A Holistic Framework for Addressing Challenges in the Energy and Mobility Sectors

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Abstract

Surplus energy from renewable energy sources can be stored in electric cars, which is a boon to the industry, but this might potentially clash with meeting the needs of electric vehicle owners who want to keep their vehicles mobile. Both previous and future efforts at DAI-Labor have focused on these two facets of management. Energy and mobility are two benefits of electric automobiles. We created standardized domain models characterizing the many facets of the e-mobility domain to standardize and ease advancements across these initiatives. Many of our solutions make use of such domain models to optimize charge schedules and guarantee user mobility.

1. Introduction

True, energy and mobility don't seem like they'd have much in common at first glance. Although, with the revival of electric cars, it is becoming more obvious that solutions from the former may contribute to the latter, and vice versa. Consider the many initiatives to use EVs in solving problems that are mostly associated with power grid infrastructures, such as decreasing peak loads, boosting the utilization of renewable energy, and supplying regulatory energy. Most of these problems may be resolved by strategically placing electric car charging and feeding stations. However, this location may not be ideal for meeting the needs of unrestricted EV use, such as predetermined charging levels during times of vehicle need. On the other hand, smart grid designs are being utilized in several projects to boost the performance of electric cars in a variety of ways, including reducing their effective emissions, increasing their availability, and decreasing their total cost of ownership. Existing methods include incorporating electric cars into energy production facilities and meeting their energy needs with locally generated electricity. Still other methods use tried-and-true commercial methods with innovative new ones, such as shared-use electric vehicle fleets. Although these strategies improve the marketability of electric cars, they often come at the price of the reliability of the power infrastructure that supports them.

Though energy and mobility are inextricably linked, there have been few efforts to examine both factors simultaneously (e.g. Ruelens et al. 1). The lack of real-world experience with EVs and smart grid systems may be a contributing issue, although the exact cause is unclear. This work aims to do just that, outlining a method that takes mobility- and energy-related considerations into account. Only via the accumulation of data from both fields can such a solution emerge. Therefore, we proceed to offer finalized energy (see Section 2.1) and transportation projects (see Section 2.2). We then

Highlight the rising energy and transportation issues by outlining the needs of ongoing initiatives (see Section 3). Section 4 presents our domain-specific solutions, from which the needs for a broader strategy are derived. In Section 5 we go through these prerequisites in detail.

2. Previous Work

Too far, we have produced answers to issues concerning both energy and transportation. In what follows, we showcase these works and highlight the developing relationship between the two fields.

Energy Management

Over the last two decades, there have been extensive changes to the markets for energy production, distribution, and consumption in terms of their general infrastructure, the technological features of control and communication methods, and legal and regulatory considerations. Current difficulties include better management of energy generation, distribution, consumption, metering, and control systems, as well as general improvements in grid efficiency. Time spent on the road and pollution generated by vehicles may be cut in half with the help of e-mobility and driver aid systems. These systems include details like traffic conditions and the ability to reserve parking spots and charge stations in advance. The same strategy is applicable to transportation in the business world. Both scenarios require the creation of novel business models due to the presence of several parties with competing interests. Large battery storage systems, rather than user-owned assets like car batteries, can meet the needs of most generating and transmission services, which need capacities of a few megawatts to hundreds of megawatts. However, a pool of car batteries, for example, may be operated as a single entity with the help of a full IT-infrastructure to accomplish the dispatch of required capabilities. For this method to operate, a certain amount of centralized authority is needed so that a distribution network operator may be given the authority to regulate the charging and discharging of a fleet of cars (cf.2p. 2). Energy storage systems can be used in a decentralized manner for a variety of end-user applications, including but not limited to: storing renewable DG production; time-shifting demand to avoid peak prices; price arbitrage in real-time pricing situations; integrating plug-in hybrid vehicles through off-peak charging; targeting utility improvements; integrating demand-response / load management; integrating renewable demand response / load management; and boosting reliability. Many research initiatives in the Smart Grid area have been launched by the DAI-Labour during the last few years, beginning with in-home Energy Management (see3, 4).

Agent-based Transport Management

We're working to enhance travellers' mobility patterns by lying out and recommending more eco-friendly routes in the transportation sector. This involves a variety of measures, such as the strategic combining of various modes of transportation and the implementation of improved mobility principles. Our team created the adaptive, agent-based MiFA ridesharing system to provide a fresh take on mobility. Flexible, autonomous, and proactive planning of journeys using multi-criteria optimisation saves the time spent searching for both the driver and the passenger. Additionally, it enables the retention of riding experience. An agent-based Intermodal Day planner was built to facilitate the integration of mobility ideas, enabling the creation of itineraries that make use of public transportation, vehicle sharing from designated stations, and bike sharing. Both methods neglected the energy sector in favour of mobility concerns. While it's true that electric cars reduce harmful emissions, the energy producing process still produces carbon dioxide. Our method5, 6, 7, 8 for storing wind energy surpluses and using them to cover periods with higher demand was developed under the Mini E 1.0 and Gesteuertes Laden V2.0 projects and makes use of the vehicle-to-grid technology of electric cars. The system takes into consideration user preferences, the proximity of charging stations, and the characteristics of the local power grid to guarantee user mobility. In the Berlin Elektromobil 2.0 project, charging and feeding an entire commercial automobile fleet was synchronized with the needs of the hosting smart grid infrastructure, comparable to the developed approach3.

While recent methods have emphasized the need of taking transportation and energy concerns into account, neither the impact of mobility planning on energy restrictions nor a standardized problem definition language have been taken into account.

3. Current Work

Our latest projects follow the presentation of our prior work. The focus is on issues related to transportation and energy, respectively. IMA. The IMA9 initiative aims to improve the standard of intermodal mobility in megacities. Life in megacities by integrating various modes of transportation and offering a centralized platform for trip planning, monitoring, and analysis. Intermodal route suggestions are sent to users based on their profiles, semantic service descriptions, traffic statistics from third-party services, and GPS data gathered throughout the experiment. IMA takes into consideration identity management, encrypted communication; access control for data and services, as well as the administration, enforcement, and conflict resolution of security rules because of the platform's extensibility, and these concerns are seen as crucial to security and privacy.

Nan. Nan, short for Mehrschichtbetrieb und Nachtbelieferung mitt elektrischen Nutzfahrzeugen, is an initiative to increase the effectiveness of a delivery transport service by replacing the batteries in electric medium-weight trucks. When these batteries are used, electric cars may switch to a multi-shift mode of operation, thus doubling their utilization. By shifting package deliveries away from peak hours of traffic, we may be able to reduce overall energy use and save money. The goal of this study is to create a multi-agent software architecture that can optimize and regulate the charging operations in an adaptive manner. To begin with, it guarantees that the power levels required for electric cars to go along each route are always accessible when needed. The batteries might also be employed as storage devices according to various criteria, such as sustainability or grid stabilization, while the vehicles are not in use. Intelligent Internet user. Smart e-User is an effort to fill some of the gaps in the electric mobility market. Under this instance, it's not only commercial and individual travel that's in focus; cargo transit is also an important part of the plan. Improving performance also means reducing the time and money spent charging. But the arrival of this issue is further compounded by changeable routes. The system must adjust to the variable routes and, in turn, account for all the factors that might affect the consumption, such as the weather and the volume of traffic.

Similarities and Differences

Our current initiatives may be roughly broken down into three groups, based on their overarching aims and the primary issue areas that they tackle: energy, mobility, and the energy-mobility-mix. Sustainability, autonomy, and charge management are all part of the first group, which is concerned with energy. The second section discusses topics like road methodical organizing, traffic monitoring, and route figuring. As a corollary, the final class incorporates themes from both fields. Tabulated in Table 1 is a rough classification of the many proposals that have been submitted.

Table 1: Common types of project domains.

Project	Energy	Mobility
IMA	-	x
NaNu	x	-
Smart-E-User	x	x
Extendable and Adaptive E-mobility Services	x	x
Elektrische Flotten für Berlin-Brandenburg	x	x
MSG EUREF	x	-
Forschungscampus EUREF	x	-

We have previously demonstrated solutions for both the energy domain and the mobility domain; however, there is a need to create a solution that is able to take into account the strong interdependency between these two optimisation areas, especially as initial projects attempt to address both domains. After discussing the methods we've already developed, we'll detail how we plan to these industry-specific tools as one. We take a two-pronged strategy. We begin by showing our energy- and mobility-related domain models. Second, we demonstrate the maturity of our applications in both fields. We offer a Charging Optimisation Component, an Intermodal Trip Planning Component, and an effort to practically combine these two distinct areas.

Models

Both an energy-based and a mobility-based model were created by our team. Next, we'll give you a more in-depth look at both models.

Energy Domain Model

Any form of integrated consideration requires a uniform way to represent problems. Based on the analysis of ongoing projects, we can state that project-specific requirements look similar but include challenging differences as well. From our point of view, the most challenging factors are:

Exchangeable batteries: So far, a car battery was assigned to one vehicle only. The Nan project, however, requires the concept of exchangeable batteries. *Increasing complexity:* Energy producer and -consumers, or *presumes*, were presented as uncontrollable demander availability forecasts. Yet, novel concepts, such as hydrogen electrolysers, charge heating power plants, and electrical warm water storages require for a more sophisticated representation. Fleets with several bookable operators are new territory for the field. Recent efforts, however, have cantered on transportation fleets made up of privately owned electric cars, car-sharing networks, and other forms of decentralized, ad hoc transportation. All things considered, there is a shaky connection between cars and gas stations. Requirements at a low level: There is always a discrepancy between the ideal and the actual. For instance, the effective current is often not at the desired levels since bottlenecks (such as the cable, battery, vehicle, and charging station) dictate it.

Figure 1 depicts an early version of our shared domain model's design that takes into account some of the difficulties and insights we've gained.

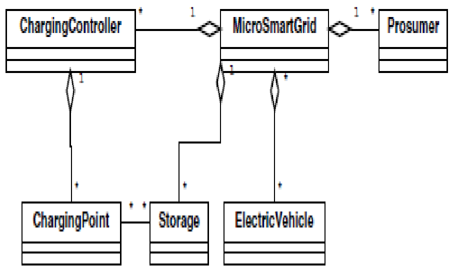

Fig. 1. Draft of architecture of the common domain model.

Some details of the model are readily apparent upon closer inspection. Initially, the domain model does not include a relation between an electric car, a charging station, or a battery. Since this data represents the current system state, it is no longer part of the static architecture. Such a precondition is necessary. By Nan, with its swappable batteries, and the Micro Smart Grid EUREF, which requires a volatile association to handle fleets with many owners? Secondly, to highlight the fact that electric cars might live in separate grids, the cardinality of the interaction between them and the Micro Smart Grid has shifted from 1: n to n: m. Third, charging ports have to be included into the model since the maximum current that can flow through the charging station limits the current that can flow through any one charging port. Fourth, special properties were included to account for individual charging- and feeding-behaviour since various battery types (e.g. lead, Li-Ion) suggest varied charging behaviour. Finally, because local battery storage and vehicle battery storage share many characteristics, they are both represented by the same class, with a type property used to distinguish between them.

Mobility Domain Model

The project IMA, in contrast to many of the others listed in Section 3, places more emphasis on mobility and transportation difficulties than on energy considerations. As a result, we made the decision to create a domain model that accounts for the many facets of mobility support. Since in IMA we want to dynamically embed various kinds of mobility service into the platform, we need a clear description of which information a service does give. 1. Mobility Service. Because of this, we established the mobility service class, which details such things as cost, service type, and rate. Second, transportation methods: all transit options should be modelled. Our model incorporates details on subways, buses, and suburban trains in addition to automobiles, cycles, electric pedicels, and e-bikes.
Thirdly, requisite infrastructure is required for mobility assistance to be useful. Therefore, our model includes things like highways, traffic reports, charging stations, and parking garages. Fourth, the routing function specifies the trip's modular phases to help the user out at every turn.
5. Events: since routing queries are always time-related, the responses must include more than simply the route. Time of departure, transfer, and arrival; names of cars used; cost and carbon footprint estimates; list of vehicles used. You need a comprehensive picture of the user and their characteristics, such a driver's license, memberships, impairments, and preferred routes, for user-centric mobility assistance to be effective. Many of these sub-domains already have standards or are working toward standardization. Although each of these fields is rather specific, we have chosen to focus on the most important parts of them in our model. In order to accommodate future additions to the Mobility Service suite, the model was built with flexibility in mind.

Applications

As a whole, we built three programs: a Charging Optimisation Component, an Intermodal Trip Planning Component, and a working effort to combine domains. We then proceed to present these three applications in further depth.

Subsystem Charge Optimisation

To maximize the efficiency of charging times for electric cars, the common energy domain model may be used to add a planning, or scheduling, component. Many of our e-mobility initiatives need this, since it helps reduce strain on the regional power grid and maximizes the use of renewable energy sources without restricting the accessibility of those who participate. Based on a general optimisation framework established in an earlier project, EnEffCo4, we implemented such a system in the Berlin Elektromobil 2.0 project. We used both the optimization framework and the generic process model created for the prior project in our initial prototype. While the optimization's end result was usable, the general Meta model just couldn't capture the nuances of the system well enough to do so. This approach does not, for example, permit the use of variable assignments of reservations to electric cars, nor does it enable charging stations with constant levels of charge. As a result, we developed a micro smart grid-tailored domain model for EVs.

5. Challenges

The purpose of this presentation was to raise consciousness about the growing interdependence of two traditionally distinct fields: energy and transportation. We saw this pattern in first-generation initiatives, but when we examine current projects, the correlation is clearer. The results of our domain-specific solutions cantered on our first priority: creating a unified, comprehensive plan of action. We then go on to talk about the biggest obstacles you'll face. Several problems have arisen as a result of the e-mobility initiatives. Rather of recreating substantial portions of the solutions for each individual project, it would be more efficient to use a shared one due to the similarity between the many projects. Although there are numerous similarities across the projects, there are also some key variances that must be accounted for in the shared components, in particular the shared domain models.
Nan, to provide just one example, has automobiles equipped with various, interchangeable battery packs. There are some initiatives that solely back fully integrated, single batteries. To address this, we included support for numerous batteries in the Meta model. The process of allocating these batteries to real cars was separated from the main component of the optimization in order to keep things reasonable. Using the energy domain paradigm to create mobility services is a natural progression from the development of energy services. Each step of energy optimization will be modelled as a separate service, with the ultimate goal of orchestrating a full scheduling service that can be included into the user's mobility planning services.

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