Interoperability of vehicular communication technologies in smart cities

– Ph.D proposal in computer science –

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Context and challenges

One research topic developed by the Network and Telecommunication team relies on vehicular networks. Significant results have been got on the assessment of wireless links quality and the prediction of the link failure [GHD+14] [LDD+16] [BCH16]. Another contributions have addressed issues about data diffusion in autonomous unmanned vehicles [BCHL17]. Designed solutions combine distributed algorithms and signal processing, applied to wireless mobiles networks. This approach has the main benefit to make possible the design of solutions going from the physical to the application layer.

In a novel project, the team aims to work on communication between vehicles and the infrastructures of a smart city. This topic opens the way to applications such as the real-time traffic management in urban areas. This is a major issue in France, since during the period 2011-2016 the number of private vehicles has increased (+742000) as well as the number of distance traveled (+582km) [INS17b]. At the same time, the increase in registrations of new vehicles [INS17a] embedding communication interfaces, i.e. Bluetooth, Wi-Fi or cellular networks allow for vehicles to communicate each other and with the urban infrastructure. The goal of the proposed Ph.D is to improve the interactions between vehicles and the infrastructures of smart cities, especially in crossroads for the management of the road traffic [DDMM15].

Research project

The proposed topic is going to continue the current Ph.D thesis carried out in the team. It is divided into two parts. The first one is focusing on the management of multiple communication interfaces embedded in a vehicle. Marvell and Qualcomm are the major manufacturers developing systems on chips (Marvell 88W8987xA, Qualcomm QCA6584AU and Qualcomm C-V2X 9150) including Bluetooth, IEEE 802.11p and 802.11ac interfaces. Inter vehicular communication can be performed with IEEE 802.11p interfaces [JD08] but also with Bluetooth interfaces [BFCE16]. The exchange of data through multiple interfaces enables the send of data streams between an emitter and a receiver. The allocation of flows sent by interfaces can be considered as a multi-commodity flow problem [BCLR03] in

dynamic graphs [CFQS11]. We assume that nodes can be mobile and the links capacity mused be fair, with the possibility of applying additional constraints. This part will be devoted to the design of a load balancing algorithm between embedded communication technologies. This algorithm will be tested and validated with the JBotSim simulator [Cas15].

The second part of this thesis is about protocol engineering. The aim is to design a protocol that could be deployed over Wi-Fi, Bluetooth and cellular networks (4G/5G). It will implement the algorithm designed in the first part and deals with the optimization problem on the size of messages and the link capacity, in order to reduce loss rate, the bandwidth consumption and the overhead. Issues related to the management of queues dedicated to communication interfaces will be addressed. All these problems will be studied in a vehicular problematic, in a smart city environment. The protocol will be modeled and tested with the ns-3 network simulator [RH10]. It will also be implemented on a physical demonstrator deployed on a fleet of autonomous communicating electric vehicles as part of the SMART-UHA project.

The implementation of the protocol in a demonstrator will reinforce research results got previously. It will be a starting point for the development of innovative solutions of communicating vehicles and the intelligent cities of tomorrow. In addition, to the best of our knowledge, any similar solutions have been proposed.

Provisional schedule

Tasks of the thesis :

- State of the art
  - Study of different communication technologies embedded in vehicles,
  - Investigation of algorithms related to dynamic graphs and multi-commodity flow problems,
  - Determination of possible application scenario for a vehicular networks in a smart city environment.
- Design of algorithms and protocol
  - Prototyping the flow distribution algorithm,
  - Development of an algorithm to optimize the message size related to the loss ratio,
  - Integration of the designed algorithms into a protocol.
- Design of a physical demonstrator
  - Choosing the technological solutions for the demonstrator,
  - Definition of the evaluation context for the protocol,
  - Implementation and validation of the protocol in real situations.

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