

## **T9. Vehicular Ad-Hoc Networks: Technical Challenges, Solutions, and Evaluation Methodologies**

### **Abstract:**

Vehicular ad hoc networks (VANETs) provide connectivity among vehicles on the road and between vehicles and the roadside infrastructure. They are considered as one of the most valuable means for improving road safety and transport efficiency and as an enabler of value-added services for passengers and drivers. Worldwide research projects and initiatives, supported by car manufacturers, automotive and electronic industries, governments and academia, are working on protocols and applications design for VANETs and are running first field trials. Dedicated band in the 5.9 GHz range has been allocated for vehicular communications in US, Europe and Japan. The recently released IEEE 802.11p standard specifies tailored amendments for the vehicular environment of the physical (PHY) and medium access control (MAC) layers of 802.11, while the IEEE 1609 family is currently specifying the upper layers of a lightweight protocol stack for vehicular communications. The unique features of the vehicular environment, such as the quickly changing network topology, the variable node density, the short connection lifetime, the multi-hop vehicle-to-vehicle communication, the hostile radio propagation environment, make the design and deployment of VANETs very challenging and pose several issues which are still unsolved. The tutorial introduces the peculiarities of vehicular environments and briefly describes the IEEE 802.11p and 1609 standards. Then, by critically surveying the main technical solutions for vehicular networks, it provides key findings that serve as guidelines for the PHY layer modeling, the design of effective MAC and routing solutions, and the development of innovative performance analysis tools and methodologies. The main focus of the tutorial is on MAC layer design. MAC solutions based on 802.11p-compliant CSMA (carrier sense multiple access) approaches well handle vehicle mobility and dynamic topologies, but they hardly ensure successful and time-bounded data delivery. On the other hand, synchronous solutions based on TDMA (time division multiple access) ensure relatively good quality of service (QoS) at the expenses of low scalability and more complex synchronization. Synchronous MAC protocols for VANETs constitute a hot topic, particularly in Europe, where synchronous VANETs are studied within ETSI (STF395). Notably one of the tutors participates in STF395, being recognized as an expert on synchronous MAC for VANETs.

Probably none of the aforementioned approaches can be claimed to be able to simultaneously cope with the challenging and conflicting issues of scalability, reliability, QoS, and simplicity in VANETs. Solutions leveraging on the adaptability of MAC/PHY parameters (e.g., priority, contention window, data rate, transmission power) and hybrid MAC approaches, combining the benefits of both deterministic and contention-based channel access solutions, which behave adaptively to applications requirements, traffic load and interference on the channel, vehicular topology and speeds, have recently pursued and appear as the most promising candidate solutions to cope with the shortcomings mentioned above.

Methodologies and tools for VANET performance evaluation are also subject of the tutorial. Experience will be shared about preliminary real-world implementations, simulation tools (network, channel, mobility modeling) aimed to improve the realism of performance evaluation, and about analytical models helping in taking wiser decisions on the adoption, adaptation, and improvement of the upcoming standards and alternative solutions.

### **Speaker's Biography:**

**Claudia Campolo, University Mediterranea, Reggio Calabria, Italy**  
**Antonella Molinaro, University Mediterranea, Reggio Calabria, Italy**  
**Riccardo Scopigno, Istituto Superiore Mario Boella, Torino, Italy**

**Claudia Campolo** received a Laurea degree in Telecommunications Engineering (Oct. 2007) and a PhD degree (Feb. 2011) from the University Mediterranea of Reggio Calabria, Italy. Since March 2011 she has been with the same university as a Post-doc researcher. She was a visiting PhD student at the Department of Electronics Engineering of Politecnico di Torino (from May to Oct. 2008). Her main research interests are in the field of vehicular and cooperative networking. In the past three years she has published about 15 papers in prestigious journals (Ad Hoc Networks, IEEE Communications Letters), leading IEEE conferences (VNC 2009, GLOBECOM 2010, WCNC 2011, PIMRC 2011) and workshops addressing vehicular networking topics (IEEE Vehi-Mobi co-located with ICC 2009, Net4Cars 2010, ITST 2010, ITST 2011). Moreover, she has been recipient of the Best Paper Award in Nets4Cars 2009 (co-located with ICUMT) and in ITST 2011.

She served as a TPC member of several international conferences and as a technical reviewer of several journals. She is a student member of IEEE and IEEE Communications Society.

**Antonella Molinaro** is an Associate Professor of Telecommunications at University Mediterranea of Reggio Calabria, Italy. Before her current appointment, she worked at the University of Messina (1998-2001) and the University of Calabria (2001-04) as an Assistant Professor, and at Polytechnic of Milano (1997) as a research assistant. She worked with Telesoft S.p.A. in Rome as a network designer (1992-93), and with Siemens AG, Munich, Germany (1994-95) as an EU Fellow within the RACE II ATDMA (Advanced-TDMA Mobile Access) project. She received the Laurea Degree in Computer Engineering from University of Calabria in 1991, a post-laurea master diploma in Information Technology from CEFRIEL/Politecnico di Milano in 1992, and a Ph.D. degree in Multimedia Technology and Communication Systems in 1996. She has served in the Technical Programme Committee, Steering Committee, and Advisory Board of several IEEE conferences related to the vehicular networking area. She has published more than 150 publications in international conferences, journals, and book chapters, and has recently received two best-paper awards for research into vehicular networks.

**Riccardo Scopigno** (M.Sc. 1995, Ph.D. 2005) has matured a 15-year working experience in the TLC field, obtaining, in the meantime his Ph.D. His skills cover very different aspects of the Telecommunication architectures, from theory to practice, as matured from his variegated working experience. In fact, he was first a hardware designer for TLC systems in Italtel-Siemens (1997-1999); afterwards, in Marconi (2000-2003), he achieved a good expertise in IP network design, especially for multimedia contents (he got also a certification as network engineer at Marconi Pittsburgh PA). He is currently active in advanced research on wireless networks; he has been Director of Networking Lab (and now of Multimedia Wireless Dept.) of ISMB for nearly 8 years (since April 2003), leading a team of 20 people. Concerning the specific topics addressed by this tutorial, the following experiences seem relevant. 1) He is ISMB's representative in ETSI ITS (the working group on intelligent transportation systems of the European standardization body on TLC where he has also been called within a Specialist Task Force) and within Car-to-Car Communication Consortium (C2C-cc). 2) He published about 30 papers on WiFi and about 15 on vehicular communications in the last two years at important IEEE conferences (VTC, VNC, PIMRC, QShine, ...), acting also as TPC and co-chair. He is author of 3 patent pending techniques for VANETs (synchronous MAC MS-Aloha, georouting MapCast and TD-uCSMA, a CSMA/CA improvement for QoS). 3) His team simulates new protocols (they carry out performance evaluations and comparative analyses on NS-2 simulator as well as mixed simulations involving mobility) and carries out practical measurements. They have defined new propagation models, MAC solutions and georouting techniques. 4) He contributed to ISMB tasks within EU FP7 projects and to ISMB's role within Ertico Consortium. He also participates in national (Easy-Rider) and international (DAMASCO, with STM and University of California Los Angeles) research programs.