Connected Vehicles—Advancements in Vehicular Technologies and Informatics

VEHICLES are becoming increasingly more sophisticated and the technology being developed in them covers a number of areas. At the heart of these developments are often the communication, information and control systems. This is very much illustrated in this "Special Section on Connected Vehicles—Advancements in Vehicular Technologies and Informatics" of the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS that we are pleased to present.

The Special Section contains twelve papers related to automotive technology. Obviously there a range of areas covered from very high speed machines [1], that could be used for cooling fans in automotive fuel cells or scaled up for drive motors, to energy management [2], [3] and into various communications aspects of vehicular technology [4]–[12].

In [1], the design process for a 2.62-kW 150 000-rpm high-speed surface-mounted permanent-magnet synchronous motor is presented. This has various applications in automotive technology and the drive motor is one of the major components in electric and hybrid-electric vehicles which is a rapidly expanding technology. Currently, drive motors run up to speeds of possibly 13 500 rpm (Toyota Prius generation III drive system) so this could represent a step change in technology. High speed motor drives can produce high efficiency and compactness.

One of the other key technologies in electric and hybrid-electric vehicles is the energy storage and management systems. [2] presents a reinforcement learning-based adaptive energy management (RLAEM) system for a hybrid electric tracked vehicle (HETV). A control oriented model of the HETV is first established, in which the state-of-charge (SOC) of battery and the speed of generator are the state variables, and the engine's torque is the control variable. Subsequently, a transition probability matrix is learned from a specific driving schedule of the HETV. The simulation results demonstrate the adaptability, optimality and learning ability of the RLAEM and its capacity for reducing the computation time.

System integration and power-flow control of on-board power sources are critical to the performance and cost competitiveness of hybrid-electric vehicles. Reference [3] presents an innovative multi-criteria optimization approach and gives a case study for a fuel cell hybrid bus. Three key contributions are made. First, a convex multi-criteria optimization framework is devised for quickly and efficiently evaluating the optimal trade-offs between the fuel cell durability and hydrogen economy in the bus. Second, the impact of driving pattern on both the optimal fuel cell size and Pareto optimality is investigated. Finally, a preliminary but useful economic assessment is explored for the most cost-effective tradeoff.

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To increase road safety, vehicle manufacturers have until now used on-board sensors like radars, lasers and cameras to detect other vehicles or pedestrians. The next step would be to use the information from off-board sensors placed in surrounding vehicles. Data requiring low signal latency can be sent between the vehicles in the dedicated frequency band, 5.9 GHz, using the wireless communication standard IEEE 802.11p. Wireless communications can make it possible to detect objects around the corners even if, e.g., the visual line-of-sight is blocked, which is not possible for the sensors on the car today. Such information will allow the drivers to take actions even earlier than today to avoid collisions. A first step towards using a vehicle with antennas in an over-the-air multi-probe test system is presented in [4]. In this paper, both experiments and characterization of the measurement uncertainty of an over-the-air multi-probe setup for vehicles at 5.9 GHz are put forward.

On a similar theme to [4] in terms of the requirement for vehicle to vehicle (V2V) communications, [5] presents a dynamic wideband directional model for time-variant V2V channels. The model is developed in V2V suburban, urban, and underground parking environments and it is based on a large set of measurements at 5.3 GHz. By incorporating both angular and delay domain properties as well as dynamic behavior for the MPC evolutions. The model is capable of handling time-variant V2V scenarios with dynamic scatterers. The proposed model shows insight into the dynamic behaviors of MPCs in a V2V environment.

Again, on a similar theme to [4] and [5], vehicular ad hoc networks (VANETs) help improve traffic safety and lessen traffic congestion. Roadside units (RSUs) play a key role in serving as the event and data broker in the form of vehicle-to-infrastructure communication to supply wireless and mobile vehicle-to-vehicle communication. Recently, hybrid VANET-sensor networks have attracted much attention as events are detected by sensor nodes and are spread to a wider area via VANETs. [6] investigates the problem of minimizing the total cost of deploying RSUs and sensor nodes along the two sides and the median island of a two-lane road to cover the whole road, represented as a grid, and to form a connected VANET-sensor network. Experimental results show that the approach can perform well for moderate-size problems.

It is possible to use Internet-based vehicular ad hoc networks (IVANETs). In IVANETs, users often access multimedia content from anywhere using Internet connectivity to remote video streaming servers. However, maintaining quality of service (QoS) in IVANETs for video streaming applications is a challenging task. To address these challenges in IVANETs, [7] proposes a new QoS-aware hierarchical web caching (QHWC) scheme. The authors propose two new metrics: load utilization ratio (LUR) and query to connectivity ratio (QCR), in order to maintain the QoS for various video streaming applications in IVANETs.

Reference [8] investigates whether the built-in sensors in a smart phone can accurately predict future trajectories for V2V and vehicle to infrastructure (V2I) systems. If smartphones could be used, vehicles without V2V or V2I technology could tap into V2V/V2I infrastructure. To evaluate this, the authors setup a dead reckoning system that uses Kalman filters to predict the future trajectory of a vehicle. Information that could be used in a V2V/V2I system could warn drivers if the trajectories of vehicles will intersect at the same time. The results show that some smartphones could be used to predict a future position, but the use of their accelerometer sensors introduces some measurements that can be incorrectly interpreted as spatial changes.

Vehicular delay-tolerant networks (VDTNs) proposed as a new kind of vehicular networks, whose design supports communications in environments where an end-to-end path between the source and destination may not be available. Like other ad hoc networks, VDTNs rely their operation on cooperation between mobile nodes (e.g., vehicles), which can store-carry-and-forward bundles. VDTNs consider three kinds of nodes: mobile, terminal, and relay nodes. Reference [9] presents an "adaptive Anycasting solution for Vehicular Environments" (AVE) which a message delivery protocol that combines geographical and topological information to dynamically adapt its behavior to network conditions. The authors focus on V2I connectivity for cloud services, where the vehicles send the sensed information as individual and independent messages to a cloud service in the Internet. This scenario requires the access to any available close-by roadside unit (RSU), thus making anycasting the ideal delivery mechanism. Simulation results show that the hybrid and adaptive approach of AVE is able to improve network performance.

Cloud computing is mentioned in [9]. Vehicular cloud computing (VCC) is a promising approach that makes use of advantages of cloud computing and applies them to vehicular networks. In [10], the authors propose an optimal computation resource allocation scheme to maximize the total long-term expected reward of the VCC system. The system reward is derived by taking into account of both the income and cost of the VCC system as well as the variability feature of available resources. The optimization problem is formulated as an infinite horizon semi-Markov decision process (SMDP) with the defined state space, action space, reward model and transition probability distribution of the VCC system. Numerical results demonstrate that there is significant performance gain which can be obtained by use of the SMDP-based scheme within the acceptable complexity.

In [11], the authors consider the resource management and sharing problem for bandwidth and computing resources to support mobile applications in cloud-enabled vehicular network. In such an environment, cloud service providers can cooperate to form coalition to share their idle resources with each other. The authors propose a coalition game model based on two-sided matching theory for cooperation among the cloud service providers to share their idle resources. As a result, the resources can be better utilized and QoS can be improved. Numerical results indicate that their scheme can improve the resource utilization which can produce a 75% improvement in the QoS.

Returning to the theme of VDTNs, in these, an end-to-end relay path between bundles source and destination nodes may not be available. To accomplish such a goal, VDTNs rely on node cooperation. Thus, in order to maintain network efficiency, it is very important to ensure that all network nodes follow the protocol. This is not an easy task since nodes may diverge from the protocol due to a selfish behavior or to maintain their data or resources integrity. Reference [12] proposes a cooperative watchdog system to detect and act against misbehavior nodes in order to reduce their impact in the overall network performance. Its operation relies on a cooperative exchange of nodes reputation along the network. Simulations were carried out using the VDTNSim tool and the Spray-and-Wait routing protocol shows that the cooperative watchdog method proposed for VDTNs is not only effective in detecting misbehaving nodes but also contributes to an overall network performance improvement by increasing the bundle delivery probability and decreasing the amount of resource waste.

These papers conclude the Special Section. There were many excellent papers submitted, and 12 were selected for publication. This illustrates the increasing technological developments in the area, particularly in terms of vehicle communications.

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