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Exploring Future Transportation Scenarios

Subtitle

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***Abstract*—Increasing awareness of the environmental impacts of driving has spawned many recent approaches addressing energy-efficient vehicle behavior in the context of Intelligent Transportation Systems (ITS). To address this situation, we propose an approach which is capable to address the objectives and the utilization of different infrastructures of traffic participants, charging stations and the electricity grid.**

***Keywords*—component; formatting; style; insert**

I. Introduction and Motivation

Increasing awareness of the environmental impacts of driving has spawned many recent approaches addressing energy-efficient vehicle behavior in the context of Intelligent Transportation Systems (ITS). Taking consistent steps towards CO2 reduction and independence from fossil fuels, in recent time, hybrid electric vehicles (HEV) and electric vehicles (EV) have seen increased attention in research. In this context, addressing both (1) energy-efficient vehicle coordination and (2) energy-efficient driving behavior of individual vehicles remains a challenge. For future transportation systems it is crucial to understand the resulting interactions between these concepts.

II. Related Work

A. Approaches

When examining energy-efficient vehicle coordination, two directions of approaches can be distinguished: For one, Urban Traffic Control (UTC) approaches describe the behavior of and the interactions between multiple traffic participants. Facilitating traffic supervision and control, they impose objectives of congestion avoidance and collision avoidance on a global level on the traffic infrastructure. Secondly, focusing on Electric Vehicles, approaches balancing charging demand across different charging stations within the traffic infrastructure are another direction. In terms of their objectives, specific approaches help reducing the potential for queuing at charging stations [1, 2] and/or help to avoid overloading in the electricity infrastructure at charging stations [3]. When looking at energy-efficient driving of individual traffic participants, Eco-Driving/Eco-Routing approaches target energy-efficient driving behavior. In terms of their objectives, Eco-Driving approaches target energy-efficient route selection, while Eco-Routing approaches target energy-efficient intermediate driving behavior.

B. Limits of Related Work

Approaches for balancing charging demand mainly focus on the interactions between EVs and charging stations within a given traffic infrastructure independent of electricity infrastructure interactions and its reactiveness to changing objectives. Demand alleviation at charging stations remains the main objective an underlying electricity infrastructure with a given set of objectives is not considered in detail. However, rapidly changing objectives are considered through exploring alternative options in terms of charging stations to drive to, based on current suitability. Approaches for balancing charging demand also mainly neglect energy-efficient routing/intermediate driving behavior. On the other hand side, while current eco-routing/-driving approaches consider energy-efficient driving behavior on a given route, they dont consider interactions with and objectives of charging stations and the electrical infrastructure. Furthermore, Eco-Routing/-Driving approaches do not employ global planning of the individual traffic participants routes and interactions, therefore coordination between multiple vehicles remains an issue, which is only partially alleviated by incorporating real-time traffic information. Because of this, especially Eco-Routing approaches are susceptible to congestions and do not address rapidly changing objectives. Consequently, all approaches have in common that they aim to address the objectives of energy-efficient system behavior. However, the presented approaches are limited in their scope and objectives and dont consider interfacing infrastructures and factors at play.

III. Contribution

To address this situation, we propose an approach which is capable to address the objectives and the utilization of different infrastructures of traffic participants, charging stations and the electricity grid. The main contributions of this paper are:

1) Extension of an existing lightweight approach to traffic flow modeling with electric infrastructure components.

2) Description of a lightweight approach to modeling future transportation scenarios and exploring their dynamics.
3) Demonstration of the approach including a basic traffic network with electric vehicles and power grid with charging stations.

Our objective in this paper is to extend initial work described in [4] regarding early multi-objective traffic flow estimation and demonstrate the variability of the approach for traffic flows depending on different infrastructures and their imposed objectives.

IV. Method

Our approach is based on emergent property estimation techniques [5] and their adaption to the ITS domain [4]. The approach facilitates the formulation of traffic flow as an optimal control problem consisting of state variables, control variables, constraints and objectives. For behavior estimation the approach employs a generic solver. We extend our work with power grid and transportation scenario modeling as shown in Figure 1. The models include objective, situation and infrastructure parameters both for the power grid and the traffic network.

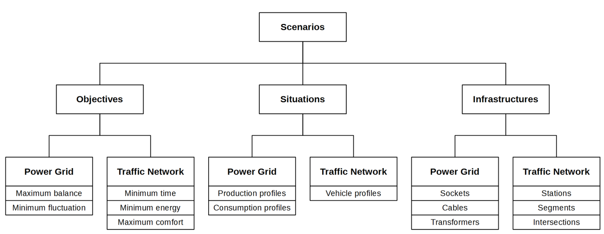

Fig. 1. Overview of transportation scenario modeling including objective, situation and infrastructure parameters for the power grid and the traffic network.

In the following, the parameters for describing the objective, situation and infrastructure configurations are explained in detail.

A. *Scenarios*

B. *Objectives*

In essence, objectives represent operational costs of the traffic network and the power grid. To ease modeling, we distinguish two main categories:

1) *Global objectives* applying to infrastructures, e.g. objectives for the traffic network, such as minimum travel times, or the power grid, such as maximum load balance.
2) *Local objectives* applying to single components such as routing criteria for traffic participants or charging objectives for charging stations.

Note that Figure 1 only concentrates on the global objectives, which typically aggregate the local objectives by means of respective weights.

C. *Situations*

The situation mainly includes the individual traffic participants and loads on the power grid (i.e. production and consumption profiles). In our scenario, traffic participants travel from given origins and to specific destinations on the traffic infrastructure. As traffic participants start out with different levels of state of charge and depending on distance from the destination, charging stations can be utilized by the traffic participants: In order to reach their respective destinations, traffic participants can recharge at charging stations. While travelling, based on their local objectives, costs are incurred for the traffic participants. Local costs, i.e. the costs of individual traffic participants are aggregated at system level.

D. *Infrastructures*

Within our system model the employed infrastructure can be distinguished into two main parts: The traffic infrastructure and the electricity infrastructure. The traffic infrastructure is modelled as a directed graph, whereby nodes represent reference points in the environment such as intersections, while edges in the graph represent road segments between these reference points. Nodes are defined by absolute position based on real-world coordinates, i.e. latitude, longitude, and elevation. Edges, i.e. road segments are defined through source and target node. Furthermore, they are also defined through an assigned number of lanes, a possessed road type, such as residential streets or highways, and a capacity which regulates in- and outbound traffic flow. The electricity infrastructure is defined by components connected to each other via an electricity grid. It contains the charging stations, which facilitate the charging process of traffic participants. Bridging the gap between traffic infrastructure and electricity infrastructure, charging stations can be assigned to given road segments within the traffic infrastructure.

V. Demonstration

VI. Discussion

VII. Conclusion and Future Work

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