PhD Student :

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Title :

Optimised management of a fleet of electric autonomous vehicles

Abstract

The last reports of environmental agencies show that our mobility system is unsustainable : emissions in the transportation sector have increased by 10% between 1990 and 2018 according to the high counsel for the climate, june 2019. One possible partial solution is to improve the performances of collective transportation systems. The key to the development of such systems is the budgetary constraint.
Therefore there exists an increasing need for more flexible Public Transports (PT) allowing to serve low density suburban areas with a limited cost, as well as a growing preoccupation concerning polluting emissions of urban and suburban PT. A possible answer to these challenges is the deployment of on-demand public transports based on a fleet of electric vehicles (Archetti et al 2018). In order to guarantee the necessary level of flexibility for on-demand transportation and to optimise the use of the fleet, the use of autonomous vehicles is often suggested. Several approaches exist to handle optimally situations with on-demand transportation, sometimes called Dial A Ride Problem (DARP) (Ho et al 2018). This type of transport has often been studied in very specific situations. A big part of the literature focuses on a taxi configuration where only one passenger is present in a given vehicle at all times (Hyland and Mahmassani 2018), or on cases with very specific requirements such as the mobility of handicaped people (Lehuédé et al 2014).
The working group « Navette autonome » of the federating project Infrastructure de transition énergétique regrouping more than 35 experts has proposed an innovative direction of research.
The thesis fits into this research direction. Its objective is the conception of optimisation algorithms for a planification tool for the use of autonomous electric vehicles in urban and suburban PT. This system is conceived as an evolution of High Level Service Buses (HLSB), adapted to lower population density areas compared to the typical areas served by HLSB. The infrastructure on which the vehicle will travel will be a dedicated infrastructure, with only a few intersections with regular traffic. It will be composed of a main central part and additional branches leaving and reentering the central part. On the central part the vehicle will follow a regular schedule while on the secondary branches it will provide an on-demand service. In this sense the problem will be fundamentally different from on-demand transportation problems studied up to now, whose main issue is usually to build the itinerary between the pickup and delivery points without worrying about inserting this inside an existing service. It will however be closer to the problems of railway traffic management for which the ESTAS and LEOST laboratories, which participate in this thesis, display a great scientific ability (Pellegrini et al 2014, 2015, 2016).
The demand on the secondary branches will be considered random, for example provided through a mobile application : the user will indicate the initial and final stations of his trip and the prefered pickup time. The planification tool designed during the thesis will decide which vehicle will handle each demand and in which order, all the while respecting the scheduled traffic on the central infrastructure. The objective of the optimisation algorithm will be to maximise the level of service (for example minimising the waiting time or the travel time of the passengers). The algorithm will have to provide a solution in real time : the problem is thus intrinsically dynamic and will necessitate frequent reoptimisations. Such problems usually call for the use of heuristic or metaheuristic algorithms to obtain good quality solutions in a limited amount of time : the host laboratories possess scientific skills on such algorithms recognised by several publications in international journals (Aringhieri et al 2016 ; Samà et al 2016). The algorithms will be tested on nominal scenarios as well as perturbed scenarios. The perturbations will be due to the behaviour of the users (e.g. delay with respect to the agreed pickup time or a door blocked on a vehicule), to the higher flow of passengers than anticipated, to hardware failure or to a change in the traffic light cycle at intersections along the route.
The autonomous characteristic of the vehicles implies the absence of constraints linked to the working time of the driver, while their electric propulsion imposes constraints in terms of residual charge and charging time.
After the conception and the evaluation of the algorithms, the fleet of vehicles proposed will be compared with a HLSB, inspired by those already working in different cities, that might cover the same territory. This comparison will allow to identify conditions in which the autonomous vehicles might be the most

advantageous PT system from different points of view (service provider, user and the environment). The performances of the new system will be studied considering the use of both autonomous vehicles and vehicles with drivers, in order to compare the costs, the constraints and the benefits of the two possibilities.
This subject is strategic for IFSTTAR since it is at the heart of research efforts on autonomous vehicles :
It allows to broaden the work of the postdoc financed by SNCF which will start in January 2020 with the same scientific supervisors but with a narrower scope compared to the thesis ;
It is an excellent complement to the work of project ENA (Expérimentation de Navettes Autonomes) on the limits of the speed of autonomous vehicles :
It runs in parallel to the work led by SNCF and IFSTTAR on the evaluation of the environmental impact of autonomous vehicles through the PhD thesis financed by ADEME and SNCF on the subject, the postdoc financed by the projet tremplin Mutandis in 2020 and the proposition of the project Impulsion Ame.
Therefore, IFSTTAR has a unique system knowledge and ability for this new transportation mode.
The thesis subject fits into axis 1 of the COP of IFSTTAR : Transporter efficacement et se déplacer en sécurité.
Moreover, the work achieved during this thesis will be integrated inside the federating project « Infrastructure de Transition Énergétique » of IFSTTAR. This will allow to include multi-disciplinary skills. Aspects of the definition of an energy efficient infrastructure (Bosquet et al 2014) will be considered, for example through the location of charging stations for the vehicles. Moreover, the recharging modality of the vehicles will also be studied in conjunction with the working group Route électrique of the federating project.

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