Advances in Vehicular Communications Networks

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Vehicular communications are being applied to improve safety, decrease fuel consumption, and increase the capacity of existing roadways. Both vehicle-to-vehicle and vehicle-to-infrastructure communications are used to implement a number of promising applications such as local hazard warning, efficient route planning, and coordination of traffic flows. Even truly cooperative and therefore extremely challenging applications like cross traffic collision avoidance are being considered.

In the last years a number of intelligent transportation system (ITS) related projects and initiatives have been carried out (or will be completed soon). In Europe, for example, the European Commission initiated the Intelligent Car Initiative in February 2006, aimed at reducing car accidents and traffic congestion. These research and development (R&D) projects have created a solid technical basis for vehicular communications, and some of them have also provided preliminary experiences, from which some important results have been obtained ("lessons learned"), such as the Vehicle Infrastructure Integration (VII) in the United States as well as several projects in Europe.

All the aforementioned research efforts and initiatives can be considered "phase 1" in the development of vehicular communications networks. This phase represents an initial and very important step toward the goals of improving road safety and traffic efficiency, and providing Internet services to vehicles. Important achievements, architectural decisions, and conclusions have been the outcome of this phase 1, such as the development of wireless physical and medium access control (MAC) protocols suited for the vehicular environment (e.g., IEEE 802.11p), new network architectures (some of them not based on classical TCP/IP), and so on.

We are now witnessing phase 2 of R&D in vehicular communications networks, a new phase in which the refinement and extension of the network architectures and protocols defined in phase 1 will play a key role. This special issue is intended to present some research developments and efforts of this new phase in the vehicular communications area. In response to the open call, we were pleased to receive 32 submissions from which five articles were accepted for this issue. The large number of submissions is a proof of the high level of interest in advanced topics in vehicular communications.

The first four articles in this Special Issue deal with the refinement of several different important mechanisms (one-hop and multihop broadcast, beaconing, and secure data aggregation) in vehicular communication protocols, with the aim of controlling and reducing the overall network offered load, while guaranteeing a good level of accuracy, efficiency, and security. These refinements are needed in order to enable feasible and practical deployments, and therefore are considered phase 2 research efforts.

Reducing the network load offered by one-hop broadcast communications is a critical issue in vehicular communications due to the trade-off between required bandwidth and accuracy of cooperative awareness. The first article, "Adaptive Intervehicle Communication Control for Cooperative Safety Systems" by Huang *et al.*, proposes a protocol to control the load offered to the wireless channel by the expected periodic self-information broadcast messages. This novel approach adapts both rate and power (instead of just only one) to reduce the tracking error in congested scenarios. The robustness of the protocol in homogeneous highway scenarios is evaluated via simulations, studying the tracking accuracy of neighboring vehicles.

In the second article, "Exploration of Adaptive Beaconing for Efficient Intervehicle Safety Communication," Schmidt *et al.* consider the problem of beaconing in vehicular networks. Based on a review of the issues of existing solutions, they propose an adaptive approach, in which the load offered to the network is controlled by adjusting the beacon rate. The authors analyze the effects of the different proposed adaptation schemes, in terms of accuracy reduction and offered network load, and propose to combine them to achieve better performance.

Broadcast communications are often not limited to the one-hop coverage area of the sender. Information flooding within a region of a vehicular network exacerbates the problems of broadcast communications. The third article, "Broadcasting Safety Information in Vehicular Networks: Issues and Approaches" by Chen, Jin, and Regan, reviews the role of broadcasting in vehicular networks, and provides some design considerations to achieve high broadcast reliability and efficiency in dense scenarios. The authors also provide a complete survey of existing broadcast protocols, classified according to several criteria, such as their communication methods and the network simulation environment used to validate them.

The fourth article, "Resilient Secure Aggregation for Vehicular Networks" by Dietzel *et al.*, addresses the problem of data aggregation as a solution to provide scalability in vehicular networks. Novel security mechanisms — based on selective attestation and trust fusion — to protect data aggregation techniques are proposed and evaluated through simulation. Results show that the proposed techniques are effective to protect against under concealment attacks and efficient — in terms of bandwidth overhead — compared to the use of no aggregation.

The use of heterogeneous access technologies in vehicular environments would enable new and richer communication opportunities; hence, it is also a phase 2 research topic. In particular, the use of second-/third-generation (2G/3G) cellular systems for vehicular communications is being considered as a backup for data communication among vehicles, as well as a supporting tool to improve the performance and reliability of vehicular ad hoc protocols. In the last article, "Improvement of Vehicular Communications by Using 3G Capabilities to Disseminate Control Information," Lequerica, Ruiz, and Cabrera propose a system architecture, called VISIONS, that makes use of the 3G network to disseminate control information. The control information helps routing protocols improve their route selections. Simulation is used to show the improvement of different VANET routing protocols when VISIONS is enabled, as well as to evaluate the overhead introduced in the 3G network.

Finally, we would like to thank all the authors who submitted their research to this Special Issue. As Guest Editors, we thank all the peer reviewers for their time and wonderful job, which has definitely helped to improve the quality and readability of this issue. We are also grateful to Editor-in-Chief Thomas Chen for his continuous and prompt support in the development of this Special Issue. Last but not least, we hope that all readers find the articles accepted in this issue informative, interesting, and useful.

Biographies

CARLOS J. BERNARDOS (cjbc@it.uc3m.es) received a telecommunication engineering degree in 2003 and a Ph.D. in telematics in 2006, both from the University Carlos III of Madrid, where he worked as a research and teaching assistant from 2003 to 2008, and since then as an associate professor. His Ph.D. thesis focused on route optimization for mobile networks in IPv6 heterogeneous environments. His current work focuses on vehicular networks and IP-based mobile communication protocols. He has published over 30 scientific papers in prestigious international journals and conferences, and he is also an active contributor to the Internet Engineering Task Force (IETF). He served as TPC chair of WEEDEV 2009.

ANDREAS FESTAG (Andreas.Festag@nw.neclab.eu) is a senior researcher at NEC Laboratories Europe, Heidelberg, Germany, and leads a research team on vehicular communication. He received a diploma thesis in 1996 and a Dr.-Ing. in electrical engineering from the Technical University of Berlin, Germany, in 2003. Before joining NEC Laboratories he worked as a research assistant at the Telecommunication Networks Group of the Technical University of Berlin and the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute. He has been active in various national and international research projects in the area of wireless and mobile communication networks. He contributies to the CAR-2-CAR Communication Consortium and standardization efforts in ETSI Technical Committee ITS. Currently, he serves as Chairman of ETSI TC ITS WG3 (Networking and Transport).

NICHOLAS F. MAXEMCHUK [F'89] (nick@ee.columbia.edu) received his B.S.E.E. degree from the City College of New York, and M.S.E.E. and Ph.D. degrees from the University of Pennsylvania. For the past five years he has been a professor in the Electrical Engineering Department at Columbia University. Prior to joining Columbia he spent 25 years at Bell Labs and AT&T Labs as a member of technical staff, department head, and technical leader. Prior to joining Bell Labs, he spent eight years at the RCA David Sarnoff Research Center as a member of technical staff. He has been Editor-in-Chief of *IEEE JSAC*, an Editor for *IEEE Transactions on Communications* and the *Journal of the ACM*, was on the founding committee of *IEEE/ACM Transactions on Networking*, and served on their steering committee for 11 years. In 2006 he received the Koji Kobayashi Award for his work in computer communications. He was also awarded the IEEE's Leonard G. Abraham Prize Paper Award in 1985 and 1987 for his papers on data and voice on CATV networks and the Manhattan Street Network, and the William R. Bennett Prize Paper Award in 1997 for his paper on an anonymous credit card.

CAROLINA PINART (cpg@tid.es) is a graduate and Ph.D. in telecommunications engineering of the Universitat Politècnica de Catalunya (April 1999 and December 2005, respectively). Since December 2009 she is a senior manager in the New Business and Innovation Unit of the Telefónica Corporation, Madrid, Spain. From 2007 to 2009 she served as head of Telefónica I+D's Networked Vehicles Division. From 2001 to 2007 she was director of Institutional Relations of the Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Barcelona, Spain. Previously, she worked in the telco and automotive sectors for Siemens Munich, Germany, 1998–1999, and Altran, Paris, France, 1999–2001. She has over 50 publications in journals and conferences. She received a Post-Graduate Prize from the Fundació Agrupació Mútua (2003), a Best Ph.D. Dissertation Prize from the Spanish Association of Telecom Engineers (2006), and a postdoctoral fellowship from the Japan Society for the Promotion of Science (2006).

CHRISTIAN WEIß (christian.a.weiss@daimler.com) received Dipl.-Ing. and Ph.D./Dr.-Ing. degrees in electrical engineering and information technology in 1995 and 2001, respectively, both from Munich University of Technology (TUM). In 1996 he worked for Siemens Ltd., Seoul, Korea, in telecommunication networks. From 1997 until 2002 he was a member of the research and teaching staff at the Institute for Communications Engineering of TUM. After completing his doctoral studies he started his industry career at DaimlerChryser AG, where he initially worked in telematics research and development. Since 2006 he is the manager of the Vehicle-Centric Communication team that covers all aspects of car-to-car and car-to-infrastructure communication. He is also the coordinator of the German field operational test simTD. He held a scholarship from the Heinz-Nixdorf Foundation in 1996. His dissertation received the Texas Instruments Award in 2002, and his paper "On Dualizing Trellis-Based APP Decoding Algorithms" was awarded the ITG Award 2003.