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A concept for the architecture of an open platform for modular mobility services in the smart city

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Abstract

It is difficult for developers of mobility solutions to gather accurate mobility data, such as the traffic flow or available parking spaces. This data is available in a smart city, but it is not made accessible to external developers for creating innovative mobility solutions. As it remains unclear how this could be done, this paper proposes a concept for the architecture of an open platform for modular mobility services. The design of the architecture follows a design science research approach. The developed concept for the architecture of the platform consists of the following elements: data sources, layers of modular services, integration layer and solutions. Additionally, possible modular services are described. This paper is limited by the fact that the architecture has not yet been implemented and evaluated. However, this is planned for future research. This paper contributes to theory by giving guidance for future research on service platforms and to practice as it shows how available mobility data could be made accessible for mobility solution developers.

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Keywords: Mobility services; mobility solutions; platform; smart city; open platform

1. Introduction

Today, the traffic situation in many cities is challenging. Due to increasing traffic volume, people lose more and more time in traffic jams and additionally the search for parking spots takes up a lot of time representing up to 30% of the traffic in cities (Banister, 2011; Priester, Miramontes, & Wulfhorst, 2014; Van Ommeren, Wentink, & Rietveld,

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2012). It is estimated that European cities lose between 2.69% and 4.63% of their Gross Domestic Product (GDP) because of traffic congestions (Willoughby, 2000).

Many different providers offer digital mobility solutions to improve and ease an individual's mobility. Due to their benefits, a variety of smartphone based services are being developed. For instance, a study clarified the benefits of a journey planner for public transport, testing how people plan their trips (Cain, 2007). They asked people to plan a trip with a map and timetables and only 52.5% could plot the trip, triggering the development of the digital journey planners (Cain, 2007). Smart navigation tries to avoid traffic jams by suggesting alternative routes, carpooling and ridesharing applications encourage individuals to share their cars and multi-modal traffic information offers alternatives to car-based transportation. Many of those solutions are dependent on accurate data, e.g. the location of the users, time-schedule of public transportation or information on the current traffic or parking situation.

However, it is difficult for developers of mobility solutions to gather this data, because there are only a few platforms, such as Google Maps (2016) or Bing Maps (2016), that offer mobility data and services through standardized interfaces. The access to these data and services is often limited and restricted according to the interests of the providers. Furthermore, these providers only offer isolated services with a specific focus and therefore it is necessary to access many different platforms in order to develop a mobility solution. This limited availability of data sets and services is limiting the capabilities of the developers. After reviewing the current digital services for urban transport, Schreieck, Wiesche, and Krcmar (2016) state, the existing services are not yet integrated, the landscape of digital solutions is vast and unstructured.

On the other hand, a smart city generates quite extensive mobility data, but it is not offered to external providers for developing mobility solutions. For instance, municipalities gather a lot of data in particular on traffic to measure and predict the traffic situation within the municipality. These data are mostly used in traffic management to improve traffic routing and other aspects such as parking. These data could be made accessible for the development of innovative mobility solutions. However, only offering data might not be sufficient, because it creates a high effort for mobility solution providers. They have to understand the structure of the data and also have to aggregate as well as analyze it on their own. Because of this, offering standardized modular services that aggregate and analyze the available mobility data eases the effort for mobility solution providers. For instance, floating car data of individual vehicles is quite complicated to handle, but a service that has analyzed this data and offers information on the traffic intensity on certain roads through a standardized interface can be used by mobility solution providers more easily.

The aim of this research is to design an open platform for modular services that facilitate the development of mobility solutions within a smart city. Instead of focusing on isolated mobility services, we develop a concept for the architecture of a platform that offers modular services that can then be integrated in apps via open and standardized interfaces, so called Application Programming Interfaces (API). This architecture allows the usage of existing data in different services which can then be used for the development of innovative mobility services. The platform is a key contribution and will bring together stakeholder that offer digital services or plan to offer one.

The remainder of the paper is structured after the publication schema for design science research studies suggested by Gregor and Hevner (2013). First, we present the theoretical background on existing digital mobility services as well as on existing mobility data and services platforms. Then, the research method is outlined in detail and the concept for the architecture of an open mobility services platform is presented. After that, there is a discussion of the concept and the paper ends with a conclusion.

2. Theoretical Background

2.1. Digital mobility services

The world is getting digital, the current digital revolution triggers innovation in many industries, one of them is personal mobility. A big variety of services is offered in the market and the popularity of smartphones is intensifying it. The digital mobility services are well received by the public, forming the fourth most important application category used in smartphone, just after weather, social networking and communication (Forrester, 2013). The variety of services provided include journey planning, ride-share matching, maps, navigation etc. and use a variety of data sources. For instance, the solutions that support the search for parking spaces are either based on data from sensors, on statistical prediction or on data provided by the crowd (Greengard, 2015; Inrix, 2015; McNeal, 2013; Nandugudi, Ki, Nuessle,

& Challen, 2014; Nawaz, Efstratiou, & Mascolo, 2013; ParkNav, 2015). There are also end user solutions that support finding the optimal route like AllyApp (2016) or Maps by Google Maps (2016) and solutions that show information about traffic alerts like Waze or the traffic maps by Google Maps (2016). Many public or private transport providers also have their own mobility services that inform the user about their services, costs or their timetables such as Uber (2016) and the Munich Public Transport Association MVV (2016). The disadvantage of these services is that they do not offer open interfaces, because they were designed as end user solutions. Because of this, these services cannot be embedded into other solutions. This leads to monolithically single services which have the disadvantage that a user needs to combine several different of these single services to get the required solution. For instance, a user has an appointment at a crowded place in a city. As he wants to take his own car, he uses many different solutions for finding the optimal route, checking whether there is a traffic jam and where he could park his car. Although he is only interested in arriving at his appointment in time, he has to use many different single services.

Offering digital mobility services through APIs on an open platform enables the development of a single service that addresses the above described problem. There are already first attempts for open platforms for mobility services, but they have some shortcomings, which will be discussed in the following section.

2.2. Existing mobility data and service platforms

It is possible to distinguish two forms of mobility platforms. There are platforms that focus on the provision of raw data through open interfaces and there are platforms that provide digital mobility services.

An example for an open mobility data platform is the New York City Open Data portal (New York City, 2016). It makes thousands of data sets generated by public agencies and organizations available for public use. Anyone can use these data sets to create applications, conduct research and perform analyses. The data sets are available in a variety of machine-readable formats and are categorized by topic, city agency or organization.

Mobility data platforms have some disadvantages. For instance, providing raw data, such as floating car data, can be subject to data regulation issues. Additionally, they have the shortcoming that users have to process the data on their own while most users would prefer to use a standardized service that handles the analysis of the data.

Two well-known mobility services platforms are Bing Maps (2016) and Google Maps (2016). It is possible to access several services, such as routing or traffic alerts through standardized interfaces. However, they only offer a limited amount of services and cannot be regarded as open.

A smart city that already offers mobility related data, but also services on open platforms is Barcelona. It provides a variety of digital platforms with services at different levels for developers, institutions and citizens. For instance, the initiative “Sentilo” provides data from sensors in real time on an open data platform, the platform “City OS” provides services of data analysis from different sources and they also offer end user services as an app market “Apps4bcn”, Apps for transportation as bike-share, public transport and parking and others (City of Barcelona, 2016). Despite these existing attempts, it remains unclear how the concept for the architecture of an open and modular mobility service platform should look like.

3. Research method

Our development of a concept for the architecture of an open and modular mobility service platform follows a design science research approach. Design science seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts, they can be a process (set of activities) or a product (an artifact) (Hevner, March, Park, & Ram, 2004). Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) suggest a six-step process. First the motivation and the problems are outlined. Second, the objectives of a possible solution are defined. Third, the artifact is designed and developed. Fourth, the ability of the artefact to solve the addressed problem is demonstrated. Fifth, the developed artefact is evaluated. Additionally, it is possible to go back to the second and third step to improve the artefact. Sixth, the developed artefact is communicated to an interested audience.

In this article, we focus on the first three and the last step. The remaining steps will be conducted in future research. The motivation and the addressed problems have been outlined in the previous sections. The objectives of a solution and the developed artefact are described in the following section.

4. Concept for the architecture of an open mobility services platform

The main objective is to design a concept for the architecture of an open mobility services platform. This platform should offer several modular mobility services with different levels of granularity. These services should access different data sources and refine their information. Additionally, the services should be hosted in a secure and safe environment. As many of these mobility services are quite computation intensive, the platform needs to be able to handle sufficient parallel service calls. Finally, each user should be identifiable by the platform.

The platform furthermore supports developers that contribute services to the platform's ecosystem. To implement services, the developers need access to raw or analyzed data, analysis tools as well as specifications on how to develop the services according to the platforms standards. In existing mobility platforms, a variety of formats, owners and regulations impedes the efficient development of additional third-party services. At the end what is built in the solution is limited by the resources available and the capabilities of the team. The Open Mobility Services Platform provides a direct connection between the resources the developers using them.

The resources on the platform are standardized, this way similar datasets from different sources can be presented and understood in a similar way. For instance, the Public Transport Data can be in different formats from city to city. The platform will propose the Public Transport providers to use a standard format i.e. GTFS (General Transit Feed Specification) or require to the sources to indicate in which format is their data shown.

At the front end, the platform looks as a website. Users will provide their credentials and have access to the different resources available in the form of API's. This way, the API's and the data will be in a safe environment. A well-known example of this kind of websites is the framework for API's "Swagger" (Swagger, 2016). The proposed platform will create cooperation between the public and the private sector. They can create consortiums or public private partnerships and define who will operate the platform. Moreover, the cooperation with the governments ease the compliance of the personal data protection laws (European Comission, 2016).

Figure 1 shows the concept for the architecture of an open platform for modular mobility services. It consists of the following elements:

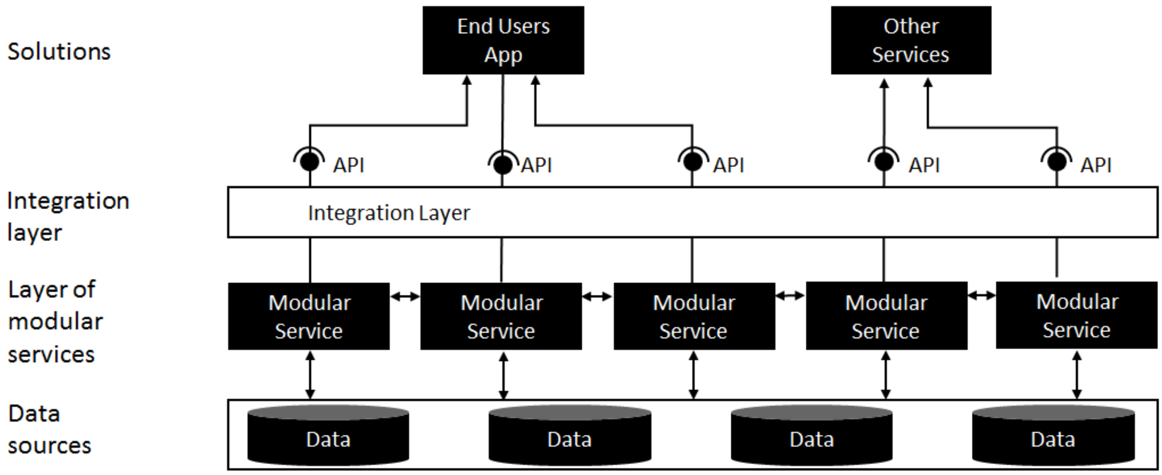

Fig. 1. Concept for the architecture of an open platform for modular mobility services.

<u>Data sources</u>

The platform is based on several different data sets. One data set could be floating car data, which can be generated through on board units within cars or through smartphone apps of drivers. This data can be used for approximating the flow of traffic within the city and to detect traffic congestion. It has been shown that it is sufficient to get data from only 2-3% of all cars to provide accurate measurements of the velocity of the traffic flow (Herrera et al., 2010).

Another relevant data source is parking lot data. This data could come from parking garages, which already have a good knowledge about their available parking spaces. Data on on-street parking spaces is harder to get. It could either come from sensors or from the crowd. For instance, 8.622 parking spaces have been equipped with sensors in San Francisco (McNeal, 2013). Several companies offer sensors for surveilling parking spaces (General Electric, 2015; Siemens Mobility, 2015; SmartParking, 2015). Other solutions are based on the crowd that reports free parking spaces with an app (ParkMünchen, 2015; Parkonaut, 2015).

Additionally, data from public transportation providers and taxi corporations could also bet relevant. They often already have own solutions that show time tables or the position of the next available car. This data could also be a basis for the platform.

Layers of modular services

The modular services form the core of the platform. There are actually several layers where the level of granularity increases from the top to the bottom. The services at the bottom focus on analyzing and refining the data sources, whereas services on higher levels reside on services from lower levels. The services on higher levels integrate the services below using their results. On the highest level, end-user services are built on these integrated services.

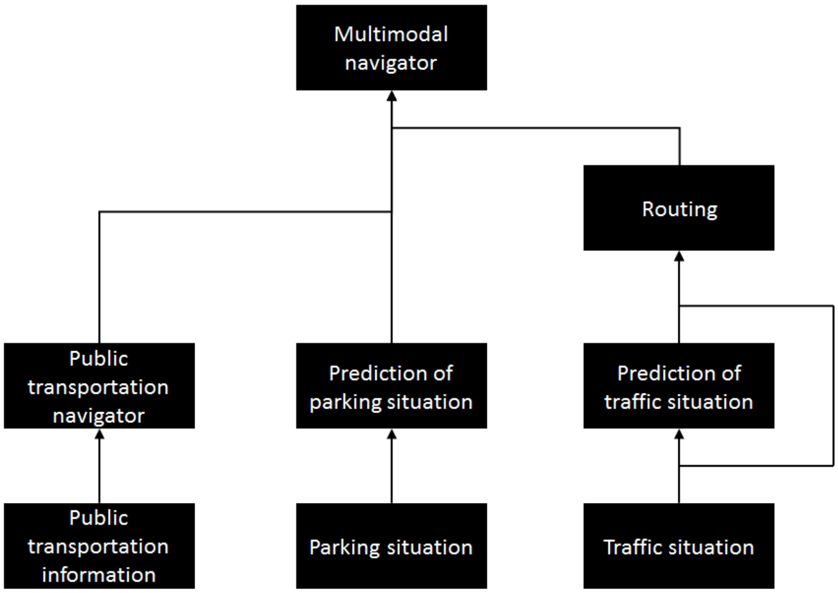

Fig. 2. Layer of modular services with example services.

Figure 2 illustrates these different levels and shows some example services. A simple modular service could show the current traffic and parking situation on the streets in a certain area. Another modular service could use this service, analyze the delivered information and predict the parking situation for a specific point of time in the future. The following services are examples for possible modular services:

- *Parking situation*: The parking situation service shows the current availability of parking spaces. It is based on data provided by the parking garages, sensors or the crowd.
- *Prediction of parking situation*: This service predicts the parking situation for a certain point of time in the future. It is based on the parking situation service and the traffic information service. This service processes the provided data with machine learning algorithms. Additionally, it is possible that this service also accesses other information such as weather data.
- *Traffic situation*: The traffic information service collects the traffic data from different sources like floating car

data, road sensors and road alerts. Then, it combines this data and estimates the current traffic situation.

- *Prediction of traffic situation*: This service predicts the traffic situation for a certain point of time in the future. It is based on the traffic situation service and on other data sources such as weather data. This service processes the data with machine learning algorithms.
- *Routing*: The routing service calculates the best route between two points. The user can specify whether the current traffic situation or the predicted traffic situation for a certain point of time in the future should be considered.
- *Public transportation information*: This service shows current and future timetables of trains, subways and buses. It also provides information about any failures or unforeseen situations.
- *Public transportation navigator*: The public transportation navigator service suggests the best public transportation route between two points for a certain point of time. It is based on the public transportation information service.
- *Multimodal navigator*: This service offers the optimal route within the city for car drivers. It considers the traffic situation for selecting the optimal route, but also checks where it is possible to find a parking space at the destination. Additionally, it checks whether it is better to park the car near a bus station and to use public transportation. This service is based on the previously described modular services.

Integration layer

The integration layer creates a secure and safe environment. The modular services can only be accessed through the integration layer. The integration layer buffers service calls and acts as a load balancer for the services. The user management and access control also reside in this layer. As all service calls go through this layer, it can also be used for analysis of the service calls.

Solutions

These are the solutions that users of the platform create. It is possible, that these solutions are end user solutions or that the services are integrated into services outside of the platform. One example for a possible solution is a scheduling and routing service for small and medium-sized businesses that have multiple appointments within one or several cities. By considering the routes between appointments and the predicted traffic situation at that point in time, the scheduling of appointments can be optimized. For example, a nursing service could optimize the daily schedule and save driving time that could be dedicated to the patient care.

5. Discussion

The developed concept for the architecture of an open platform for modular mobility services can be used to make data available that already exist in many smart cities, such as data on public transportation, parking spaces and traffic. Such a platform creates a mobility ecosystem and fosters the development of innovative mobility solutions based on the offered modular services. Without such a platform, each developer has to gather data on his own, which is difficult, if at all possible. Furthermore, without services that offer the required information, the developers have to analyze the mobility data by themselves. As most developers often are not experts in data analysis, this forms a barrier for the development of innovative services.

The exemplary modular services describe the different layers of modular services. Each service can be issued individually, but it is also possible to combine different modular services in order to create a new service. This combination can be done within the platform, but it is also possible that an external developer combines them and offers the new service. This paper contributes to theory by giving guidance for future research on service platforms. It shows a concept for the architecture of such platforms. Additionally, it contributes to practice as it shows how available mobility data could be made accessible for mobility solution developers.

The data related to mobility is highly sensitive to privacy issues. This initiative understood the main concerns, implications and mechanisms for privacy through the research of Christin (2016). Methods to preserve privacy while managing mobility related data are presented as an alternative to a trusted authority by Sucasas, Mantas, Saghezchi, Radwan, and Rodriguez (2016) and as the “Semantic Cloacking” by Barak, Cohen, and Toch (2016). Each of the owners of the data sets, services and users can set their privacy requirements inside the platform in a standardized way. For instance, the tracking data is anonymized and assigned to a regularly changing ID and the data set owners can track who is using their data for which services. By this means, privacy and transparency are ensured in the services provided.

This paper is subject to some limitations. First, the developed concept for the architecture of an open and modular service platform has not yet been evaluated. Additionally, only a few exemplary modular services are presented and not a comprehensive list of modular services that would be useful for mobility solution providers.

As previously mentioned, the remaining steps of the design science process of Peffers et al. (2007) will be conducted in future research. The concept for the architecture could be evaluated with qualitative approaches, such as expert interviews and case studies, and also with quantitative approaches, such as surveys. Additionally, future research could provide a comprehensive list of useful modular mobility services that should be developed. Furthermore, the concrete implementation of such an open platform for modular mobility services could be examined.

6. Conclusion

This paper presents a concept for the architecture of an open and modular service platform for e.g. transportation, parking and traffic in the smart city. The platform supports the development of mobility solutions through the provision of mobility data and services through open and standardized interfaces.

The provision of the data and the services that analyze it triggers the innovation in mobility services even more. This platform provides a broad variety of services at different analysis levels, from very detailed and simple to more aggregated and complex. The developers can find the services that best fit to their initiatives.

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