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Editorial

Communications and Networking for Connected Vehicles

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New wave of urbanization, ever more stringent emission standards, and high pressure on improving efficiency of private and public transport have made the development of more sustainable transportation systems one of the fundamental societal challenges of the next decade. Connected vehicles have been envisioned to provide enabling key technologies to enhance transportation efficiency, reduce incidents, improve safety, and mitigate the impacts of traffic congestion. The seamless integration and convergence of vehicular communication networks, information and transportation systems, and mobile devices and networks will face a number of technical, economic, and regulatory challenges. It is of paramount importance to (i) design vehicular communication systems that enable road users and other actors to exchange information in real time with high reliability, (ii) enable pervasive sensing to monitor the status of vehicles and the surroundings, (iii) develop data analytics tools for processing large amounts of data generated by the connected vehicles, and (iv) develop middleware platforms for data management and sharing.

In this context, we present a collection of high-quality research papers on recent developments, current research challenges, and future directions in the use of control, communications, and emerging technologies to realize communications and networking for connected vehicles that are safer and more efficient.

Bin Ran and his research fellows aim to integrate the traffic features extracted from the wireless communication records and the measurements from the microwave sensors for the state estimation. A state-space model and a Progressive Extended Kalman Filter (PEKF) method are proposed. The results from the field test exhibit that the proposed method efficiently fuses the heterogeneous multisource data as well as adaptively tracking the variation of traffic conditions. The proposed method is satisfactory and promising for future development and implementation.

Safety messages propagation is the major task for Vehicular Cyber-Physical Systems in order to improve the safety of roads and passengers. However, reducing traffic and car accidents can only be achieved by disseminating safety messages in a timely manner with high reliability. Although mathematical modeling of the delay of safety messages is extremely beneficial, analyzing the safety messages propagation is considerably complex due to the high dynamics of vehicles. Moreover, most of previous works assume that vehicles drive independently and the interaction between vehicles is not taken into consideration. The authors in Beijing University of Posts and Telecommunications propose an analytical model to describe the performance of safety messages propagation in the VCPSs under platoon-based driving pattern. Infrastructure-less and RSU-supported scenarios are evaluated independently. The analytical model also takes into account different transmission situations and various system parameters, such as communication range, traffic flow, and platoon size. The effectiveness of the analytical model is verified through simulation and the impacts

of different parameters on the expected transmission delay are investigated. The results will help determine the system design parameters to satisfy the delay requirement for safety applications in VCPSs.

Urban rail transit plays an increasingly important role in urbanization processes. Communications-Based Train Control (CBTC) systems, Passenger Information Systems (PIS), and Closed Circuit Television (CCTV) are key applications of urban rail transit to ensure its normal operation. In existing urban rail transit systems, different applications are deployed with independent train ground communication systems. When the train ground communication systems are built repeatedly, limited wireless spectrum will be wasted, and the maintenance work will also become complicated. Researchers in Beijing Jiaotong University design a network virtualization based integrated train ground communication system, in which all the applications in urban rail transit can share the same physical infrastructure. In order to better satisfy the Quality of Service (QoS) requirement of each application, the authors propose a virtual resource allocation algorithm based on QoS guarantee, base station load balance, and application station fairness. Moreover, with the latest achievement of distributed convex optimization, they exploit a novel distributed optimization method based on alternating direction method of multipliers (ADMM) to solve the virtual resource allocation problem. Extensive simulation results indicate that the QoS of the designed integrated train ground communication system can be improved significantly using the proposed algorithm. X. Wang et al. in Beijing Jiaotong University set up an Enhanced Ultra-High Throughput (EUHT) wireless communication system for urban rail transit in high-speed scenario integrating all the traffics of it. An outdoor testing environment in Beijing-Tianjin high-speed railway is set up to measure the performance of integrated EUHT wireless communication system based on urban rail transit. The communication delay, handoff latency, and throughput of this system are analyzed. Extensive testing results show that the Quality of Service (QoS) of the designed integrated EUHT wireless communication system satisfies the requirements of urban rail transit system in high-speed scenario.

Safety services of Vehicular Ad Hoc Network (VANET) require reliable broadcasts. Urban road characteristics such as frequent intersections, high traffic density, and traffic concentration caused by wait traffic signals are not carefully taken into account. Inaccuracy of beacon information due to losses of beacons caused by high traffic density or by the signal attenuation at intersections may result in choosing suboptimal forwarding vehicles and lead to broadcast collisions or unnecessary broadcasts. In particular, the inaccuracy of information tends to aggravate the broadcast inefficiency more seriously when traffic is heavily concentrated. Therefore, Y. Sung and M. Lee propose "VANET Broadcasting for Urban areas based on Road Layout (VBURL)," which minimizes the dependency on information that may become inaccurate in order to maximize the efficiency of broadcast. VBURL takes into account the road layout information accessible from the digital map and only the real-time information obtained from the broadcast messages or beacons instead of leveraging the holding information from beacons or implicit guess about the status of neighboring vehicles. VBURL basically makes the vehicle that is farthest from the current forwarding vehicle take the role of next forwarding vehicle. Furthermore, VBURL makes an additional broadcast happen at the intersections in addition to the one made by the farthest vehicle as long as there exists a vehicle hearing the broadcast at the intersection or else at least there exist one or more vehicles that are moving toward the intersection with that intersection within their transmission range. Through a course of simulations, the performance of VBURL is compared with that of the legacy schemes proposed for reliable broadcast on urban roads. The simulation results verified that VBURL achieves the same high performance as that of the compared schemes in terms of reliability with much higher efficiency.

E. M. Ghourab et al. in Alexandria University propose a novel approach to enhance wireless vehicle-to-vehicle channel-secrecy capacity by imposing signal transmission diversity. This work exploits cooperative vehicular relaying to extract the associated underlying multipath and Doppler diversity using precoding techniques. We evaluated the capacity and diversity gain for the presented approach to ensure its effectiveness and efficiency. The abundance of moving vehicles, operating in an ad hoc fashion, can eliminate the need to establish a dedicated relaying infrastructure. A relay selection scheme is deployed taking advantage of the potentially large number of available relaying vehicles. Further, they derivate a closed-form mathematical expression for the channel-secrecy capacity, diversity order gain, and the intercept probability. We used the direct transmission scenario as a reference to assess our analysis. Our analytical and simulation results for the presented model showed that channel-secrecy capacity and performance-indicators improved significantly.

The next generation of mobile communications, 5G, will provide a wideband network based on microwave and millimeter-waves (mmW) communication radio links with the goal of fulfilling the strict and severe requirements of the future test cases. In particular, D. Oliva et al. in University of Madrid focus on mmW bands in metropolitan railway tunnels. For that purpose, a propagation measurement campaign is performed at 24 GHz band in a passenger train on a realist subway environment and these results were combined with ad hoc simulations for tunnels and a theoretical modal propagation model. Narrowband and wideband study have been conducted with the aim of obtaining the path loss, fading, power-delay profile, and angle of arrival, all of this taking into consideration a horizontal and vertical polarization in the receiving and transmitting antennas. This validation can be used to design and deploy wideband mobile communication networks at mmW bands in railway scenarios. Passenger trains and especially metro trains have been identified as one of the key scenarios for 5G deployments. The wireless channel inside a train car is reported in the frequency range between 26.5 GHz and 40 GHz. These bands have received a lot of interest for high-density scenarios with a high-traffic demand, two of the most relevant aspects of a 5G network. C. Calvo et al. provide a full description of the wideband channel estimating power-delay

profiles (PDP), Saleh-Valenzuela model parameters, time-of-arrival (TOA) ranging, and path-loss results. Moreover, the performance of an automatic clustering algorithm is evaluated. The results show a remarkable degree of coherence and general conclusions are obtained.

The communication system presently applied in the European Train Control System can only support data exchange between vehicles and ground, but the direct vehicle-to-vehicle communication is not available. The details of interlocking information and other vehicles' movements are invisible to drivers who are the last defense to prevent unsafe scenarios. As connected vehicles have been envisioned to enhance transportation efficiency and improve safety, the direct vehicle-to-vehicle communication network is involved to increase the safety critical needs of railway transport. T. Shen and H. Song propose a new train movement authority (MA+). Apart from a wireless communication unit, this system does not require any other infrastructure. With the assistance of vehicle-centric communication technology, MA+ can detect the condition of switches and trains within a certain scope. Additionally, different implementation scenarios are also discussed. The detection range is estimated and validated based on mathematical calculation and experimental equations. An application demo of the MA+ is presented on the Driver Machine Interface of the onboard equipment. The results indicate that MA+ can be a flexible and scalable system for furthering the improvement of railway safety.

Greater demands are being placed on the access bandwidth, stability, and delay of network because of the quickening rhythm of life and work, especially in mobile scenario. In order to obtain a stable network with low latency and high bandwidth in mobile scenario, taking advantage of the wireless heterogeneous network in parallel is a good choice. Nowadays, people are increasingly concerned about the network quality under the mobile scenario. Some scholars have done the relevant measurements. However, all of those measurements mainly investigate part of the network parameters or part of mobile scenarios. T. et al. in Beijing Jiaotong University make the following contributions. Firstly, in high-speed mobile scenario, the wireless network qualities of different vendors are measured synthetically. Secondly, they analyze the benefits of taking advantage of the different vendors. Thirdly, they deploy the replication link mechanism in high-speed mobile scenario and propose an algorithm to remove the duplicate packet in high-speed mobile scenario. And the algorithm can also be used in other multipath schedule algorithms to improve the reliability.

Existing intelligent transport systems (ITS) do not fully consider and resolve accuracy, instantaneity, and compatibility challenges while resolving traffic congestion in Internet of Vehicles (IoV) environments. D.-B. Nguyen et al. in Feng Chia University propose a traffic congestion monitoring system, which includes data collection, segmented structure establishment, traffic-flow modeling, local segment traffic congestion prediction, and origin-destination traffic congestion service for drivers. Macroscopic model-based traffic-flow factors were formalized on the basis of the analysis results. Fuzzy rules-based local segment traffic congestion prediction was performed to determine the traffic congestion state. To enhance prediction efficiency, they present a verification process for minimizing false predictions, which is based on the Rankine-Hugoniot condition and an origin-destination traffic congestion service is also provided. To verify the feasibility of the proposed system, a prototype was implemented. The experimental results demonstrate that the proposed scheme can effectively monitor traffic congestion in terms of accuracy and system response time.

VBTC (Vehicle-to-Vehicle Communications-Based Train Control) has gradually become an important research trend in the field of rail transit. This has resulted in advantages of decreasing the amount of wayside equipment and improving the efficiency of real-time system communication. Characteristics and mechanism of train-to-train communication, as key implementation technology of safety critical system, are discussed by H. Feng in China Academy of Railway Sciences. A new method, based on the LTS (labelled transition system) model checking, is proposed for verifying the safety properties in the communication procedure. The LTS method is adapted to model system behaviours and analysis and safety verification is checked by means of LTSA (labelled transition system analyzer) software. The results show that it is an efficient method to verify safety properties and to assist the complex system's design and development.

H. Wenqian and D. Wenrui in Beihang University propose a novel length adaptive method for time domain equalizer by taking the channel attenuation ratio between different multipath components into account in UAV-UAV and UAV-ground channels. Then, considering received image quality, the minimum bit error ratio (MBER) criterion is exploited to design adaptive equalizers for both amplify-and-forward (AF) and decode-and-forward (DF) relaying systems by the proposed length adaptive method. Results show that proposed MBER adaptive equalizers outperform the traditional ones in both AF and DF relaying as channel attenuation ratio in UAV-ground channel increases. Moreover, DF outperforms AF as channel attenuation ratio in UAV-UAV channel increases. Furthermore, bit error ratio (BER) and peak signal-to-noise ratio (PSNR) performances in both AF and DF are evaluated to show the enhancement by the proposed MBER adaptive equalizers.

Vehicle-borne battery condition is an important factor affecting the efficiency of the Maglev train operation and other connected ones. To effectively eliminate the influence of the battery condition and improve the operation efficiency of the connected Maglev trains, an operation control strategy is proposed to guarantee train operation safety by W. Zhang et al. in Beijing Jiaotong University. Based on Internet of Things, a sensor network is designed to monitor vehicle-borne battery condition in each vehicle of the train. The train Operation Control System collects battery data of all vehicles in a Maglev train by Train Communication Network. All connected Maglev trains share the battery data via a 38 GHz directional Radio Communication System and adjust operation control strategy accordingly. Simulation results indicate that the proposed strategy can guarantee the operation safety of the connected Maglev trains.

Overall, it is imperative that we continue to progress in our search for appropriate models, which can adequately and faithfully improve the safety and performance of communications and networking for connected vehicles. The progress reported in this special issue suggests that, in the future, achieving these aims might be a distant prospect but an unattainable one.

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