Efficiency determinants in intelligent transportation networks

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The advent of smart connected vehicles is changing the how the transportation networks operate in modern cities. The availability of constant data exchange technologies — vehicle-to-vehicle (V2V) as well as vehicle-to-infrastructure (V2I) models and the technologies for autonomous vehicles are being developed at a rapid pace. This technological shift brings new ways of transport network optimization - both for commuter traffic as well as for transportation system in general. One of the major challenges in this new emerging environment is to identify the optimal policies on how participants of such system are allowed to access road system and schedule their own routes. When full information on the system state is available the decisions optimal for individual users of the transportation network are not necessary globally optimal for the entire system — the state of transportation system naturally converges to Nash Equilibrium (NE) — however, the NE does not guarantee that the system is in a Pareto-efficient (that is other equilibria that are better for all users of a transportation system). Hence, on one hand, centralized decisions lead to a better equilibrium but on the other hand participants of the system (further in the text we will call them *agents*) have very strong motivation to not follow the central guidelines.

The goal of the project is to identify determinants for an optimal set of rules and regulatory policies for an intelligent transportation system. This is essentially a question on what determines the optimality of a mechanism design of such system where the agents cannot be assumed to follow the algorithm but rather try to optimize their own self-interest (the so called "free rider problem"). There are many complexity layers in this problem. Firstly, a modern transportation system consists of heterogeneous vehicle types (human driven smart/not-connected, autonomous) where where decisions are taken independently by drivers or AI-based solutions. Secondly, the problem is non deterministic — the flow of vehicles in the transportation system is changing constantly. Thirdly, such design should be able to work with real world transportation networks. Hence, the design of such mechanism includes incentivizing solutions (such as dynamic road utilization pricing, co-payment, co-financing), optimal route planning for swarms of vehicles with decision interdependence (decisions of one agent affects the decision of other agents) - in deterministic as well as stochastic environments.

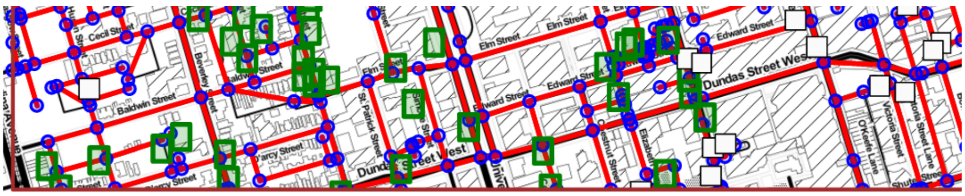

Figure 1: A sample agent based simulation state of a transportation system. Cars are marked with squares and intersections with circles.

The approach used this family of problems is agent based modeling and simulation (ABMS). In this approach a Digital Twin of a real city can be created (eg. see Figure). Such a digital twin can in turn be used for experimentation in order to understand and evaluate the outcomes of various regulatory policies. Once created tool is combined with a set optimization models and heuristics that can efficiently search for the best sets of rules and policies for a transportation system.