Emerging Technologies for Connected and Smart Vehicles

Syed Hassan Ahmed, Jalel Ben-Othman, Jaime Lloret, Ashfaq Khokhar, Raheem Beyah, Antonio Sanchez, Wael Guibene

Due to the rapid growth of connected vehicles, many research constraints need to be addressed, e.g., reliability and latency, practical MAC and routing protocols, performance and adaptability to the changes in the environment (node density and oscillation in network topology), and validation of protocols under the umbrella of coherent assumptions using simulation methodologies. In this Feature Topic, we present 10 papers proposing very interesting solutions and architectures for futuristic and smarter connected vehicles.

The first article, entitled "Spatial Intelligence toward Trustworthy Vehicular IoT," presents two unique techniques for mobile and multi-tier edge access via clustering of the nodes. The authors have further used this notion of 'vehicle as an edge', where a fuzzy logic considering multiple conflicting metrics and using Q-learning is used to improve overall network performance by enabling data caching, store-carry-forward, and processing at the vehicle edge. The key idea is also evaluated with supporting simulations and qualitative discussions.

Recently, mm-Wave technologies have been attracting a lot of attention from the wireless community. Likewise, researchers from both academia and industry have started considering mm-Wave communications for connected vehicles. In the second article, entitled "Key Technologies, Modeling Approaches and Challenges for Millimeter-Wave Vehicular Communications," the authors propose a combination of analog beam-forming with a location-based beam searching protocol while using full-duplex radios. Furthermore, a very unique and interesting set of future research directions are presented.

The third article, "Interference-aided Vehicular Networks: Future Research Opportunities and Challenges," presents a very informative tutorial regarding the technical and socio-economic challenges that must be addressed for a successful implementation of interference-aided vehicular communication networks.

The fourth article, entitled "SLP-MCAF: Multiple Clusters of Connected Vehicles Authentication Framework in a Smart Life Platform," is one of the positive steps toward verifications and authentication processes in the arena of connected vehicles. In this article, the authors propose a smart life platform by combining the concepts of connected vehicle and smart home. The authors also discuss a Multiple Clusters of Connected Vehicles Authentication Framework in Smart Life Platform (SLP-MCAF) to provide security services within the platform. Similarly, in the fifth article, entitled "Block4Forensic: An Integrated Lightweight Blockchain Framework for Forensics Applications of Connected Vehicles," the authors integrate Vehicular Public Key Management (VPKI) to the blockchain to provide membership establishment and privacy. Also, they design a fragmented ledger that stores detailed data related to the vehicles such as maintenance information/history, car diagnosis reports, etc.

Moving ahead, in the sixth article of this feature topic, entitled "Vehicular Fog Computing for Video Crowdsourcing: Applications, Feasibility and Challenges," the authors highlight challenges to be faced when bringing Fog computing to the connected vehicles arena. The selected real-time applications are crowdsourcing and camera video data. Rather than forwarding all the video data to the cloud, the authors propose to turn public vehicles (e.g., buses and taxis) into vehicular fog nodes, and to utilize these nodes to gather and process video data from the private vehicles within communication ranges. This unique idea also opens further research challenges and questions within the article itself.

Another vital application of vehicular networks would be density awareness on the road. In the next article, entitled "Real-Time Density Detection in Connected Vehicles: Design and Implementation," the authors present a novel idea of bringing robustness to detect density. Unlike existing time division concepts, the proposed architecture introduces parallel detection of neighboring vehicles via frequency division, largely reducing the time cost. The authors further implement the proposed system in USRPs and discuss several practical design issues.

The article entitled "Improving EDCA for Efficient Channel Access in Vehicular Communications" presents a dynamic allocation of message priority by estimating the transmission delay of each access category (AC) queue and dynamically adjusting the CW value for efficient channel access at the MAC layer followed by several important research challenges listed for the readers. While in the second to last article, entitled "Route Planning Considerations for Autonomous Vehicles," the authors provide a timely survey and technical review of the enabling technologies for more capable

route planning techniques and describe the inevitable elements and considerations for routing autonomous vehicles in dynamic traffic conditions.

We conclude our Feature Topic with the article entitled "Design Guidelines for Information-Centric Connected and Autonomous Vehicles," in which the authors introduce and highlight the very timely topic of the emerging future Internet architecture known as ICN into connected vehicles.

As we conclude this editorial, we would like to express our sincere gratitude to all the contributing authors, the reviewers for providing constructive reviews, and the *IEEE Communications Magazine* publications staff, in particular, the Editor-in-Chief. Finally, we believe that this Feature Topic will open many research doors for all active researchers, including students, academicians, and industry personnel.

Biographies

Syed HaSSan aHmed [S'13, M'17, SM'18] completed his BS from KUST, Pakistan and his M.S./Ph.D. from Kyungpook National University, South Korea, both in computer science, in 2012 and 2017, respectively. Later, he was a post-doc with the University of Central Florida, Orlando. Currently, he is on the faculty of the CS Department of Georgia Southern University (GSU) at Statesboro, USA, where his research interests include sensor and ad hoc networks, cyber-physical systems, vehicular communications and Future Internet.

Jalel Ben-OtHman has been a full professor at the University of Paris 13 since 2011. His research interests are in the area of wireless ad hoc and sensor networks, VANETs, IoT, performance evaluation and security in wireless networks in general. He is currently on the Steering Committee of the *IEEE Transaction on Mobile computing* (IEEE TMC) and an editorial board member of several journals. He has also served as TPC Co-Chair for IEEE Globecom and ICC.

Jaime lloret received his B.Sc. + M.Sc. in physics in 1997, his B.Sc. + M.Sc. in electronic engineering in 2003, and his Ph.D. in telecommunication engineering (Dr. Ing.) in 2006. He is associate professor at Polytechnic University of Valencia. He has authored 22 book chapters and has more than 450 research papers published in national and international conferences and international journals. He is IEEE Senior Member, ACM Senior Member, and IARIA Fellow.

aSHfaq KHOKHar, is a professor and Palmer Chair of the Electrical and Computer Engineering Department at Iowa State University and a recipient of the prestigious NSF CAREER Award He has published over 260 technical articles in peer reviewed conferences and archival journals. His research work has received several outstanding paper awards. Khokhar was elevated to the grade of IEEE Fellow in 2009 for his work on multimedia computing and databases.

raHeem BeyaH is the Motorola Foundation Professor and an Associate Chair in the School of Electrical and Computer Engineering at Georgia Tech. He is also a co-founder of Fortiphyd Logic, which provides cybersecurity solutions for industrial control systems (ICSs). He received the NSF CAREER award in 2009. He is a member of AAAS, ASEE, a lifetime member of NSBE, a senior member of IEEE, and an ACM Distinguished Scientist.

antOniO SancHez [M'07, SM'07] received the Ph.D. degree in the field of QoS over IP networks from the University of Valladolid, Spain, in 2004. He has managed innovation at Telefonica, has been an adjunct professor and honorary collaborator at the University of Valladolid, supervising several Ph.D. students. He has coordinated very large international R&D projects and has over 50 international publications and several patents. His current research interests include digital services and machine learning.

Wael GuiBene is a senior systems engineer at Intel, based in Santa Clara, USA. Prior to this, he was a research scientist at Intel Labs working on next generation Internet of Things technologies and protocols. Before joining Intel, he worked for Semtech as a wireless protocol engineer for LoRa/LoRaWAN. Prior to that, he worked at EURECOM on EU projects related to 4G/5G. His research interests include 5G, M2M/IoT, and E2E system architecture.