PhD Proposal 2016

<u>School</u>: **Ecole Centrale de Lille**	
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Title: **Control and Optimization in Vehicular Networks**

Scientific field: **Advanced Control, Optimization & System Reliability**

Key words: **Intelligent Transportation Systems (ITS), Optimization, Decision Making, Traffic Simulation, Performance Analysis**

- **Context:**
- Cooperation program between Professors Liming ZHANG (U. of Macau) and A. EL KAMEL (EC Lille/CRIStAL) started in 2013
- Cooperation program between Professors Zhuoyue SONG & Yue YU (Beijing Institute of Technology, BIT) and A. EL KAMEL (EC Lille/ CRIStAL) started in 2012
- Cooperation program between Professors G. GONG (Beihang U., BUAA/AST Key-Lab), S. WANG (Beihang U., BUAA/MC Lab) and A. EL KAMEL (EC Lille/ CRIStAL) started in 2007
- Joint project, involving the 3 partners in the frame of China-French Network LIA 2MCSI
- A. EL KAMEL is Regular Visiting Professor to BUAA since 2008 involved in KEY-Projects, to BIT since 2013 in charge of two courses and to U. of Macau
- Visiting Professor position at EC Lille to G. GONG (2009), to S. WANG (10) & to Z. SONG (15)
- 6 CSC-supported PhD dissertation by Jin ZHAO in 2010, Minzhi LUO in 2012, Yue YU & Tian ZHENG in 2013, Daji TIAN in 2014, Chen XIA in 2015, Bing LIU in 2016
- 3 Chinese PhD students, with CSC support, are now working in my Research Group

Detailed subject

- **Background:**

Intelligent Transportation Systems (ITS) can be broadly defined as the application of advanced technologies, such as communications, sensors, and computing, to the transportation systems, in order to supply real-time information to improve safety, efficiency and comforts, at the same time reduce the impact to environment.

The development of ITS depends on results from research activities in many different areas such as electronics, control, communications, sensing, robotics, signal processing and information systems. This multidisciplinary nature increases the problem's complexity due to the requirement of knowledge transfer and cooperation among different research domains. The purpose of ITS is to take advantage of the appropriate technologies to create more intelligent roads, vehicles and users.

Autonomous vehicles and vehicular ad hoc networks (VANET) are two booming directions in research and development. The combination of these two aspects is considered to be highly potential to improve the safety and efficiency of road transportation. A vehicle in VANET doesn't have to detect the environment all by itself (such as the autonomous vehicles today), but with the help of other vehicles and roadside infrastructures. Thus the vehicle's range of awareness can be greatly extended.
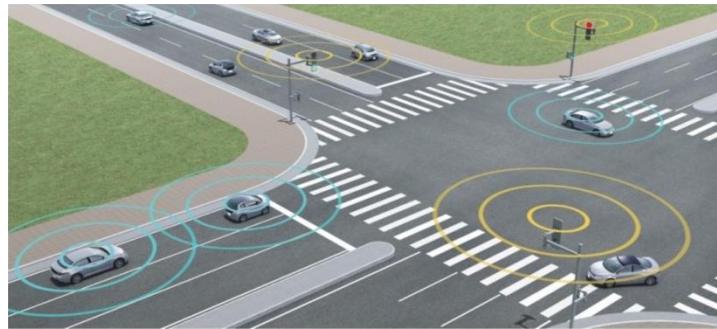

Figure 1 VANET in vicinity of an intersection

For example, if VANET is applied in vicinity of intersection, on one hand, the traffic lights could be more intelligent: the information of vehicles, such as their number in each lane, their positions and speed, can be acquired via V2I (vehicle to infrastructure communications), so that the lights can optimize their timing in order to reduce the queue length; on the other hand, vehicles can also be intelligent: given the information of the surrounding vehicles and the signal timing of traffic lights, a vehicle can optimize its trajectory to get through the intersection with no collision, reduced delay and reduced fuel consumption.

Researchers in our group have been working on this subject for years. Many approaches in the context of connected autonomous vehicles are proposed, such as

- Cooperative adaptive cruise control in vicinity of intersections (CACC-VI), which is used to improve the throughput of intersections by taking advantage of the redundant road capacity and reorganizing the current vehicular platoons.
- Trajectory planning for autonomous intersection management (TP-AIM), which is used to manage the intersection in an autonomous way (without traffic lights) by planning the trajectories locally for each vehicle.
- Longitudinal and lateral control of vehicles to maintain safe distance to preceding vehicle, to overtake autonomously.
- The communication protocols in VANET and the impact of service quality on vehicle control.

☐ **Work plan, Research program:**

- To establish possible interaction ways between vehicles and infrastructures in ITS in order to improve the efficiency while guaranteeing safety
- To investigate the impact of penetration rate of connected autonomous vehicles on the designed approaches
- To find the way how the connected autonomous vehicles interact with normal vehicles
- To study the scalability of the approaches when applied in larger scenarios, e.g. several neighboring intersections, road network in a city
- To integrate fault tolerant mechanism in the approaches to deal with errors in communication and in vehicle model

- **References:**

[1] Liu, B., & El Kamel, A. (2016). V2X-Based Decentralized Cooperative Adaptive Cruise Control in the Vicinity of Intersections. IEEE Transactions on Intelligent Transportation Systems, 17(3), 644-658.

[2] Liu, B., Sun, Q., & El Kamel, A. (2016). Improving the Intersection's Throughput using V2X Communication and Cooperative Adaptive Cruise Control. IFAC ICONS 2016, Reims, 49(5), 359-364.

[3] Liu, B., & El Kamel, A. (2016). Trajectory Planning for Autonomous Intersection Management using Communications. IEEE Transactions on Intelligent Transportation Systems, 1st revision.

[4] Liu, B., Zhang, J., & El Kamel, A. (2016). Decentralized Autonomous Intersection Control using V2X Communications. Journal of Intelligent Transportation Systems, Under review.

[5] Liu, B., Sun, Q., & El Kamel, A. (2016). Cooperative Driving for Connected Autonomous Vehicles at Intersection. IEEE ITSC 2016, 8th International Workshop on Planning, Perception and Navigation for Intelligent Vehicles, Accepted.

[6] Liu, B., Zhang, J., & El Kamel, A. (2016). Decentralized Autonomous Intersection Control in Connected Vehicle Environment. IEEE ITSC 2016, 6th International Workshop on Artificial Transportation Systems and Simulation, Accepted.

[7] Sun, Q., EL Kamel, A. & Liu, B. (2016) Decentralized Longitudinal Tracking Control for Cooperative Adaptive Cruise Control Systems Based on Multiple V2V Communication. ICSTCC 2016, Sinaia.

[8] Yu, Y., El Kamel, A., & Gong, G. (2014). Modeling and simulation of overtaking behavior involving environment. Advances in Engineering Software, 67, 10-21.

[9] Jin, Z. H. A. O., & El Kamel, A. (2009). Integrated longitudinal and lateral control system design for autonomous vehicles. IFAC Proceedings Volumes, 42(19), 496-501.

[10] Zhao, J., Oya, M., & El Kamel, A. (2009, June). A safety spacing policy and its impact on highway traffic flow. In Intelligent Vehicles Symposium, 2009 IEEE (pp. 960-965). IEEE.