Probabilistic predictive analysis of smart city IoV networks

CONTEXT AND OBJECTIVES

The technological rise is moving towards a digital world in which a large number of highly intelligent and connected devices are widely deployed and collecting versatile data, in the shade of what is known today the Internet of Things (IoT) and smart cities. This revolution is spreading across all aspects of our lives and impacting all industries, and the automotive sector is not an exception. Modern vehicles and road infrastructure are slowly becoming more and more IoT-enabled, and contributing to make users better informed about the traffic flow, and allow safer, more coordinated and smarter the transportation network [3]. This ecosystem lays the foundation for a whole new promising field known as the Internet of Vehicles (IoV), joining the areas of intelligent transportation systems, vehicular wireless communications, and mobile cellular networks [1].

The IoV entails Vehicle-to-X (V2X) communications with third party entities X (vehicles, stationary road-side devices, infrastructure, buildings, pedestrians, etc) through adapted networking technologies and standards (IEEE 802.11p, LTE-V, 5/6G, etc). All sensors inside and outside of a vehicle gather endogenous and exogenous information (such as speed and position, oil and tire pressures, forward obstacles, weather and road conditions, etc) to be shared, in real-time, with the other IoV entities. They are then interpreted in order to, not only understand the circulation circumstances, manage road congestion and streamline the traffic flow, but also mitigate potential accidents and perform urban surveillance. The IoV technologies are currently embryonic, and still more of an R&D domain. Only a small part of the industrial efforts is available to the public as trial testing versions [1]. Safe driving is among the main challenges facing the behavioral control of vehicles under a massive deployment of IoV systems, in surroundings that are becoming more and more ambient, open and hazardous. Cooperative accident avoidance systems are expected to use the different IoV entities to warn the drivers in real-time of impending dangers so that they take corrective actions, or intervene on their behalf. Vehicular networking technologies and their highly dynamic topology (bearing in mind the increasing number of vehicles) directly impact safety, timing, and message criticality requirements. The study of their underlying latency, end-to-end delay, throughput, scheduling, and packet delivery success rate are mandatory not only in software design and network analysis, but also to perform urban tests [3].

POSTE ET MISSIONS

This doctoral project aims to predict by abstraction and analyze (simulate and verify) the integrity of IoV systems with regards to safety driving requirements, under real city traffic scenarios constrained by probabilistic connectivity metrics (on data rate, bandwidth, signal strength, congestion, etc). To this end, the interactive behavior of IoV entities is of a cornerstone importance to reach the required high level of system integrity. It should be specified and analyzed in relation to concrete traffic scenarios mapped to time-driven probabilistic distributions of connectivity metrics. For example, in a particular position at a specific time in the traffic scenario, this predictive analysis make it possible to decide (with respect to the connectivity metrics of that position and time) which critical messages should be privileged by the IoV interactions to guarantee safety requirements [3, 4]. This kind of decisions could be taken by computing the probability p of some connectivity property ϕ to be satisfied (quantitative analysis), and verifying if p is grater than a certain threshold θ (qualitative analysis). An interesting perspective of this project is to use machine learning techniques to reach, from real/random congested (diminished) traffic scenarios, IoV models allowing a smoother traffic flow with optimized connectivity metrics.

Traffic scenarios could be shaped and emulated by urban mobility simulation tools like SUMO [1], and interfaced with networking simulators (like ns-3 [2] and Omnet++ [3]). Formal stochastic IoV models could be then analyzed in relation to these scenarios using statistical model checkers like UPPAAL-SMC [2] and PLASMA Lab [5]. A stochastic-free similar approach of connected rescue drones is presented in [6].

[1] https://sumo.dlr.de/docs/Tutorials/Import_from_OpenStreetMap.html

[2] https://www.nsnam.org

[3] https://omnetpp.org

After studying the state of the art on IoV systems in the light of the previous issues and challenges, the work could be conducted by following these steps:

1. setup of a suitable modeling, verification and simulation environment using the aforementioned tools;
2. carry out a theoretical analysis of relevant IoV models based on the propositions previously introduced;
3. prototype IoV software applications based on these models and, evaluate their reliability under candidate run-time and hardware platforms;
4. perform outdoor urban experiments.

References

[1] L.-M. Ang, K. P. Seng, G. K. Ijemaru, and A. M. Zungeru. Deployment of IoV for smart cities: Applications, architecture, and challenges. *IEEE Access*, 7:6473–6492, 2018.

[2] A. David, K. G. Larsen, A. Legay, M. Mikučionis, and D. B. Poulsen. UPPAAL-SMC tutorial. *Int. Journal on Software Tools for Technology Transfer*, 17(4):397–415, 2015.

[3] S. Djahel, R. Doolan, G.-M. Muntean, and J. Murphy. A communications-oriented perspective on traffic management systems for smart cities: Challenges and innovative approaches. *IEEE Communications Surveys & Tutorials*, 17(1):125–151, 2014.

[4] L. George, D. Masson, and V. Nélis. Selective Real-Time Data Emission in Mobile Intelligent Transport Systems. In *Proc. of the 5th Int. Workshop on Mixed Criticality Systems*, Paris, France, 2017.

[5] C. Jegourel, A. Legay, and S. Sedwards. A platform for high performance statistical model checking – PLASMA. In *Proc. of the Int. Conference on Tools and Algorithms for the Construction and Analysis of Systems*, pages 498–503. Springer, 2012.

[6] S. Mouelhi, M.-E. Laarouchi, D. Cancila, and H. Chaouchi. Predictive formal analysis of resilience in cyber-physical systems. *IEEE Access*, 7:33741–33758, 2019.

DESIRED SKILLS & APPLICATION

Minimum qualifications: master or engineering degree in computer sciences and/or networking.

Additional knowledge topics: wireless networking, formal methods, machine-learning, embedded applications ...

Programming and working environment: C/C++, Ada, Python, Liunx ...

Proven written and verbal communication skills.

Hard working, open minded, autonomous.

Application documents: Detailed CV (grades, training, projects, tools, skills, etc), cover letter (futur projects, and motivations), scores of the last two years, reference contacts, recommendations letters are appreciated.

CONTACT

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INSTITUTION

ESTACA (an engineering school belonging to the ISAE group, and accredited by the CTI (Commission des Titres d'Ingénieurs) is a major player in the engineering training of in the fields of transportation and mobility. Located on 2 sites (Saint Quentin en Yvelines and Laval), it hosts 2000 students.

JOB LOCATION

RESEARCH DEPARTMENT

☐ POLE MECANIQUE DES STRUCTURES COMPOSITES ET ENVIRONNEMENT (MSCE)

☐ Qualité de l'air ☐ Allègement

☑ POLE SYSTEMES ET ENERGIE EMBARQUES POUR LE TRANSPORT (S2ET)

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CAMPUS

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