Flexible Software Support of Imovated Mobility Business Models

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1. Introduction

More than 60% of the population in Germany lives in rural areas [1]. For these areas, it becomes increasingly difficult to ensure a basic supply of public transport services because of the demographic change and the proceeding urbanization. Therefore, a main challenge is to ensure the accessibility of infrastructure, such as medical services or shopping centers that are mainly located in nearby cities. It is often not possible to reach central destination reliable by public transport [2], [3].

The objective of the interdisciplinary research project NEMo (Sustainable satisfaction of mobility demands in rural regions) is to improve the sustainable mobility supply in rural municipalities and counties [4].

Because of the interdisciplinary of the NEMo project, a taxonomy is necessary to build a foundation for communication between the different disciplines [5]. The taxonomy highlights four layers, separating the mobility services, the business models and processes, as well as IT-services and IT-components. Using the taxonomy, the NEMo project can be more structured. Especially the business models can be divided in this four layers and misunderstandings will be reduced/avoided. The first layer describes the mobility service, how a citizen uses a service and how the customer interacts with the different systems. The second layer describes the business processes and activities that have to be accomplished, to use this mobility service. So, NEMo divides activities as “go to the bus stop” (activity) and “pay a ticket” (business process). The business processes are supported by the third and fourth layers, the IT-Services and IT-Components.

NEMo will analyze rural areas to determine information of how citizens deal with the lack of mobility infrastructure and weak mobility opportunities. Due to the growing problems, the focused model region needs “imovate” business models. Therefore, known and successful business models for mobility services can be imitated and new models based on this imitation can be the result of innovation (imovation).

NEMo will offer new sustainable und eco-friendly opportunities of mobility services for rural citizens. This work will deepen (imovative) business models with indirect and direct influence on the mobility of the rural citizens, which preserve the environment [6]. The business models “carpooling in

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rural areas" and the "rural supermarket collecting service" will be explained in detail. Other "imovative" mobility services are "collecting service for groups", "supermarket delivery service", "babysitting vs. shopping" and "social cooking".

Some mobility services have a direct impact on the mobility, simplifying it while others have an indirect impact. The mobility services with indirect impacts addressing mobility of citizens in rural areas and try to surrogate services. As example, the mobility service "supermarket delivery service" is assigned in the category of mobility services with an indirect impact on the mobility. This mobility service reduces the traffic and the citizens in the rural area will not need to drive to the supermarket. Their personal objective will be reached, when their goods are delivered to them. This mobility service is eco-friendly because the amount of traffic is reduced by this service. As an ideal situation, the service could replace as many vehicles as possible, maximizing the utilization rates.

Using ICT (information and communications technology), new offered mobility services can be supported. To offer these developed business models, new flexible and sustainable software is needed, which is able to integrate new business models, components and processes [7], [8].

SENSEI (Software Evolution Services Integration) can help to support including, modifying, replacing and removing business models without changing the whole software. Software systems with this opportunity are durable and thus sustainable because of their flexibility. SENSEI supports three flexibility scenarios, maintaining the durable of the software [9]. The first scenario is to add or modify capabilities, which make possible that instead of the "fastest route" the "shortest route can be added. The second one is to extend or modify the existing orchestration or re-orchestration, for example add a new map for finding bus stops. SENSEI can orchestrate both maps and find a combined route between consisting components. The third scenario can change component mappings, which allows to find the best solution for the users request.

2. Taxonomy

To clearly differentiate between the different parts, a taxonomy is needed to understand the several levels of a mobility service. The taxonomy helps to outline the different levels to describe a mobility service. Therefore, it defines a common language in the NEMo project to prevent misunderstandings between the different disciplines. The following graphic shows the taxonomy (Fig. 1). It outlines the four sections building up on each other. The taxonomy uses the separation of concern approach [10], to separate the different parts and show their interconnections.

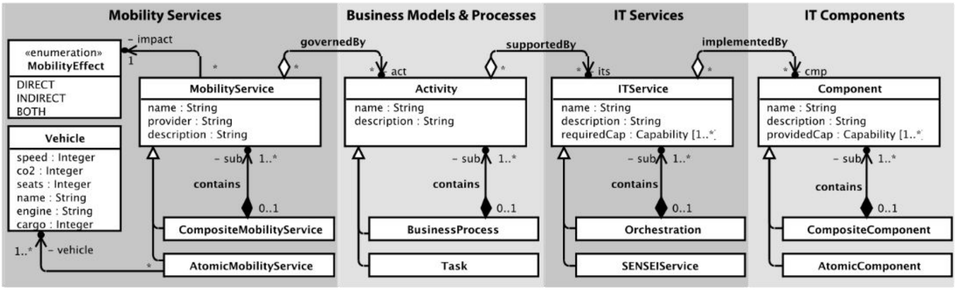

Figure 1: UML class diagram depicting the main concepts of the NEMo taxonomy

The first level contains the business model of a mobility service. The main facts about the mobility service are considered, e.g. vehicle facts or mobility effects. These facts help to understand the general work of a special mobility service. A mobility service is the description of the supply of services to support people in their mobility or the transportation of goods [11]. It shows the way the mobility service works out strategical and functional.

The next level are the business processes, which contain the business process view combined with the mobility service level [12]. One activity of the mobility service describes one combination of tasks a user must accomplish using it. Each task is human made and must be seen completely separated from the IT-Services because of the supporting function of IT-Services.

The IT-Services are the supporting activities of tasks. They can be seen as the technical view in combination with the components. The IT-Services define the function of a (sub) software system after its implementation as a component [13]. It must be granular but not too complex that a software architect could build a component with the description. In NEMo, the SENSEI – Software Evolution Service Approach [14] – is used to make the software as flexible as possible.

The last level are the components, which act as the implementation of a SENSEI-Service. The components must be seen completely differentiated from the business process view because of its content. Here, it is needed to build components as part of the NEMo software system to support mobility services demanded by users.

In conclusion, the taxonomy is a guideline for describing mobility service on different levels.

3. Business Models

To improve the mobility, it is necessary to develop business models that have a positive effect on the environment, the citizens and the local economie. Concurrently it is important, that these new mobility services are affordable and accessible for the citizen. Each developed business model in NEMo can be divided in two categories. Table 1 shows mobility services separated by the two different impacts. In the first category, the business models with a direct impact on the mobility are listed (Table 1, mobility services 1-3). The second category includes the mobility services with an indirect impact on the mobility of the citizen in rural areas (Table 1, mobility services 4-6). These services avoiding mobility services by providing surrogate services. All services are developed and generate the additional value to simplify the mobility and to improve sustainability.

The first and the second business model will be explained more detailed, other mobility services will be presented and described in a short form. Business model no 1 is developed for the mobility service of carpooling, which realizing an intelligent coordination platform of prosumers.

Business model 1 is the mobility service of carpooling realizing an intelligent coordination platform.

No	MS with direct impact	No	MS with indirect impact
1	Carpooling	4	Supermarket delivery service
2	Collection service for groups	5	Babysitting vs. Shopping
3	Supermarket collection service	6	Social cook

Table 1: Mobility services sorted in types

To sign up, the user has to enter his email address and a nickname. It is optional that a user gives information about himself and his preferences. The user who haves a car can provide information about the routes he usually takes into the platform (e.g. to work). On each route, he must state information such as start location, start time and destination. Users without a car have two opportunities, the first one is that they can search for routes, they want to drive with other people. The second one is that they can state a new route, he would like to drive.

The NEMo platform will identify possible carpools and initiate the communication between driver and passenger. A user, searching for available routes will get the results of his search request shown on a dashboard. The request can be accepted or denied by the car owner.

The next business model „collection service for groups„ (No 2) will improve the mobility for a group of people through the NEMo platform. The objective is to provide a sustainable mobility service in rural areas. This service is designed as a pick-up and delivery service, it is flexible to use and eco-friendly when citizens create groups to use it. The NEMo platform will support the communication between the supermarket and citizens and between citizens for creating traveler groups. The supermarket can offer events for shopping trips. People can register for these trips, when a minimum number of person is reached the supermarket will know that they can provide the shopping trip. All members of the group will get a notification about the route information. It is also possible that citizen offer a shopping trip with their own car. In this case customer can change their status from customer to provider. A flexible scenario of this business model could be the next business model, which corporates with supermarkets and can be extended to the next business model, the „supermarket collection„ service (No 3).

This mobility service will collect a group of users for a shopping trip to a nearby supermarket. After their purchases, they will get home via the collecting service. The supermarket earns a profit by offering mobility service because of the increasing number of customers. Additionally, the citizens of the rural areas have a better and more comfortable opportunity to get to a supermarket.

The „supermarket delivery service„ (No 4) is also a kind of delivery service but eco-friendlier and could be seen as extension of the previous business model. This business model is a mobility service with an direct impact to the environment by avoiding separated trips of the household. The difference from a classic delivery service is, that the delivery starts, when several households order their goods in a closed area. The supermarket will deliver as often as needed, if more households take an order. If the supermarket collecting citizens from the rural areas, they can deliver goods on the same route to people.
The business model „babysitting vs. shopping„ (No 5) is also a mobility service with indirect impact. This mobility service creates an additional value for users. People, who are not able to drive to the shopping center, can state on the NEMo platform for compensating services as babysitting. Parents with children can search on the platform for a babysitter. They have to state the times a babysitter is needed. In return for the work of the babysitter, the parents will do the shopping for them.

In the next chapter one IT service is described in detail: findRoute. The IT service was chosen because it takes part in each mobility service. The SENSEI approach is used to build up a catalog of IT services generating a higher level of flexibility. These flexibilities can be mapped to the mobility services (sec. 4).
For example, the first flexibility scenario for findRoute is to add capabilities, add a vehicle, and find the shortest route with a specific vehicle (sec. 4.1). The second flexibility scenario demonstrates the support of finding intermodal routes (sec. 4.2). Different mobility services, such as carpooling and supermarket collection service can be orchestrated, whereby the user gets the maximum amount of flexibility. The third software flexibility support of SENSEI enables components to be modified, updated or replaced (sec 4.3). Therefore, it is possible to add a new or specialized route-finding components, modifying current route-finding components, or replace the current route finding component with a new one.

4. SENSEI Support

SENSEI (Software Evolution Services Integration) is a service-oriented approach and framework for building and integrating highly flexible applications from reusable components [1]. It provides the separation of conceptual services and the implementation. As described in Section 1, the service and component layers are bridged using model-driven techniques, to automatically derive processes and integration logic from high-level models – either by means of code generation, or by a model interpreter at runtime. In the SENSEI approach, basic units of functionality, their inputs, outputs, and capabilities are defined, described, and collated in a **service catalog**. Subsequently, desired application behavior is modeled as **orchestrations** of services. SENSEI specifies control and data flow between instances of services selected from the catalog.

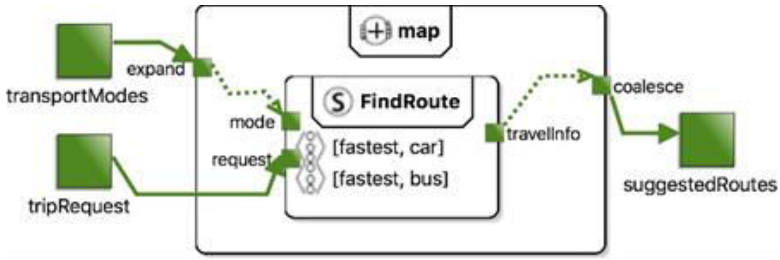

Figure 2: Simplistic SENSEI service orchestration for basic route planning.

Figure 2 shows a very simple orchestration, using only a small IT service, *FindRoute*, to implement basic route planning functionality. The service catalog defines *FindRoute* to require two inputs, the desired *mode of transportation*, and the *trip request*, which encodes starting point, destination, time of departure or arrival, and potentially further traveling constraints. The service's output contains the *traveling information* (e.g. a list of driving directions). The orchestration nests the service instance within a map control flow construct. This is basically a (potentially concurrent) loop that executes its body once for every element in the input stream (expand), and collects the individual results (*coalesce*). As a result, this orchestration calculates a route for each of the specified transportation modes, and returns them as collection of *suggested routes*.

SENSEI services can further have *capabilities* to model specific features which implementations may or may not support. For *FindRoute*, there are *two capability classes* defined in its catalog entry, which represent variation points for implementing components: an *optimization goal*, with individual capabilities to find (e.g. the *fastest*, *shortest*, or *cheapest* route), and a *transport mode*, whose capabilities representing support for finding (e.g. *car*, *bus*, or *walking* routes). In the orchestrations of carpooling and supermarket collection service, their required capabilities for each instantiated service can be declared: in Figure 2, the *FindRoute* function is required to support finding the fastest routes for private cars.

The actual implementation of the functionality, defined by the IT services, is implemented by components, listed in SENSEI's **component registry**. Besides each IT component implementing specific IT services, registry entries also declare *provided capabilities* to further specify the extent of the provided functionality. SENSEI's capability model is leveraged by its tooling to automatically match orchestrated IT services and their required capabilities to appropriate IT components that provide them.

SENSEI provides the identification of three basic flexibility mechanics such as adding, modifying capabilities, extending orchestrations, and changing component mappings:

– **Adding Capabilities.** As long as the NEMo project aims at supporting mobility in rural regions in a sustainable, environmental friendly manner, mobility services like the *carpooling* can be improved if route planning would also provide *shortest* routes, instead of *fastest* routes, assuming the former are generally more ecological than the latter due to lower carbon emissions. Subsequently, support for additional transportation modes can be added. If the actual functionality is already available, implemented in registered components, SENSEI is able to integrate them into the modified software solution, fully automatic. In the same vein, all the mobility services displayed in Table 1 can easily be orchestrated by adding new service capabilities or modifying existing ones.

– **Extending Orchestrations.** As long as NEMo considers that the combination of mobility services are quite essential to provide comprehensive, demand-based mobility options, the basic route planning is not sufficient for providing *inter-modal routing* i.e. the combination of multiple transportation modes within a single route [2]. To provide the evolution of such route planning software systems integrated into SENSEI, the existing orchestrations can be extended with additional IT service instances. SENSEI allows for either generating integration logic automatically or providing it at runtime by an interpreter. This helps to avoid providing interface adapter and data transformation logic from software integrators to component developers.

– **Changing Component Mappings.** To implement the functionality modeled in orchestrations, SENSEI creates mappings between the instantiated IT services and the IT components. Thereby, a small service can be implemented by combined components using different capabilities, and vice versa. SENSEI always assumes that invoking IT services for IT components does not any knowledge about the overall process of the services-to-components communication. All information goes through a specific *composer*. The composer realizes the control and data flow specified by the orchestration, invoking the right IT components in the right order, and passing along data. The composer is either fully auto-generated, or is embodied by an interpreter. Thus, the IT services can be instantiated in other orchestrations, forming the hierarchy of IT services and orchestrations depicted in the IT *Services* layer of Figure 1.

This architecture of completely isolating individual components is essential goal of SENSEI sustainable, high flexibility and reusability. This allows for direct communication between components and interdependencies. While orchestrations are also IT service instances, they can also be mapped to other atomic IT components (Figure 1). Such IT components implement a more complex route-finding algorithm. In comparison the individual service-providing IT components, SENSEI views such atomic IT components as black box. With this mechanism, SENSEI allows trade performance and scalability against flexibility and reusability. The latter only has to be sacrificed for select parts of an overall software system, for which performance is critical. Also, such monolithic implementations fit into SENSEI seamlessly, being treated like any other component.

5 Conclusion

The challenge of the inter- and transdisciplinary research project NEMo was to improve the insufficient mobility offers in rural areas. To prevent misunderstanding, a taxonomy was created for the project. Furthermore, business models with direct and indirect impact were developed to simplify the sustainable mobility. For realization, an intelligent and flexible software is required to integrate new business models. With the application of SENSEI, the software system is sustainable and supports three flexibility scenarios that will be test in field trails during the NEMo project.

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