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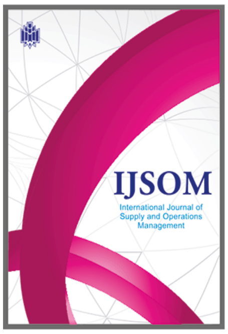

Smart City Reference Model: Interconnectivity for On-Demand User to Service Authentication

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Abstract
The Internet of Things and Services (IoTS) has encouraged the development of service provisioning systems in respect to Smart City topics. Most of them are operated as heterogeneous systems which limits end customers' access and contradicts with IoTS principles. In this paper, we discuss and develop a reference model of an interconnected service marketplace ecosystem. The prototypical implementation incorporates findings from an empirical study and lessons learned from research projects. The elaborated ecosystem enables service request roaming between different parties across system boundaries. The paper presents a feasible centralized architecture, introduces involved parties and parts of a developed message protocol. Why a contracting mechanism is indispensable for request roaming is also outlined. The model's feasibility is demonstrated by means of a current electric mobility use case: providing access to foreign charging infrastructure without multiple registrations. This work contributes to simplify the data exchange between service platforms to improve Smart City solutions and to support travelers with intelligent mobility applications.

Keywords: Smart City; Interconnected Services; Connected Mobility; Internet of Things and Services.

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1. Introduction and Problem Description

Topics related to IoTS, Industry 4.0 and Smart Cities are emerging and already impact well matured industrial sectors. The possibilities provided to industry and society, while combining and connecting Information and Communication Technologies (ICT) with Network Embedded Devices (NEDs), offer a wide range of new business cases. As the internet is developing towards a fully connected system which connects objects and things (ALL, 2013; Balakrishna, 2012), it enables the development of mutual benefits for all involved parties. Although a well-equipped infrastructure is prerequisite, the infrastructure alone does not increase smartness (Monzon, 2015; Nam & Pardo, 2011). (Balakrishna, 2012) identifies the cooperation between infrastructure and appropriate applications and services as key for Smart Cities, IoTS and Industry 4.0. Therefore, the current approach of excessively information gathering without providing access on the data to third parties which process it further is not expedient. Therefore, commercial and research platforms have been developed to facilitate and manage the access on collected data and, based on this data, develop dedicated services.[1]

A service platform is the environment where Business to Business (B2B) service trades can be accomplished between service operators and service consumers. Although platforms can provide trading capabilities too, the term does not connote a strong trade orientation. Therefore, the term marketplace is preferred as it suggests significant trading characteristics. A platform is assumed to be a sub-type of a marketplace. The number of operators and consumers for services (e.g. mobility services like car sharing, vehicle charging, parking, routing, public transportation) is considerably increasing. The raising number of marketplace participants will, as a consequence, increase the number of service offerings and the demand for services (Thitimajshima, Esichaikul, & Krairit, 2015). However, a registered participant is limited in its business due to constrains imposed by the marketplace's operational boundaries. A participant can therefore only trade (offer or consume) services within the same service marketplace (Strasser, Weiner, & Albayrak, 2015).

1.1. Contribution to smart cities

This paper presents a reference model which caters interconnectivity between fragmented service marketplaces. Due to the achieved connectivity, marketplaces are enabled to exchange all kind of information. While doing so, no information about another system's precise location, function stack or internally used communication protocol is required. The achieved interconnectivity presented in this work enables the exchange of information which enables the discovery and consumption of mobility services across marketplace system boundaries. This enables mobility service providers to offer their mobility services to more service consumers while the service consumers gain access to a broader range of mobility services. These services are then incorporated into mobility applications which are offered to mobility end customers. Such an applications support citizens, commuters and tourists in their everyday mobility in cities. Another benefit of the interconnected service marketplaces is that the services and infrastructure of the service providers are used more often, the service consumers can build more sophisticated mobility solutions and that the end customers

[1] Even though the paper focuses on the mobility domain, which is related to smart cities, its concepts can be applied and adopted to other domains which make use of ICT service functionalities.

experience an improved mobility situation that satisfies their demands more appropriate. The exchange of information and the establishment of appropriate communication channels between service marketplaces reduce the effort for marketplace participants in respect to multiple registrations, protocol implementation and its maintenance or quotation publication. Cities benefit from sophisticated mobility applications because they may mitigate traffic problems caused by traffic jams, road maintenance, accidents or a bad parking situation. The applications can provide alternative routes based on real time data, detect free parking spaces and provide guidance, enable to buy public transport tickets online with the same account which they would use to access a car sharing vehicle. All that contributes to an environmental improvement which increases a city's attractiveness because noise, heat and emission are reduced. Our contribution is a feasible ICT based service ecosystem architecture that enables the accomplishment of the above described scenario.

The prototype consists of a centralized management unit as proposed by (Strasser & Albayrak, 2015). This ensures a good scalability, simplifies management and reduces the number of messages sent within the network (Strasser & Albayrak, 2015). A sophisticated contracting mechanisms has been incorporated to manage business relationships between service providers and consumers which are registered on different marketplaces (Strasser, 2015). The solution's feasibility is demonstrated on a roaming use case in which an end customer claims access to infrastructure with his Radio Frequency Identification (RFID) mobility-card. Parallel to the prototypical implementation, a messaging protocol has been developed. This protocol enables the information exchange (roaming) between the directory agent management unit and its connected marketplaces. This protocol contributes to the development of a standard protocol for interconnectivity between B2B service marketplaces. The protocol requires a minimum set of data to authorize end customer service requests. The proposed solution considers requirements which were pointed out by interviewed experts[2]. In conclusion, the elaborated solution makes services visible across marketplace boundaries which increases the mobility possibilities of the end customers (travelers).

Having introduced what can be expected by the work on hand, the following section outlines the current state of the art for interconnectivity in the domain of B2B mobility service platforms. It is based on existing literature and an empirical study which has been conducted between July and August 2015. Section 3 demonstrates service request roaming via service marketplaces based on an electric vehicle charging use case. Section 4 presents the elaborated interconnected reference model and demonstrates its advantages over homogeneous service solutions. The conclusion in Section 5 briefly outlines the solution's contribution, limitations of the research and managerial implications.

2. State of the Art

Interconnectivity between service provisioning marketplaces, especially in the mobility domain, has been discussed by (Fricke et al., 2012; Pfeiffer & Bach, 2014; Strasser & Albayrak, 2015; Strasser, 2015) in detail. It has been already successfully established in other domains, for instance in the hotel or flight sector. Interviewed experts (Rives, J.M et al., 2015) identified the missing mass

[2] The interviewed experts are shown in the References as Rives, J.M et al. 2015.

market as key why interconnectivity did not found its way to mobility marketplaces in the smart city context so far. Platforms which deal with charging infrastructure for electric vehicles and support service requests roaming between their own participants are, for example, *Hubject*, *Gireve* or *e-clearing.net*. *ParkU* or *Parkopedia* are examples of well-established platforms in the parking domain. *Car2Go* or *Drive Now* are platforms which provide vehicle sharing services. The service variety leads to many different protocols, different requirements upon the data set and its quantity and quality, different demands on service availability and the used technologies. Due to this diversity, tightly coupled systems with proprietary protocols are the preferred choice (ALL, 2013) when operating a service platform. (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014) emphasize the non-interoperability of the heterogeneous technologies as a great obstacle. (Tcholtchev et al., 2012) assumes that the charging stations of a smart city are connected in a single network. However, this is not yet the case and charging stations, among other infrastructure or NEDs, are located inside proprietary operated networks.

Various research projects try to face these challenges with the help of ICT. One example is TEXO which is a use case of the *THESEUS* project in which various European companies and research institutions profoundly analyzed how to combine services via semantic. Furthermore, the European project *Green Emotion* and the French-German cooperation *CROME* connect charging stations of different providers and roam service requests among them within one platform. *Stuttgart Services*, *Streetlife* and *Olympus* are research projects throughout Europe. These projects elaborate services as well as trying to simplify the access upon them in the context of Smart-Mobility, Utilities, Buildings and Environment (Zanella et al., 2014). *COMPOSE*, a European project, targets the provisioning of services that integrate object data. The *VeMB* project aims at connecting services of different smart city service providers while the *EMD* project focuses on the development of mobility services in general.

By the current date, a participant of mobility marketplace A is not able to contract and consume a service that has been offered by a participant of mobility marketplace B. Reasons for this are, according to the literature and the experts (Rives, J.M et al., 2015); i) marketplaces have no comprehensive set of appropriate Application Programming Interfaces (API) in place, ii) a communication protocol for interconnectivity does not exist, iii) mechanisms for contract signing are not implemented, iv) fear of maintaining 1:n platform connections and v) fear of losing business when collaborating with others. The lack of interconnectivity between marketplaces interferes with the concept of processing and transforming a wide range of complex smart city data (Chourabi et al., 2012; Dirks & Keeling, 2009; Yonezawa et al., 2015). Due to a service solution's singularity, it is difficult to achieve synergy effects among them. Interconnectivity bridges IoTS solutions and enables access to and integration of a large number of data collected by sensors, systems and processing capabilities (Yonezawa et al., 2015). Being able to exploit and process all available information would contribute to smarter cities and help to face challenges in respect to energy management, mobility, infrastructure development or pollution prevention.

(Tcholtchev et al., 2012) suggest sharing data in an open cloud. This approach assumes that there are no proprietary networks but one big single data network. In (Christ et al., 2015), a pair-weird approach has been applied by connecting two platforms for charging infrastructure. Their platforms forwarded charging requests without taking care of contracts or business relationships, although roaming agreements have to be considered properly (Grathwohl, 2015; Vidal et al., 2011). Business relationships are built upon contracts (Grathwohl, 2015) even if the relationship has been established across platform boundaries (Strasser et al., 2015). The pair-wired approach leads to a complicated network of bilateral connections and an increasing number of agreements and connections (Pfeiffer & Bach, 2014). A different connection approach has been proposed by (Strasser & Albayrak, 2015) who suggest to apply a centralized architecture similar to some file sharing concepts.

Although there are ongoing efforts in the smart service and service provisioning domain, interconnectivity in the mobility domain is a difficult topic. Neither an appropriate protocol nor respective interface standards are available which could guide the development of an ecosystem of connected service marketplaces.

3. Service Request Roaming Use-Case

The problem of missing interconnectivity in the mobility domain is described by the following vehicle charging use-cases.

3.1. Use-Case: Current situation in service roaming

An energy supplier (ES) is a service provider and offers services for charging infrastructure via marketplace A. The ES creates a service offer quotation which contains a description and the usage conditions. This offer quotation is found by car manufacturer (CM) who is a service consumer. The CM intends to offer its end customers access to a wide range of charging stations. Thus the CM accepts the conditions of the ES's charging service and both sign a paper contract. An end customer (EC) of the CM visits her relatives in France. She has to drive about 300 km and crosses one country boarder. Before the journey, the EC charges her vehicle's battery on a charging station of the ES. For the on-site authorization she uses her mobility-card which she got from her CM. The ES forwards this request to marketplace A because it does not recognize the EC. Marketplace A checks all contracts of the ES and identifies the CM as a business partner to whom the request is forwarded. The CM identifies the EC as its own end customer and responses with a positive authorization. Marketplace A receives the response and forwards it to the ES respectively. Because the EC belongs to a business partners of the ES, access is granted to the EC and she can use the charging infrastructure. The ES will send an invoice to the CM later, which in turn will send an invoice to its EC. Figure 1 presents a logical architecture of the marketplace with the connections between the involved parties and their systems along with the service quotations, contracts services and infrastructure.

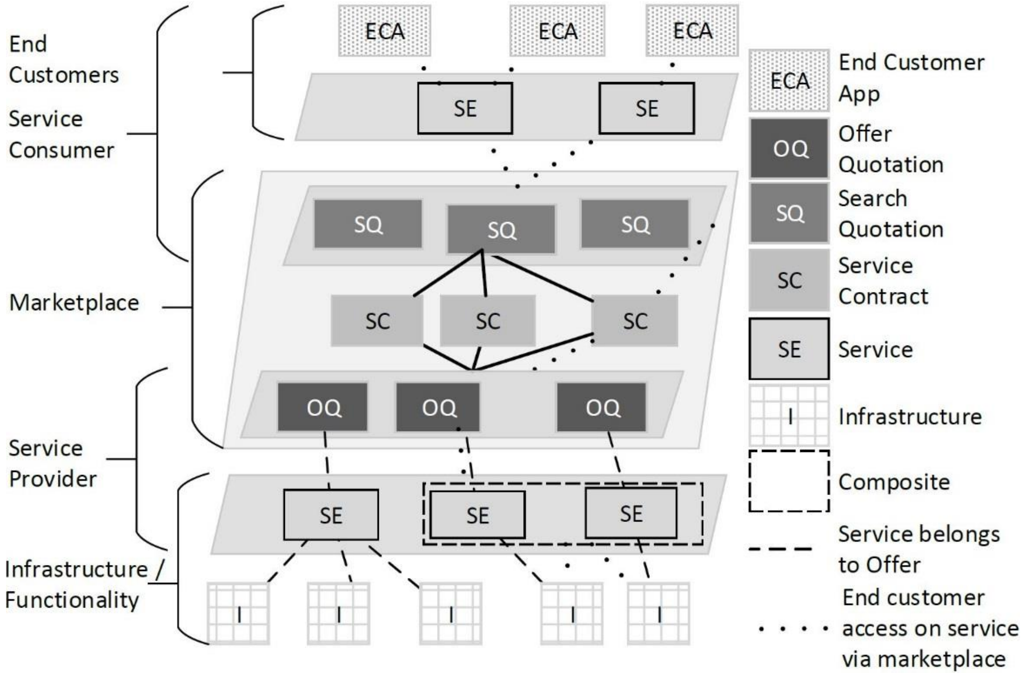

Figure 1. Abstraction of current logical connections and information flow.

Once the EC reaches her destination, the battery is nearly empty. The EC finds a charging station operated by a local French energy supplier (LES). There, the EC tries to access this charging station by authenticating herself with her mobility-card which she got from her CM. However, the LES does not recognize her and forwards the request to the marketplace with whom the LES is registered with, which is marketplace B. Marketplace B distributes the request to all business partners of the LES but none of them know the EC. Therefore, the LES denies the access request of the EC who cannot charge her vehicle's battery.

To overcome this inconvenient situation, the following options are currently possible: i) the EC registers with multiple service consumer, which operate on different marketplaces, to get more mobility-cards or ii) the CM registers with multiple marketplaces and signs contracts with various potential service providers for charging infrastructure. However, multiple registrations are inconvenient (Kampker, Vallée, & Schnettler, 2013) and impracticable due to factors like time, costs, administration or implementation work.

3.2. Use Case: Desired situation in service roaming

Marketplace A and marketplace B want to increase their business and therefore register themselves with the ecosystem. Once registered, they are part of the interconnected network of service marketplaces. Due to interconnectivity, a service consumer (e.g. CM) of marketplace A is able to search for service offer quotations, not only within marketplace A but within all marketplaces of the interconnected ecosystem. This enables the CM to find the service offer quotation of the LES and, if the conditions are acceptable, to contract the charging infrastructure service without an additional marketplace registration. If an access request does not lead to a positive authorization within marketplace B, it is checked whether the LES has contracts with service consumers from other marketplaces. Marketplace B determines the digital contract which the LES has signed with the CM and sends the request to the directory agent which is the ecosystem central manager. The directory agent validates whether marketplace B and marketplace A have a valid relationship and forwards the request accordingly. Marketplace A checks which participants have a contract with the LES from marketplace B and determines the CM. The CM knows the EC and responses with a positive authorization. This response is returned to the LES on the same way as the request was delivered. The LES lastly grands access to its charging infrastructure and the EC can charge her vehicle's battery. The CM will receive an invoice for the provided energy of the LES.

This scenario is far away from being implemented. A logical architecture depicting involved systems, parties and connections is presented in Figure 2. This elaborated architecture is domain independent. It is not limited to marketplaces for mobility services but applicable for all kind of service marketplaces which want to cooperate with each other to establish a fully connected service environment with a broad access on service functionality, data or infrastructure.

4. Reference Model for Interconnectivity

4.1. Concepts and Mechanisms

The solution elaborated in this section consists of a centralized management entity between service marketplaces. Although this entity is called *Directory Agent* it provides more functionalities than meta data management as ordinary service directories do (Tcholtchev et al., 2012). It is responsible for marketplace registration, service search, contract and relationship establishment and service request forwarding between all registered marketplaces. The centralized approach guarantees a good scalability and management while keeping the number of connection links to a minimum (Strasser & Albayrak, 2015). Furthermore, this architecture does not stress the network unnecessarily like free-floating architectures that use discovery messages.

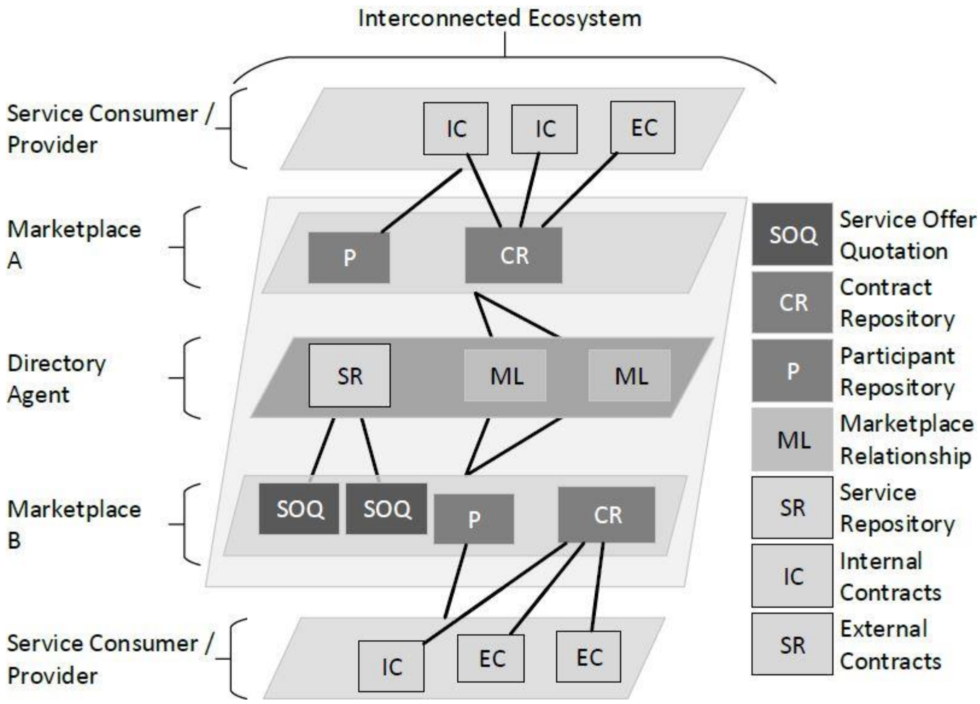

Figure 2. Abstraction of an interconnected service ecosystem.

Due to the contracting mechanism and the therein defined Service Level Agreements (SLAs), marketplaces do not enter or leave the ecosystem unexpected (Strasser, 2015). This is a major advantage and leverages the issue that leaving and joining participants have a great impact on a centralized managed architecture.

The sequence diagram in Figure 3 depicts a high level representation of actions and processes between a marketplace and the directory agent to join and benefit from the ecosystem.

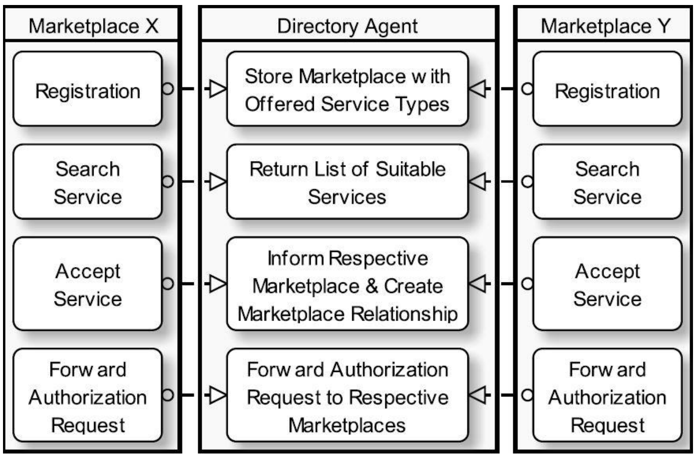

Figure 3. Interactions between marketplaces and directory agent.

First, a marketplace has to register with and connect to the directory agent. Then a list of all supported service types is uploaded to directory agent. Services and their descriptions remain at the marketplace. A participant can search for service quotations using key words. The directory agent queries the marketplaces and returns a list of filtered services to the requester. If a service suits, an accept message is send to the respective service provider. Certificates are used for authentication. Once the service provider created a contract a respective acknowledgement message is returned to the requester. This response message triggers that all parties which receive this message create contract and relationship artifacts too which represent the just established business relationship. Figure 4 depicts which parties have to have contracts with each other to enable request roaming within the ecosystem.

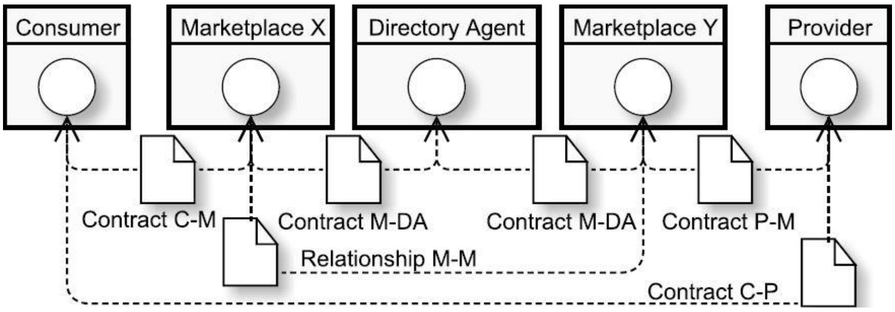

Figure 4. Artifacts depicting relationships.

For example: a service provider (SP) is registered with marketplace Y and thus has a contract P-M. The SP receives a contracting request of a service consumer (SC) which is registered with marketplace X. Thus, the SP creates a contract (C-P) and sends an acknowledgment with its certificate back to the SC. Marketplace Y also creates a contract entry (M-M) in its database which is used for request roaming. The directory agent creates a contract (M-M) to keep track of the cross-marketplace business relationship. The SC and marketplace X also create a contract artifact in their databases. The foundation for data exchange between foreign service providers and consumers is settled as soon as all entities have created respective contracts in their systems.

4.2. Implementation and Evaluation

A central directory agent and multiple fragmented service marketplaces have been developed for the reference model implementation. The actions and processes shown in Figure 3 have been implemented as well as the contract mechanism to establish the respective business relationships. A process engine has been used to develop the prototype. The communication is realized with web services build on Simple Object Access Protocol (SOAP). The developed ecosystem is depicted in Figure 5. Marketplace A, B and D are connected to the directory agent, thus generate an extended service trading network in which they cooperate with each other. All of them have several service providers and consumers which have established various internal business relationships. Contracts have been closed, in an automated fashion, in accordance to Figure 4.

Marketplace C operates in isolation without any connection to the other marketplaces A, B and D. The service provider P1, for instance, offers a charging infrastructure service S1 over marketplace A. On the same marketplace, service consumer C1 contracts S1 which appears in C1 business partners list as S1'. Marketplace A also stores the business relationship, illustrated by C(P1-C1). Due to interconnectivity, C5 can search and contract services provided by P1 (marketplace A) and P3 (marketplace B) (see entries in the lists). End customers of C5 are therefore able to use charging infrastructure not only from P5 of the same marketplace D but also foreign charging infrastructure of P2 and P3 that has been offered as service S1 and S4 respectively. The directory agent stores the relationships between marketplaces A-B, A-D and B-D and forwards request accordingly as long as the relevant relationship is active. It is active until the last contract between a provider and consumer, which has been established via the directory agent, expires. All roles in the interconnected ecosystem profit from the connectivity.

The participants registered with marketplace C are not able to expand their business. They could as soon as marketplace C joins the ecosystem by setting up a communication channel with the directory agent and register itself.

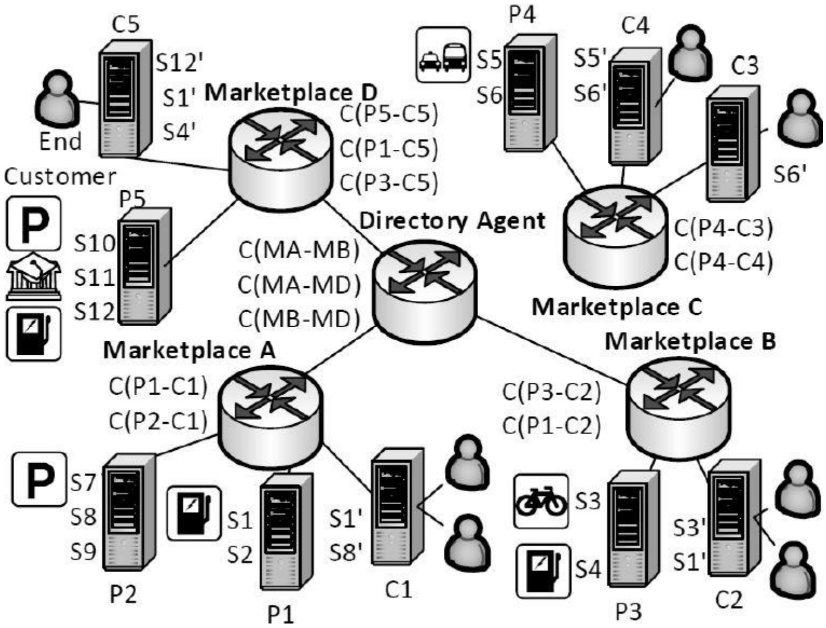

Figure 5. Architecture of the elaborated reference model.

Once all contracts are in place (Figure 4) and the ecosystem is set up appropriately (Figure 5) an end customer is able to access foreign services which have been contracted by his mobility provider (service consumer). The end customer does that i) without multiple mobility provider registrations, ii) with one single Unique Identifier (UID) (mobility-card) which ensures anonymity, iii) in real-time to access timely relevant services (e.g. traffic data, house monitoring data, charging stations, ticketing systems). The end customer authorization process within the elaborated ecosystem is shown using a Business Process Diagram (BPD) in Figure 6.

The authorization process starts with the end customer who triggers the authorization on a charging station with her mobility-card. The figure demonstrates what actions are necessary and which roles have to collaborate at what time to achieve the desired roaming situation described in Section 3.2. This BPD graphically represents what has been implemented by the prototype and what has been achieved - service authorization across system boundaries to provide access on services and data to a broader field of end customers and service compositors (service consumers).

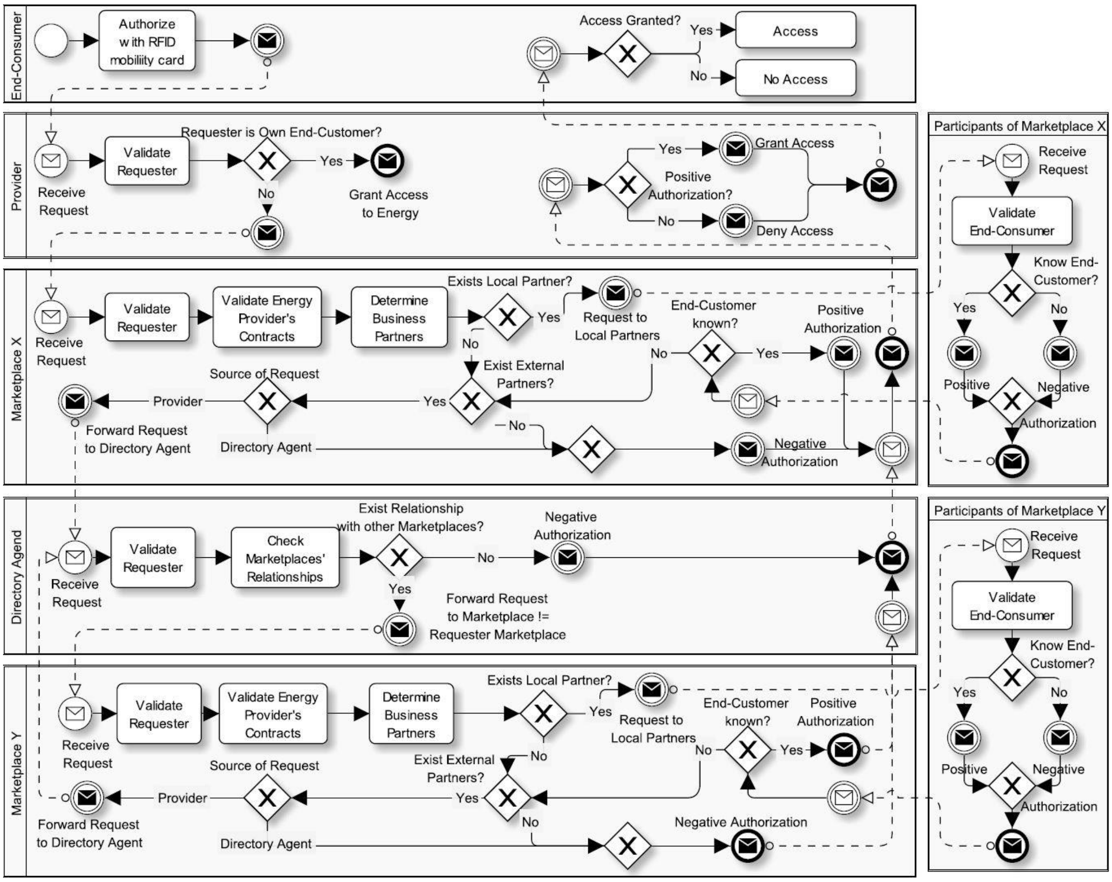

Figure 6. Authorization request roaming process throughout the complete ecosystem.

The data object diagram in Figure 7 presents the parameters for an end customer service authorization request as shown in Figure 3 and Figure 6 respectively. It represents an artifact of the message protocol that has been designed to accomplish interconnectivity between service marketplaces via a central managed entity. These parameters represent the minimum data set that is necessary to successfully proceed through all the tasks and validations shown in Figure 6. The data object diagram is shown to justify the statement that the implementation effort of a marketplace to connect to a directory agent and to authorize an end customer across marketplace ICT boundaries has its limits. Although the end customer authorization BPD and its respective data model are shown only, it can be said that the previous required actions like registration, search and contracting have a similar scope in respect to the BPD and the message protocol.

A marketplace sends an *AuthorizeStartReq* request to the directory agent in case it cannot be processed internally. After processing the authentication request in Figure 6, the directory agent responses with an *AuthorizeStartResp*. The presented data is the only information that has to be exchanged, via a single interface, between a marketplace and a directory agent to achieve interconnectivity. The UID is required to identify the end customer, thus is does never change. The *Provider ID* identifies a marketplace participant who received an end customer request.

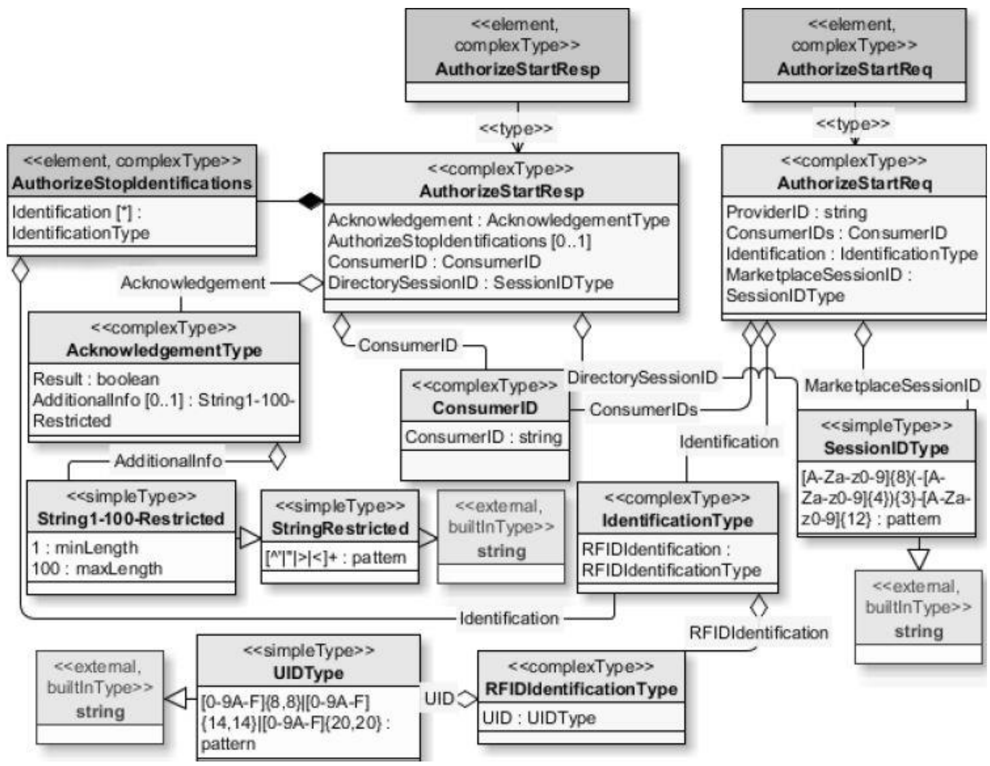

Figure 7. Object diagram for the authorization process.

The *Consumer IDs* represent those with whom the provider has signed contracts but are located on different marketplaces. The *DirectorySessionID* is for transparency, logging and to send the authorization stop message in a direct way as soon as an end customer logged out from the used service. The *Acknowledgment* in the *AuthorizeStartResp* contains whether an UID is positive authorized or not. The *ConsumerID* shows which service consumer did send the response and might has authorized a requesting end customer. The other actions of Figure 3 require different interfaces and information. The marketplaces also have to provide capabilities to receive requests from the directory agent. However, they are processed similar to the internal request forwarding and no major changes are required.

5. Conclusion

Unique contribution of the paper

The elaborated reference model demonstrates a feasible architecture to establish interconnectivity between service marketplace without creating a complete graph network. Interconnectivity is, from a technical perspective, achievable with acceptable effort and with one communication protocol. The paper shows necessary interactions between those parties which participate in the elaborated service ecosystem. The reference model also demonstrates that a contracting mechanism is important to identify roaming partners and to keep the exchanged messages to a minimum. A marketplace ecosystem provides not only benefits for those directly involved in a service consumption. Cities and citizens are also beneficiaries. When, for example, more people are able to

access mobility infrastructure and services in an easy manner, the more relaxed will the traffic situation of a growing city become. Using sharing, parking, public transport or charging services without multiple registrations may reduce the number of cars, the number of unnecessary journeys looking for a parking space or charging station and furthermore improve the situation for electric vehicles which might reduce the number of combustion vehicles. All this positively influences noise, heat and emission within cities. This improves a city's attractiveness and the citizens' quality of live. It also enables cities to connect each other's services and provide easy access to them for tourists or commuters. The proposed solution has been developed in such a generic and open manner that all kind of service marketplaces can connect, not only those for mobility services.
Considering the travelers in a city as individual swarms which movements depend on events (traffic jam, maintenance, demonstration, accidents and so on). Interconnectivity between the service marketplaces can support their movements accordingly, using real time information obtained by services. The closing of a road is for instance compensated by re-routing the traffic or by providing a suitable public transport connecting. To accomplish this, it is necessary that various services interact with each other and that their functionalities are orchestrated into an intelligent application. The connection of different services from different domains is believed to mitigate problems which cities currently face but also to provide new possibilities.

Managerial implications

The management of a service marketplace should acknowledge current trends and invest into functionality to satisfy potential participants. They need to invest into new functionalities and broaden their offerings even if the improvements might not completely correlate with their long term strategy or objectives. This is necessary because smart city provides various disruptive possibilities and investments are important to not fall behind competitors.
Moreover, the management has to admit that due to the domain's novelty they may have to change strategies and orientation as well as have to quickly react on new requirements or a changed market situation. Thus it may happen that earlier investments become obsolete. The management furthermore has to be aware of the competences and skills of their available resources before they define a strategy or to be used technology.

The lack of standardization and regulations is a two-edged affair. The lack provides the freedom for experiments without having restrictions imposed from the very beginning. However, having no boundaries leads to proprietary solutions which operate in isolation. This is contra-productive for long-term objectives like interoperability and cross system service consumption. On the other side, premature defined standards and regulations might not cover all aspects. Therefore, they might limit competition and creativity which are both necessary for building sophisticated service solutions in smart cities.

The study has shown a feasible approach, already acknowledged within the file sharing domain, to connect (mobility) service marketplaces within smart cities without falling into the old pattern of designing n:m networks, also called complete graphs. A complete graph solution was built in (Christ et al., 2015) with an increasing number of connections and proprietary protocols. The management of marketplaces have to understand the potential of interconnectivity on a long term rather than on short term. The 1:n connection approach is desirable to keep the implementation effort low while certain investments regarding interfaces and processes are unavoidable. However, interconnectivity increase the number of roamed service requests within a marketplace and thus a acceptable return of investment is expected.

One important aspect in roaming service requests, triggered by end customers, is data security and privacy. All entities which are involved in an ecosystem have to have appropriate mechanisms and approaches in place to guarantee that end customer data is kept safe and that it cannot be misused by unauthorized parties. The reputation of the directory agent and each marketplace is at stake if end customer data is not handled carefully.

Limitations of this research

Due to the novelty of the selected architecture it was not possible to connect existing solutions to our ecosystem manager. Although some of the interviewees are, or have been at the time of the interviews, project managers of existing solutions and agreed with the centralized architecture in general, neither a research nor a commercial solutions connected to the Directory Agent. This is, on the one hand, due to the limited development budget or different business orientations. On the other hand, is it feared that interconnectivity increases competition and that participants move to other solutions with a cheaper membership fee.

Although the interviewees shared their opinion about the potential of different architectural approaches they could not tell which implementation approach might be most promising.

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Appendix

During July and August 2015 the authors conducted qualitative interviews with experts (Rives, J.M et al., 2015) from the mobility domain. The experts have an acknowledged background in service provisioning gained throughout various commercial or research project related to the topic. They provided comprehensive inside into the current state of the art of mobility service solutions as well as outlined what they believe is required by future service trading solutions. The findings are discussed and presented in (Strasser & Albayrak, 2016). Interconnectivity, the demand for information exchange across marketplace boundaries as well as a centralized architecture were discussed. The findings of the interviews influenced the work on hand and the prototypical implementation.

The prototypically implementation consist of three service marketplaces (with rudimentary functionality to demonstrate end customer authentication) and the directory agent which roams marketplace requests between the marketplaces according to cross-system business relationships.
For the prototypically implementation we used a Business Process Modeling application called *inubit*, developed and provided by Bosch Software Innovations. We first created respective business process diagrams to depict the functionality of the overall marketplace system but also of each sub-system on an abstract level. The same was done for the directory agent. These diagrams facilitated the identification process of interfaces and data exchanges across the involved systems (e.g. by the swim lanes in Figure 6). The interfaces are designed as web services using Simple Object Access Protocol (SOAP) and Extensible Markup Language (XML). The interface description is provided via a Web Service Description Language (WSDL).
The actual data procession, transformation and sub-system calls is implemented via so called *technical workflows*. Each action shown in Figure 3 is represented as an individual web service operation and processed by a specific technical workflow. Figure 8 exemplarily presents a snipped from the main technical workflow of the directory agent. The figure shows the workflow’s start point on the left (which is actually a web service endpoint) called *...start Entrypoint*. On the right are the four operations which are necessary for a marketplace to register with the directory agent, to

search for a foreign service quotation, to contract a foreign service and to consume a foreign service (authorize end customer).

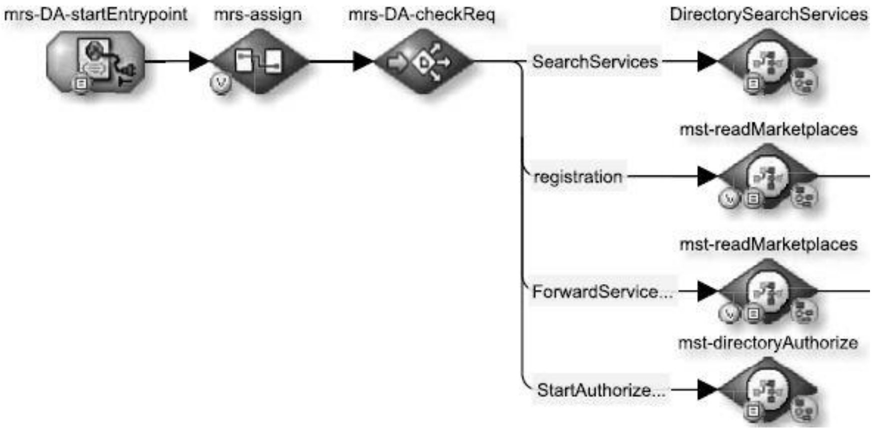

Figure 8. Directory agent technical workflow.

Based on the operation, which is defined during the interface invocation, the main workflow choses a particular branch and executes a specific sub-workflow. The graphical modeling approach facilitates discussions about what has to be done and when. It furthermore enables an easier understanding of the processes and their execution sequence as it can be done via source code.