Guest Editorial
Vehicular Communications and Networks—Part I

DUE TO the increasing number of vehicles, road accidents and traffic jams have become a serious and ubiquitous health and social issue. To fight against road transport problems, vehicular ad hoc networks (VANETs) and intelligent transportation systems (ITSs) are attracting more and more attention, thanks to the rapid development of wireless communication technologies. VANET and ITS aim to improve traffic safety, protect environment by reducing traffic congestion and fuel consumption, and enable a plethora of new applications such as mobile infotainment. Generally speaking, VANET and ITS are able to support both safety and non-safety applications. Safety applications include automatic collision warning, bad weather detection and notification, remote vehicle diagnostics, emergency management, and other assistances for safety driving. Non-safety applications include providing real-time traffic congestion and routing information, high-speed tolling, automobile high speed Internet access, vehicle tracking, and many others.

To address the special requirements of both safety and non-safety applications in the vehicle domain, there is a necessity to develop new communication technologies and find special integration solutions into vehicular and transportation systems. These result in various types of vehicular communications and networks: vehicle-to-infrastructure (V2I), vehicle-to-roadside (V2R), and vehicle-to-vehicle (V2V) communications. The goal of these communication functions is to provide highly reliable and timely information or Internet access to vehicles, drivers, and passengers. Significant efforts have been made and are still underway by governments, highway authorities, automobile manufacturers, and the academic community to accelerate the development of VANET and ITS.

In this growing interdisciplinary field, many research challenges need to be addressed. One of the most crucial challenges is how to characterize vehicular communication channels in various roadway environments due to higher mobility of vehicles, greater dynamics, and possibly more severe fading compared to conventional wireless channels. Another challenge is how to appropriately design medium access control (MAC) and network routing protocols that should essentially be scalable in performance and adaptable to environment changes due to rapid network topology changes, node density fluctuations, and fast-varying channel conditions. How to evaluate and validate vehicular networking protocols under realistic assumptions using simulation methodologies and realworld testing is also a demanding task. Other challenges for vehicular communications and networks are, e.g., achieving security and maintaining driver privacy, efficiently disseminating a large amount of data, radio resource management, and stringent quality of service (QoS) requirements in terms of latency and reliability, only to mention a few.

The goal of this JSAC special issue is to report on cuttingedge research achievements covering various aspects of vehicular communications and networks that are distinctively different from communication networks in general. In response to the Call for Papers, we received a total of 124 submissions worldwide. After a rigorous review process, 34 papers have been selected for publication and they will undoubtedly contribute to the solutions of some of the abovementioned challenges. These 34 accepted papers are classified as five categories, which are further divided into two parts. Part I, appearing in this issue, includes the first three categories with altogether 21 papers and is devoted to the physical layer, MAC layer, and physical-link cross-layer design technologies. Part II, scheduled to be published in March 2011, comprises the last two categories with a total of 13 papers, which deal with handover, routing, security, and privacy preserving technologies.

In particular, the first category is comprised of five papers focusing on physical layer aspects in vehicular communications. The second category includes five papers addressing MAC layer protocols. The third category contains 11 papers, discussing cross-layer design schemes combining mainly the physical layer and link layer techniques. The fourth category consists of six papers, addressing handover and routing protocols. Finally, the fifth category has seven papers, dealing with security and privacy preserving technologies. In the following, we briefly discuss each of the papers in the first three categories.

I. Category I: Physical Layer Technologies

The first category of five papers is devoted to physical layer aspects of vehicular communication networks.

The paper "Investigation on Antenna Systems for Car-to-Car Communication" by Pontes, Reichardt, and Zwick aims to investigate optimum antenna configurations with which the communication limits of V2V scenarios can be explored. Considering the scenarios of a street intersection with and without parked vehicles, the authors find that the use of multiple antennas increases capacity but it depends strongly on the antenna placement and the scenario given. Antennas placed below the vehicle with the square-like antenna configuration seem to be most robust in both scenarios.

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The next paper "Impact of Vehicles as Obstacles in Vehicular Ad Hoc Networks" by Boban, Vinhoza, Ferreira, Barros, and Tonguz presents a useful model for V2V communication channels by accounting for vehicles as three-dimensional objects and taking into account their impact on the line-of-sight (LOS) obstruction, received signal power, and packet reception rate. Real-world highway measurement results illustrate that considerable obstruction of LOS due to vehicles can induce significant attenuation and packet loss. It is shown that the proposed channel model is more realistic than the existing simulators with relevant implications on the design of upper layer protocols.

In the paper "Artificial Wideband Multi User Channels for Rural High Speed Vehicle to Vehicle Links", Brown, Eggers, and Pedersen address antenna array techniques applicable to a V2V communication scenario where vehicles travel in convoy, i.e., one vehicle following another at roughly constant speed on a rural highway. The deliberate introduction of delay spread through wide space and combined multiple antenna topology, thus creating an artificial wideband channel model, is proposed which results in de-correlated V2V links. Measurement and experimental results demonstrate that uncorrelated wideband channels between separate V2V links can be formed to enable multiuser capabilities specific to vehicles on a rural highway.

Zhang, in "Cognitive Non-Continuous Carrier Interferometry Orthogonal Signal Division Multiplex Transmission in Autonomous Vehicular Communications", presents a novel transmission system, the so-called cognitive non-continuous carrier interferometry (NCI) orthogonal signal division multiplex (OSDM) system, to provide autonomous broadband communications among mobile vehicles. Simulation results reveal that compared to the existing systems, the proposed cognitive NCI-OSDM system can achieve higher spectrum efficiency, better bit error rate performance, lower peak to average power ratio, lower power of inter-carrier interference, and higher complexity which is however controllable if the number of sub-carriers is not extremely large.

The paper "Coalition Formation Games for Distributed Cooperation Among Roadside Units in Vehicular Networks" by Saad, Han, Hjorungnes, Niyato, and Hossain is the last one in this category. It investigates novel distributed cooperative strategies among the road-side units (RSUs) in a vehicular network. The proposed cooperation model is formulated as a coalition formation game with transferable utility and then a coalition formation algorithm is proposed, which can enable the RSUs to maximize their payoffs and always converge to a Nash-stable partition. Simulation results show that the proposed algorithm can allow the RSUs to self-organize into independent coalitions while improving the payoff performance.

II. Category II: MAC Layer Technologies

The second category of five papers deals with MAC layer technologies.

The paper "Performance Modeling of Message Dissemination in Vehicular Ad Hoc Networks with Priority" by Khabazian, Assa, and Mehmet-Ali studies the performance of message dissemination in VANETs with two priority classes of traffic. The authors derive the distribution of the number of concurrent transmissions of lower priority messages in the system at the steady state, via a birth-death process analysis, the percentage of destination node population which cannot receive the message error free due to interference, and the average forwarding distance and the number of nodes which receive a high-priority message in the presence of low-priority traffic. Numerical and simulation results confirm the accuracy of the proposed analysis.

The next paper "A Novel Adaptive Distributed Cooperative Relaying MAC Protocol for Vehicular Networks" by Zhou, Sharif, Hempel, Mahasukhon, Wang, and Ma presents a novel adaptive distributed cooperative (ADC) MAC protocol, which exploits spatial diversities to maximize the system throughput and the service range of vehicular networks. The proposed ADC-MAC protocol is accomplished through adaptively selecting the most suitable helper and transmission mode for transmit/receive pairs among direct transmission, cooperative relay transmission, and two-hop relay transmission, in accordance with the channel quality and the positioning of relay nodes. Both the Markov Chain modeling based theoretical analysis and ns-2 simulation results show that the ADC-MAC protocol outperforms existing schemes for providing robust real-time vehicular communications.

In the paper "A Region-Based Clustering Mechanism for Channel Access in Vehicular Ad Hoc Networks", Lai, Lin, Liao, and Chen propose a Region-based Clustering Mechanism (RCM) that can be directly applied in existing MAC protocols to reduce the contention period, so that timely and reliable data delivery for mobile vehicles can be achieved. Analytical models and simulation experiments are provided to investigate the performances of RCM in terms of the total transmission time and the average contention period. Results demonstrate that the proposed mechanism is indeed an excellent mechanism to improve the performance of MAC protocols for VANETs.

The paper "Urban Infrastructure-to-Vehicle Traffic Data Dissemination Using UEP Rateless Codes" by Stefanovic, Vukobratovic, Chiti, Niccolai, Crnojevic, and Fantacci presents an end-to-end solution for urban V2I traffic data dissemination based on expanding window fountain (EWF) codes which are a class of rateless codes with unequal error protection (UEP) property. Simulation results show that EWF codes provide an efficient solution for the content reconciliation problem, adaptation to the changing link behavior, and timely and reliable delivery of important data.

The last paper in this category, "Link-Layer Scheduling in Vehicle to Infrastructure Networks: An Optimal Control Approach" by Alcaraz, Vales-Alonso, and Garcia-Haro, describes a novel link-layer scheduling mechanism for non-real-time, non-safety data transmission in V2I systems. A dynamical system model for V2I communications is developed and novel algorithmic solutions are provided. The proposed scheduler can be extended to incorporate QoS differentiation among data flows. Simulation results indicate that the proposed strategy is more beneficial than the existing mechanisms when the average packet error ratio changes notably along the covered road segment.

III. Category III: Physical-Link Cross-Layer Design Technologies

The third category of 11 papers focuses on the cross-layer design solutions, mainly combining the physical layer and link layer techniques, of vehicular communication networks.

The paper "Scalable Cross-Layer Wireless Access Control using Multi-Carrier Burst Contention" by Roman,Wassell, and Chatzigeorgiou presents a cross-layer Multi-Carrier Burst Contention (MCBC) protocol that spans both time and frequency domains, employing short and unmodulated energy bursts and a randomized and recursive node-elimination mechanism in order to resolve collisions. It can overcome many of the vehicular environment challenges and provide desirable features such as scalability, robustness, prioritized access, and others. Theoretical analysis using an analytical model and measurement results with a multi-core hardware testbed show that the proposed contention scheme has a considerable performance improvement over IEEE 802.11p.

The next paper "Probabilistic Delay Control and Road Side Unit Placement for Vehicular Ad Hoc Networks with Disrupted Connectivity" by Abdrabou and Zhuang presents an analytical framework to statistically estimate the maximum packet delivery delay from a vehicle with a random traffic source to a RSU for a low density VANET, where a data packet is being relayed via V2V communications. The framework aims at determining the minimum number of RSUs required to cover a straight road while satisfying the service requirement in terms of the transmission delay over the multiple hops. Numerical and simulation results validate the accuracy of the proposed framework, showing that a proper number of the RSUs can satisfy a certain delay bound probabilistically.

In the paper "Analysis of Access and Connectivity Probabilities in Vehicular Relay Networks", Ng, Zhang, Zhang, Yang, and Mao develop an analytical model to fully characterize the access and connectivity probabilities in a VANET considering both one-hop (direct access) and two-hop (via a relay) communications between a vehicle and the infrastructure. Analytical and simulation results reveal the tradeoff between key system parameters, such as the distance between base stations (BSs), vehicle density, transmission ranges of a BS and a vehicle, and their collective impact on access and connectivity probabilities under different communication channel models.

Ye, Yim, Roy, and Zhang, in "Efficiency and Reliability of One-Hop Broadcasting in Vehicular Ad Hoc Networks", analyze the effectiveness of one-hop broadcasting in VANETs in terms of the efficiency, measured by the average rate at which nodes receive any broadcast packets successfully, and reliability, measured by the average number of nodes that receive a specific transmission successfully. The authors demonstrate theoretical limits to and achievable tradeoffs between efficiency and reliability for a linear network under Rayleigh fading links. Power control and congestion control strategies are then provided to maximize broadcast efficiency. Ns-2 simulations are used to validate analytical results.

The paper "Low Complexity Outage Optimal Distributed Channel Allocation for Vehicle-to-Vehicle Communications" by Bai, Chen, Letaief, and Cao presents a random bipartite graph model for the subchannel allocation problem in V2V communications based on the outage formulation. The QoS requirements of real-time V2V communications are met by achieving a low outage probability and high outage capacity. It is demonstrated that the proposed method can satisfy QoS requirements while having small signaling overhead with only one-bit channel state information broadcasting for each subchannel.

In the paper "Communication-Aware Position Control for Mobile Nodes in Vehicular Networks", Roh and Lee study a communication-aware position control problem for mobile nodes in one dimensional linear vehicular networks, aiming at finding the position of each node with controllable mobility considering the network performance. Four algorithms are developed, two based on optimization theoretic approach to find the global optimal position and two based on the game theoretic approach to find the Nash equilibrium position in a distributed way. Numerical results show that the game theoretic approach can provide an efficient solution that is comparable to the global optimal solution.

The paper "Time and Location-Critical Emergency Message Dissemination for Vehicular Ad-Hoc Networks" by Zhuang, Pan, Luo, and Cai presents a time/location-critical (TLC) framework for emergency message dissemination using the so-called scalable modulation and coding (SMC) scheme. In specific, vehicles near the accident site receive guaranteed, detailed messages to take proper reaction immediately, while vehicles further away have a high probability to be informed and make location-aware decisions accordingly. Numerical and simulation results show that the proposed TLC framework with the SMC scheme is able to disseminate emergency messages effectively and efficiently, while simplifying the design of radio transceivers and MAC protocols for VANET.

In the paper "Quality-of-Service Driven Power and Sub-Carrier Allocation Policy for Vehicular Communications Networks", Zhang, Ma, Yuan, and Chen develop a cross-layer optimization framework for V2I communication networks under delay aware QoS requirements. Aiming to minimize the overall power consumption, the proposed scheme employs orthogonal frequency division multiplexing (OFDM) at the physical layer and power and sub-carrier assignment policy at the data link layer. Theoretical and numerical results reveal that the proposed policy offers a superior performance over the reported resource allocation policies.

The paper "Analytical Models and Performance Evaluation of Drive-thru Internet Systems" by Tan, Lau, Yue, and Hui analyzes the data communication performance of a vehicle in a Drive-thru Internet system, in which users in moving vehicles within the coverage range of a roadside access point (AP) can connect to the AP to obtain Internet connectivity. Practical analytical models are derived, validated by simulations, with tractable solutions for the average and distribution of the number of bytes that a vehicle can download from an AP by the end of its sojourn. The proposed model is able to quantify the impact of road traffic density, vehicle speed, service penetration rate, APs transmission range, and the corresponding bit rate on the amount of downloaded data.

Li, Yang, and Lou, in "CodeOn: Cooperative Popular Content Distribution for Vehicular Networks using Symbol Level Network Coding", present CodeOn, a novel push-based popu-

lar content distribution (PCD) scheme for vehicular networks, where contents are broadcasted proactively from a few APs to vehicles inside an interested area. CodeOn is designed to primarily achieve high downloading rate and high protocol efficiency, using symbol level network coding (SLNC), which enjoys the benefits of both network coding and symbol-level diversity, and a prioritized relay selection algorithm along with a lightweight transmission coordination MAC protocol. Extensive simulation results indicate that CodeOn significantly outperforms a state-of-the-art PCD scheme based on network coding.

The paper "Goodput Enhancement of VANETs in Noisy CSMA/CA Channels" by Chang, Lee, and Copeland demonstrates a feasible methodology that can increase the system goodput of carrier sensing multiple access/collision avoidance (CSMA/CA) in VANETs, using dynamic optimal fragmentation with rate adaptation algorithm (DORA). The proposed joint physical-MAC algorithm dynamically selects the optimal fragmentation and transmission rate in time varying channels with minimal overhead. Several testbeds are developed to evaluate the performance of DORA in channel estimation accuracy, ad hoc network goodput, and V2V network goodput, showing the applicability of the proposed algorithm to V2V communications.

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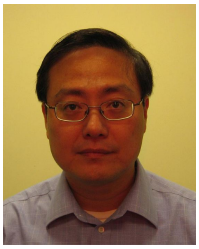

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