Challenges and Solutions for LTE and 5G based V2X Communications

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A short bio of the tutorial speaker:

Yi Qian is a professor in the Department of Electrical and Computer Engineering, University of Nebraska-Lincoln (UNL). Prior to joining UNL, he worked in the telecommunications industry, academia, and the government. His research interests include information assurance and network security, network design, network modeling, simulation and performance analysis for next generation wireless networks, wireless ad-hoc and sensor networks, vehicular networks, smart grid communication networks, broadband satellite networks, optical networks, high-speed networks and the Internet. He is serving on the editorial board for several international journals and magazines, including serving as the Associate Editor-in-Chief for IEEE Wireless Communications Magazine. He was the Chair of IEEE Communications Society Technical Committee for Communications and Information Security 2014-2015. He is the Technical Program Committee Chair for IEEE ICC 2018. He is a Distinguished Lecturer for IEEE Vehicular Technology Society & a Distinguished Lecturer for IEEE Communications Society.

Prof. Qian received the Henry Y. Kleinkauf Family Distinguished New Faculty Teaching Award in 2011, and the Holling Family Distinguished Teaching Award in 2012, both from University of Nebraska-Lincoln. In the recent years, he has been a frequent speaker on many topics in his research areas in various venues and forums, as a keynote speaker, a tutorial presenter, and an invited lecturer.

Abstract:

A wide variety of work has been down in vehicle-to-everything (V2X) communications to enable various applications for road safety, traffic efficiency and passenger infotainment. Although IEEE 802.11p used to be considered as the main technology for V2X, new research trends nowadays are considering cellular technology as the future of V2X due to its rapid development and
ubiquitous presence. This tutorial surveys the recent development and challenges on 4G LTE and 5G mobile wireless networks to support efficient V2X communications. In the first part, we highlight the technical motivations of 4G LTE for V2X communications. In the second part, we explore the LTE V2X architecture and operating scenarios being considered. In the third part, we discuss the challenges and the new trends in 4G and 5G for supporting V2X communications such as physical layer structure, synchronization, resource allocation, security, multimedia broadcast multicast services (MBMS), as well as possible solutions to these challenges. Finally, we discuss some open research issues for future 5G based V2X communications.

**Keywords:**
V2X communications, intelligent transportations, 4G, LTE, 5G wireless networks

**Objectives and Motivation:**

There have been many recent research activities to address the communication capabilities in vehicles and transportation infrastructure, which mainly include vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P) and vehicle-to-network (V2N) communications collectively termed as vehicle-to-everything (V2X) communications. This V2X communications can improve the efficiency and safety of transportation systems. V2X communications together with existing vehicle sensing capabilities provide support for enhanced safety use cases, passenger infotainment and vehicle traffic optimization. V2X communications should support variety of use cases like forward collision warning, do not pass warning, queue warning, parking discovery, optimal speed advisory, curve speed warning, etc.

Currently there exists two main technologies to support V2X communications: dedicated short-range communications (DSRC) and cellular network technologies. DSRC technology is mainly considered to support intelligent transportation system (ITS) applications in V2V scenarios. DSRC technology supports short exchange of information among DSRC devices for automotive and ITS. DSRC devices include onboard units (OBU), roadside units (RSU) and hand held devices carried by pedestrians. U.S. Federal Communication Commission (FCC) has allocated 75 MHz of spectrum in 5.9 GHz frequency band to be exclusively used for DSRC based applications. Set of services and interfaces have already been defined by IEEE 802.11p and IEEE 1609 standards, for Wireless Access for Vehicular Environment (WAVE), to be used in DSRC based applications. U.S. National Highway Traffic Safety Administration (NHTSA) worked with U.S. Department of Transportation to enable vehicular communication capabilities in new light vehicles by 2017. However, lack of infrastructure and other limiting feature of IEEE 802.11p diverted some researchers to look for other access technologies. Introduction of device-to-device (D2D) communications improved spectrum utilization efficiency and system capacity in cellular system. The limitations of DSRC and recent advancements in cellular technologies like D2D communications motivated research communities to investigate 4G LTE based V2X communications.

LTE based V2X communications can make use of high capacity, large cell coverage range and widely deployed infrastructure to support vehicular communications. Due to which the 3rd
Generation Partnership Project (3GPP) is currently working on cellular technology based V2X service and aims to provide a variety of V2X services. 3GPP has already completed its Release 14 with LTE based V2X service as one of the main features including other features like license assisted access, machine type communications, massive MIMO. Cellular-V2X Release 14 provides highly reliable, real time communications for automotive safety use cases. It will continue to evolve to Release 15 along with 5G to provide complementary and new capabilities like sensor sharing while maintaining backward compatibility. The technical organizations like 3GPP and Qualcomm have already prepared the roadmap towards 5G based V2X services. There is also active research being conducted in interworking between DSRC and cellular technology to support efficient V2X communications.

In this tutorial, we provide a comprehensive survey on state-of-the-art of various works on 4G LTE and 5G to support V2X communications. We illustrate that how strengths of LTE such as high capacity, wide coverage, high penetration to complement the drawbacks of 802.11p. We also show that several challenges lie ahead before LTE can be massively deployed in vehicular environment. The main challenge identified in supporting V2X services will be high relative mobility causing Doppler Effect and dense UEs. LTE systems need to be enhanced especially physical layer structure to address the problem of this Doppler Effect. Resource allocation will be another challenge where resources being used by the vehicular system should not conflict with the resources being used by cellular users. Interference from vehicular user to the existing cellular user need to be taken care while assigning resources. Another main challenge will be the security. As V2X network will be controlled by operator, operator can easily track the vehicular users. Several solutions have been proposed in 3GPP to address this problem. Broadcast system MBMS should be enhanced in order to better support the safety message dissemination. 3GPP has already completed work for Release 14 and is currently working for further LTE evolution and new air interface design to support vehicular communication based on 5G.

**Proposed Duration:**

Half-day

3.5 hours of instruction

**Intended Audience:**

Graduate students, professors, researchers, scientists, practitioners, engineers, industry managers, consultants, and government agencies.

**A description of the technical issues that the tutorial will address:**

There have been many recent research activities to address the communication capabilities in vehicles and transportation infrastructure, which mainly include vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P) and vehicle-to-network (V2N) communications collectively termed as vehicle-to-everything (V2X) communications. This V2X communications can improve the efficiency and safety of transportation systems. V2X
communications together with existing vehicle sensing capabilities provide support for enhanced safety use cases, passenger infotainment and vehicle traffic optimization. V2X communications should support variety of use cases like forward collision warning, do not pass warning, queue warning, parking discovery, optimal speed advisory, curve speed warning, etc.

The proposed tutorial not only covers the current research and development on V2X communications for 4G LTE mobile wireless networks, but also the latest development on V2X communications for 5G mobile systems, and the unique discussions on the challenges and open research issues in the area, based on the tutorial speaker’s own research experience and comprehensive surveys on the subject.

Outline of the tutorial content & tentative schedule:

1. Motivation for 4G LTE based V2X Communications (20 minutes)
   a. DSRC based V2X communications
   b. LTE based V2X communications and the advantages
2. LTE V2X infrastructure and operating scenarios (60 minutes)
   a. 4G LTE V2X communication model
   b. 3GPP LTE V2X communication architecture
   c. Operating scenarios
      i. Multiple operators for a given area with each UE using spectrum of its own operator
      ii. Multiple operators for a given area with dedicated spectrum for V2X
      iii. Single operator for a given area
      iv. Out of cellular coverage
3. Challenges and solutions in 4G and 5G for supporting V2X communications (60 minutes)
   a. Physical layer structure
   b. Synchronization
   c. Resource allocation
   d. Security and privacy
   e. Multimedia broadcast multicast services
4. Open research issues for future 5G based V2X communications (30 minutes)
   a. Emerging 5G technologies and V2X communications
   b. Vehicular cloud computing
   c. Vehicular fog computing
   d. Security and privacy in 5G V2X communications
5. Conclusion (10 minutes)

Previous tutorial delivery of the speaker:

Yi Qian has given several tutorials in various IEEE conferences recently:
• Yi Qian, “Challenges and Development for 5G Wireless Network Security”, IEEE GLOBECOM 2017, Singapore, 2:00 pm - 5:30 pm, December 8, 2017.


• Yi Qian, “Security in 4G & 5G Mobile Wireless Networks”, IWCMC 2017, Valencia, Spain, 9:00 am - 12:00 noon, June 26, 2017. The classroom was full, with about 30 registered attendees.


• Yi Qian, “Security for Next Generation Mobile Wireless Networks”, IEEE VTC 2016 Spring, Nanjing, China, 8:30 am - 12:00 noon, May 15, 2016. The classroom was full, with about 25 registered attendees.

• Rose Qingyang Hu and Yi Qian, “Recent Advances in Communication Infrastructures for Smart Grid”, IEEE ICC 2014. The classroom was full with the attendees.

• Rose Qingyang Hu, Yi Qian, Qian Li, “Towards Spectrum and Energy Efficient Heterogeneous Wireless Networks”, IEEE WCNC 2013. The classroom was full with the attendees.

• Dusit Niyato, Rose Qingyang Hu, Ekram Hossain, Yi Qian, “Communications and Networking for Smart Grid Systems”, IEEE GLOBECOM 2011. With more than 100 attendees.


References:


