

TOPICS IN AUTOMOTIVE NETWORKING AND APPLICATIONS



Wai Chen

Luca Delgrossi

Timo Kosch

Tadao Saito

In this 11th issue of the Automotive Networking and Applications Series, we are pleased to present two survey articles on Long Term Evolution (LTE) for vehicular networking and multichannel communications in vehicular ad hoc networks (VANETs), respectively.

Cooperative vehicular systems are envisioned to improve active road safety, traffic efficiency, and infotainment through timely and reliable information exchanges among vehicles and between vehicles with infrastructures. There is emerging consensus that heterogeneous networking technologies may be leveraged in complex vehicular environments to facilitate the deployment of cooperative vehicular systems. The first article, “LTE for Vehicular Networking: A Survey” by G. Araniti *et al.*, scans related work on the usability of LTE to support vehicular applications, and discusses the strengths and weaknesses of using the LTE access technology for vehicular communications. The authors review the vehicular applications, with a focus on active road safety and traffic efficiency, and the main candidate wireless technologies for on-the-road communications, including a brief overview of the LTE architecture and its main components. The article then discusses the motivations for using LTE in vehicular environments including coverage and mobility, market penetration, and wireless link capacity, as well as the major concerns such as centralized architecture, transport modes, and terminal setup — all with performance implications on vehicular applications. The authors summarize and discuss recent results, in literature and standards groups, concerning the use of LTE in exchanging messages for active road safety and traffic efficiency. The article concludes with an extensive set of lessons learned and discusses open challenges of using LTE in vehicular scenarios.

Multiple channels are available in the allocated spectrum (e.g., by the FCC in the United States and CEPT in Europe) to support road safety services, general-purpose intelligent transportation system (ITS) services, and commercial non-safety infotainment services. The complex nature of the vehicular environments, including the lack of central coordination, fluctuating wireless link quality,

dynamic topology, and intermittent connectivity, makes multichannel operations such as coordination, synchronization, and access very challenging. The second article, “Multichannel Communications in Vehicular Ad Hoc Networks: A Survey” by C. Campolo and A. Molinaro, presents an overview of the multichannel architectural approaches proposed by standards organizations in the United States and Europe. After an overview of the IEEE WAVE and ETSI ITS Station protocol architectures, the authors describe in detail the multichannel operations as specified within ETSI and IEEE WAVE. The article then summarizes major challenges related to multichannel management, and discusses related proposed countermeasures and their trade-offs. The authors conclude with a discussion on main open technical issues related to the use of multiple channels in vehicular networks.

We thank all contributors who submitted manuscripts for this series, as well as all the reviewers who helped with thoughtful and timely reviews. We thank Dr. Sean Moore, Editor-in-Chief, for his support, guidance, and suggestions throughout the process of putting together this issue. We also thank the IEEE publication staff, particularly Ms. Jennifer Porcello, for their assistance and diligence in preparing the issue for publication.

BIOGRAPHIES

WAI CHEN (waichen@ieee.org) received his B.S. degree from Zhejiang University, and M.S., M.Phil., and Ph.D. degrees from Columbia University, New York. While at Telcordia (formerly known as Bellcore), he led a vehicular communications research program over 10 years in collaboration with a major automaker on automotive networking technologies for vehicle safety and information applications. He was Principal Investigator of several government funded projects on advanced networking technologies research. He was the General Co-Chair for the IEEE Vehicular Networking Conference (IEEE VNC 2009–2012) and a Guest Editor for a Special Issue on Vehicular Communications and Networks for the *IEEE Journal on Selected Areas in Communications* (2011). He has also served as a Guest Editor for Special Issue on Intervehicular Communication (IVC) for *IEEE Wireless Communications* (2006), an IEEE Distinguished Lecturer (2004–2006), a Co-Chair for the Vehicle-to-Vehicle Communications Workshop (IEEE V2VCOM 2005–2008) collocated with the IEEE Intelligent Vehicles Symposium, a Co-Chair for the IEEE Workshop on Automotive Networking and Applications (IEEE AutoNet 2006–2008) collocated with IEEE GLOBECOM, and the Vice Chair of the Technical Program Committee for Vehicular Communications of the IEEE Vehicular Technology Conference (IEEE VTC-Spring 2009).

LUCA DELGROSSI is manager of the Vehicle-Centric Communications Group at Mercedes-Benz Research & Development North America Inc., Palo Alto, California. He started as a researcher at the International Computer Science Institute (ICSI) of the University of California at Berkeley and received his Ph.D. in computer science from the Technical University of Berlin, Germany. He served for many years as professor and associate director of the Centre for Research on the Applications of Telematics to Organizations and Society (CRATOS) of the Catholic University at Milan, Italy, where he helped create and manage the Master's in Network Economy (MiNE) program. In the area of vehicle safety communications, he coordinated the Dedicated Short Range Communications (DSRC) Radio and On-Board Equipment work orders to produce the DSRC specifications and build the first prototype DSRC equipment as part of the Vehicle Infrastructure Integration (VII) initiative of the U.S. Department of Transportation. The Mercedes-Benz team in Palo Alto is a recognized leader in the R&D of vehicle-to-infrastructure as well as vehicle-to-vehicle communications safety systems.

TIMO KOSCH works as a team manager for BMW Group Research and Technology where he is responsible for projects on distributed information systems, including such topics as cooperative systems for active safety and automotive IT security. He has been active in a number of national and international research programs and serves as coordinator for the European project COMeSafety, co-financed by the European Commission. He also currently heads the system development for a large German Car2X field test. For more than three years, until recently, he chaired the working group Architecture and was a member of the Technical Committee of the Car-to-Car Communication Consortium. He studied computer science and economics at Darmstadt University of Technology and at the University of

British Columbia in Vancouver with scholarships from the German National Merit Foundation and the German Academic Exchange Service. He received his Ph.D. from the computer science faculty of the Munich University of Technology.

TADAO SAITO [LF] received a Ph. D degree in electronics from the University of Tokyo in 1968. Since then he has been a lecturer, an associate professor, and a professor at the University of Tokyo, where he is now a professor emeritus. Since April 2001 he is chief scientist and CTO of Toyota InfoTechnology Center, where he studies future ubiquitous information services around automobiles. He has worked in a variety of subjects related to digital communication and computer networks. His research includes a variety of communication networks and their social applications such as ITS. Included in his past study, in the 1970s he was a member of the design group of the Tokyo Metropolitan Area Traffic Signal Control System designed to control 7000 intersections under the Tokyo Police Authority. Now he is Chairman of the Ubiquitous Networking Forum of Japan working on a future vision of the information society. He is also Chairman of the Next Generation IP Network Promotion Forum of Japan. He has written two books on electronic circuitry, four books on computers, and two books on digital communication and multimedia. From 1998 to 2002 he was chairman of the Telecommunication Business Committee of the Telecommunication Council of the Japanese government and contributed to regulatory policy of telecommunication business for broadband network deployment in Japan. He is also the Japanese representative to the International Federation of Information Processing General Assembly and Technical Committee 6 (Communication Systems). He is an honorary member and fellow of IEICE of Japan.