, short-range communication is a core technology for enabling platooning. Erik presented the European Union-funded project SARTRE where Volvo was implementing a prototype platooning system (Figure 12).

Presentations

- Falko Dressler, University of Innsbruck, Austria, "Supporting Safety at Intersections and in Road Trains: Protocol Engineering for IVC."
- Veronika Shivaldova, Vienna University of Technology, "Statistical Modeling of Vehicular Link Performance."
- Erik Ström, Chalmers University of Technology, "On 20 MHz Channel Spacing for V2X Communication Based on 802.11 OFDM."
- Fredrik Tufvesson, Lund University, "Universal Medium Range Radar and IEEE 802.11p Modem Solution for Integrated Traffic Safety."
- Annette Böhm, Halmstad University, "Medium Access Control for Delay-Sensitive Platooning Applications."
- Elad Schiller, Chalmers University of Technology, "Self-Stabilizing TDMA Algorithms for Timeslot Assignment and Alignment in Wireless Ad-hoc Networks Without External Reference."
- Erik Nordin, Volvo GTT, "Platooning Using IEEE 802.11p."

The presentations are available at http://www.hh.se/wwvc2013.

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