MATHEMATICAL MODELLING AND SIMULATION OF ELECTRIC VEHICLE CHARGING

Author: Ing. Miroslav Gardlo, Supervisor: doc. Ing. Ľuboš Buzna, PhD.

Faculty of management science and informatics

University of Žilina

MOTIVATION

With rising number of electric vehicles (EVs), load on the electric distribution network increases. In order to prevent congestion, a protocol controlling flow of electric power in the network might have to be designed and implemented in the future. The main goal of this thesis is to design, implement and analyze EV charging strategies capable of controlling assignment of electric power in decentralized fashion and potentially prevent network congestion.

EV CHARGING STRATEGY

EV charging strategy is a software agent that represents specific vehicle in the electric network during the charging process. Based on state information of the vehicle, including, but not limited to current battery level or time left for charging, the strategy computes a parameter called willingness to pay. This parameter is sent to the electric network, its purpose is to influence amount of assigned electric power.

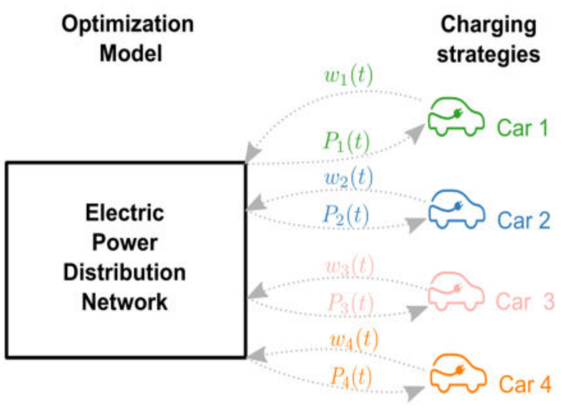

Figure 1. Concept of the proposed approach.

SIMULATION

EV charging strategies were studied using computer simulation, which was performed by two cooperating simulation cores. Event simulation core processes discrete events, such as car arrivals and car departures. Continuous simulation core is responsible for assigning electric power to EVs. Electric network collects willingness to pay parameters from all vehicles and the optimization algorithm is used to determine power allocations by solving SOCP constrained convex optimization problem. Objective function of the problem takes the form of proportional fairness, which has been shown to be effective for rate control in communication networks. After assignment of power, EVs recompute their willingness to pay or leave the network.

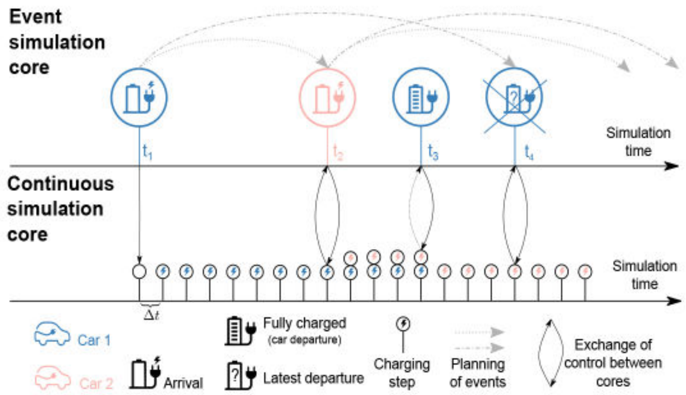

Figure 2. Cooperation of simulation cores illustrated on the example of Poisson arrival process of vehicles.

EXPERIMENTS

In the experiments, behavior of individual vehicles, groups of vehicles and average performance of the system was analyzed. In all experiments, vehicles arrive to the network with empty battery and leave when at least one of the following conditions is met: their battery is charged fully, maximum charging time elapses, or the budget reserved for charging is spent completely. It was shown that some EV charging strategies could create behavioral patterns that increase efficiency of the system as a whole. On the other hand, EV charging strategies focusing on maximization of individual utility may result in an excessive competition among the vehicles, which decreases system performance.

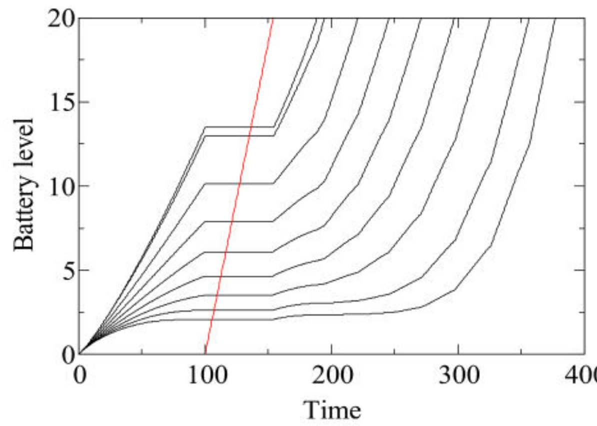

Figure 3. Evolution of the battery state for the scenario with "aggressive spender" (shown in red color). Other vehicles are able to avoid "aggressive spender" and we observe emergence of self-organized ordering in charging based on the budget that charging strategies are allowed to spend.