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The potential of interconnected service marketplaces for future mobility ☆,☆☆

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ABSTRACT

Mobility currently evolves far beyond owning a car or using public transit services. Passenger transport can be managed by mobility providers by combining and extending various mobility services either directly or by using available mobility service platforms. This paper evaluates the capabilities and technical features of existing mobility service platforms with a special focus on electric mobility. Based upon this evaluation, criteria are presented which future platforms should address. As part of this work, a marketplace approach is developed which addresses the identified criteria. Potential marketplace architectures are presented which are deemed to establish marketplace interconnectivity. The developed marketplace approach and the proposed architectures contribute to the vision of an interconnected service ecosystem for mobility services.

1. Introduction

The number of world-wide mega cities with around ten million inhabitants or more is currently more than thirty [1] and continues to grow. The citizens and the commuters demand a satisfying level of mobility, provided by the public transport system, transport companies or by themselves in any way. Electric mobility (eMobility) is still a niche, even though it has been a major topic for many years and is considered to be a tremendous market in the future [2]. A closer look unveils its sustainable potential: eMobility affects various domains which would have been undetected at first glance. The production domain for electric engines and batteries are directly involved as well as the energy domain which is in charge for providing electric power in an intelligent manner. eMobility also affects domains like the public and private transport, logistics, parking, vehicle sharing, and urban design.

A lot of research has been conducted on electric vehicles and eMobility in general. The research's achievements help to promote eMobility in our society. A good example is the North Sea region with about 70 eMobility projects [3]. To support the progress of eMobility, Value Added Services (VAS) are designed, developed and publicly provided via service platforms. This is done in various publicly founded projects[1] but also by companies.[2] To the current date, these service platforms are specialized in a particular eMobility domain like charging, car-sharing, parking or others.

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[1] Green eMotion (GeM) (www.greenemotion-project.eu/. Accessed: 02.06.2014), CROME (crome-project.eu/, Accessed: 27.06.2014), Olympus (www.proeftuin-olympus.be/en/home-1.htm, Accessed: 05.01.2015), Streetlife (http://www.streetlife-project.eu/index.html, Accessed: 05.01.2015).

[2] Hubject (www.hubject.com/pages/en/index.html#1-1-home.html, Accessed: 23.06.2014), Parku (www.parku.ch/?lang=en, Accessed: 23.06.2014), Multicity (www.multicity-carsharing.de/en/, Date Accessed 10.06.2014).

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The next section provides an insight into existing eMobility platforms and presents criteria for future service marketplaces. The criteria have been elaborated based upon the identified strengths and weaknesses of current platforms during the State of the Art (SotA) analysis. Section 3 introduces an eMobility marketplace approach and demonstrates how current limitations can be solved. Section 4 discusses current limitations of eMobility platforms and addresses the lack of interconnectivity. In this section architectural approaches are proposed which are considered to overcome the gap of interconnectivity between eMobility platforms. A conclusion is provided in Section 5 and an outlook can be found in Section 6.

2. Existing eMobility platforms

The platforms introduced in this section operate in the mobility domain. Parking, vehicle sharing and charging are part of this domain. Some presented platforms offer services for eMobility whereby some of these services are also useful for combustion vehicles. Services designed for combustion and electric vehicles might require a different treatment. A combustion vehicle for instance can use every suitable parking lot. In contrast, an electric vehicle with low battery capacity probably needs a parking lot with a charging station. If such a parking lot is occupied, the electric vehicle driver has to find another suitable parking lot with a charging station and within the vehicle's remaining range. Thus, within the parking domain, it is feasible to differentiate the kind of vehicle which occupies a parking lot. The term platform is used in this section but will be replaced by eMobility MarketPlace (eMMP) later. The authors of this work consider a trading platform which enables only one supplier to sell capabilities to multiple end-customers not as a marketplace. That complies with Petersson and Lind [4] who conclude that a *1:n* relationship violates the marketplace paradigm. That paradigm constitutes that the marketplace is a multi-party trading environment. It consists of multiple suppliers and consumers [5–8]. Therefore the marketplace is an environment of *n:m* business relationships.

Table 1 provides an extract of globally available eMobility platforms for major mobility domains. This extract does not claim to be complete but shows that eMobility is of great interest around the globe and affects various eMobility domains. The platforms have been identified using web searches, project disseminations and publications as well as internal reports.

2.1. Identified criteria for future eMobility marketplaces (eMMP)

A future eMMP should address certain criteria to develop from a basic service platform to a strong marketplace for eMobility services. The criteria has been elaborated based upon the platform capabilities identified during the SotA analysis. This analysis consists of (i) platform publications and disseminations (ii) official platform web pages and (iii) discussions with domain experts and project leaders.[3] One of the used methods during the SotA analysis has been Zwicky's morphological box [9]. The morphological box unveiled (i) current platform capabilities and (ii) feasible new platform capabilities which can improve the overall platform operation but are not yet implemented. The criteria has been defined while analyzing the current and the possible future capabilities. The identified criteria narrow down the list of existing platforms which will be analyzed and referenced later.

Future eMMPs should address following criteria:

- Span over multiple systems to access service infrastructure.
- Allow remote access on infrastructure.
- Associated service buyers must have real end-customers in the field.
- Process infrastructure information and internal data.
- Participation and contribution need to be manageable.
- Transaction data must be available and accessible.
- Host at least two different eMobility domains.
- Host multiple service buyers and service suppliers.
- Open for various mobility domains and participants.
- Use open and/or standardized protocols.
- Implement contracting approach for automated service processing.
- Support interconnectivity between eMobility marketplaces.

The strengths and weaknesses identified during the SotA analysis of current eMobility platforms are listed below. These findings among others have been used to define the criteria for future eMMPs. Ideally, future eMMPs should not only overcome the current platform weaknesses but also implement their current strengths and improve them. An improvement of a strength should not be on the expense of a weakness.

- General platform strengths:
    - Contribute to protocol standardization.

[3] Representatives of the German showcase region program. Project members of Green eMotion, CROME, Open Mobility Berlin (VeMB) and EMD (www.emo-berlin.de/en/showcase/projects/, Accessed: 27.07.2014), Stuttgart Services (www.livinglab-bwe.de/projekt/stuttgart-services/, Accessed: 10.07.2014) and Hubject.

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Table 1
Extract of existing mobility platforms.

Car-Sharing	Go Get, Car2Go, RODA RIO, eHi, BlueLy, Multicity, e-Flinkster, Zoom, GoCar, enjoy, City Car, Carrot, Cityhop, Zipcar, Drive Now, Open Mobility, Olympus, Street Life
Charging	eV-charging, Multicity, ECOtality FULLCHARGER, e-Flinkster, Plug Share, Better Place, CROME, Chargepoint, Hubject, Green eMotion, Plugfinder, Open Charge Map, Open Mobility Berlin, Olympus, Stuttgart Services, GIREVE, e-clearing.net
Parking	Multicity, Plugfinder, Streetline, e-Flinkster, Open Mobility Berlin, BestParking, Parkopedia, Park2Gether, Parku, Parkpocket

  - Partially enable communication among platform participants.
  - Contribute to the eMobility evolution and vision.
  - Support customer roaming.
  - Develop and evaluate eMobility business cases.
  - Hosting various services from different domains.
  - Perform protocol adoption.
  - Use of contracting approaches.
- General platform weaknesses:
  - Use of different (incompatible) protocols.
  - No support of interconnectivity.
  - Intermittent end-customer and service roaming.
  - Use of closed prp.
  - Host only one mobility domain.
  - Host vertical services but no horizontal/utility services.
  - Transaction data not available for further processing.
  - Contracting approach semi-optimal.
  - Communication exclusively via platform.

It is feasible for an eMMP to host multiple service operators (SO) and service providers (SP) from different locations and domains. That enables end-customers to access an even wider operational area without being concerned about any infrastructural or technical restrictions. Table 3 depicts the roles used in this work and their characteristics. The services offered via an eMMP should have a high variety in their operating domain and their functionality. These characteristics are deemed to make an eMMP attractive for new potential participants. This imposes that the eMMP needs to be an open environment. The term open needs to be differentiated into two categories. Open in the first category implies that the eMMP is generally open for all potential participants which are interested to register with the eMMP. Open in the second category implies that the eMMP is open for each kind of service, thus not exclusively limited to some service domains only, like parking or charging. Only an open marketplace assures service variety and the provisioning of vertical and horizontal services.

After obtaining membership, service operators can offer their capabilities to other participants. Service providers in contrast lack capabilities and thus look for appropriate offers from other participants. The services offered via an eMMP can be of vertical and horizontal nature. A vertical service yields a particular domain. In eMobility such a service for instance enables access to charging or parking infrastructure. A horizontal service in eMobility is of general purpose, thus does not target a particular mobility service. A payment or a weather service are examples for horizontal services in eMobility.

The real end-customers are necessary because they actually use and consume the services traded via the eMMP. The end-customers make the eMMP vital and cause service transaction data within the eMMP. Transaction data which was processed throughout the eMMP should be stored for later processing.

A service operator and a service provider that intend to conduct business via an eMMP have to sign a contract via the eMMP. This contract defines the terms and conditions of their business relationship. The contract is used to process the service requests accordingly. The contracted partners need to use a common communication protocol. A protocol-adaption needs to be in place if no common protocol is used.

Furthermore, an eMMP should not only be able to authenticate the end-customer on-site but also remotely if on-site authentication fails. Nevertheless, future work has to include comprehensive functional and non-functional requirement engineering using an appropriate methodology like Volere[4] to identify more possible criteria for future eMMPs. So far the defined criteria are sufficient enough to compare and evaluate eMobility related platforms.

2.2. Comparison of available platforms in respect to the identified criteria

The platforms presented in Table 2 are a selection out of Table 1. These platforms have been chosen in respect to their publicly available information about their used approach and implementation and discussions with experts. Most of the platforms presented in Table 1 are pure web pages and do not provide detailed information on how they operate. Comprehensive and publicly available information about the platform's approaches has been necessary to evaluate the

[4] By James and Suzanne Robertson.

Table 2
Evaluation of shortlisted platforms. Chargepoint (CP), Open Charge Map (OCM), Plugfinder (PF), X = fulfilled, – = not fulfilled, n = not applicable/no significant information found. Evaluation based on the identified criteria.

	VeMB	CROME	CP	Hubject	Streetlife	GeM	PF	OCM	Olympus
Infrastructure search	X	X	X	X	X	X	X	X	X
Infrastructure usage	X	X	–	X	–	X	–	–	n
Customer roaming	X	X	–	X	–	X	–	–	n
Cross border operation	X	X	–	X	n	X	X	–	n
Open protocol	X	–	–	–	n	–	n	–	n
Open architecture	X	–	–	–	–	–	–	–	–
Multiple provider/consumer	X	X	n	X	n	X	n	n	n
Multiple domains	X	–	–	–	n	–	–	–	n
Transaction data	X	X	n	X	n	X	–	–	n
Service provider/end-customers	X	X	n	X	n	X	–	–	n
Manage participants	X	X	X	X	n	X	–	–	n
Service contracting	X	X	–	X	n	X	–	–	n
Support interconnectivity	–	–	–	–	–	–	–	–	–

platforms according to the identified criteria. It shows that no platform fulfills all of the identified criteria for future eMMPs. Moreover, the table makes clear that there are many capability gaps which need to be addressed by future eMMPs. These gaps are for instance the capability of interconnectivity via interfaces, hosting multiple domains with multiple service providers respectively multiple service operators as well as applying an appropriate contracting methodology. Finally, the implemented communication protocol is also of high interest for future eMMPs.

Many criteria in Table 2 are marked as not applicable. That implies that not even extensive research (including contacting the platform providers) lead to information which would have been necessary to answer the question whether a criterion is met or not. Even though the platforms in Table 2 provide more information in respect to their approach than other platforms, the information is still not sufficient to successfully contribute to future eMMP design and implementation decisions. Possible reason for the lack of information are (i) the information is held back to avoid indirect support of competitors, (ii) the information is not yet ready to become published or (iii) the information is not publicly available and membership is required to get it.

Most of the identified criteria are met by CROME, Open Mobility Berlin, Hubject and Green eMotion. Thus these systems are of particular interest and will be analyzed further. Hubject has a commercial focus whereas the other three platforms are publicly funded research projects from the European Union, France and Germany. Therefore they have a research oriented focus. Despite this difference, all four platforms access the charging infrastructure of different service operators. They also overcome location and system borders. They all enable their participants to exchange data. The platforms establish a kind of service roaming for their participants' end-customers. Their operational approach is rather complex because they (i) have to cope with missing standards for protocols, interfaces and service descriptions and functionality as well as (ii) have different business models and objectives. The latter makes it difficult to define a standard for protocols and interfaces. Nevertheless, all those platforms' work contribute to standardization within the eMobility domain. Furthermore do they explore potential new business models which might increase the attractiveness of eMobility.

The other identified platforms like Plugfinder (PF), Chargepoint (CP) or Open Charge Map (OCM) offer information about charging points. They have an exclusive 1:m relationship in place and therefore are not considered as an eMMP as defined within this contribution. In contrast, CROME, Open Mobility Berlin (VeMB), Hubject and Green eMotion (GeM) have a contracting approach and manage business relationships. The transaction data can be used by a clearing provider to charge service consumption as its new business model. Additionally, the transaction data can be used to monitor infrastructural workload of, for instance charging stations or parking lots. That monitoring data can be used to adjust the usage prices for these resources dynamically.

Until now, the mentioned platforms have common disadvantages. They are not able to communicate and exchange data among each other. They also do not host different mobility domains nor do they use a common protocol. That for example prevents Hubject to determine what services or participants are available via GeM or CROME. Without a common protocol, GeM is not able to determine whether a requesting end-customer is registered with a Hubject participant or not. Interconnectivity among eMobility platforms is not yet realized and an appropriate architecture to establish interconnectivity is not yet publicly available.

3. eMarketplace for mobility services

An eMMP is a Business-to-Business (B2B) environment which enables service operators and service providers to conduct business. A service operator can be for example a Charge Point Operator (CPO) and a service provider an Electric Mobility Provider (EMP). A transaction between a service operator and a service provider is a minimal transaction. A transaction which consists of a service operator, a service provider and an end-customer is a maximal transaction.

A CPO can offer capabilities as a service via the eMMP to other eMMP participants. An EMP lacks capabilities and searches for services offered via the eMMP. After a service operator and a service provider have agreed on a service and its conditions,

Table 3
Role model: Overview of roles and their intentions and dependencies.

Role	Synonyms	Intention/value	Depends on
End-Customer	• EC • User	• Easy access to mobility services	• Service provider
Service provider	• Service buyer • Service consumer • Participant • EMP (charging) • CSP (car-sharing)	• Offers service(s) to end-customer(s) • Closes lack of functionality • Contracts many service operators • Increases profit and market share • Decreases time to market and development costs • Increases service quality	• eMobility marketplace
Service operator	• Service seller • Service supplier • Service owner • Participant • CPO (charging) • CSO (car-sharing) • SCCO (payment)	• Provides services • Contracts many service providers • Achieves higher service usage	• eMobility marketplace • Service operators if other services are aggregated
eMobility marketplace	• eMMP	• Provides trading environment • Provides protocol-adaption • Provides service routing • Binds many participants • Merges service responses • Eliminates response duplicates	• Participants (service operator/ provider)

they sign a contract to conduct business via the eMMP. Under certain circumstances it might happen that a service provider is also a service operator. This is possible because service providers can: (1) sign contracts with other service operators, (2) aggregate the services' functionality in a new service and (3) offer the new service via the eMMP.

Every new service operator that joins an eMMP increases the service variety within the eMMP. A high number of different services makes the eMMP to a valuable service environment which attracts service providers. A service provider should have business relationships with as many suitable service operators as possible to satisfy its end-customers' needs. A potential end-customer is assumed to join a service provider that offers the best and extensive service functionality rather than the one with little service functionality.

3.1. Roles within eMMP service transactions

In [10,11] various roles have been identified which are involved in a service transaction. The service provider and the service consumer are particularly emphasized because a service transaction consists of at least these two roles (minimal transaction). These two role terms are widely used within the service domain [12–14]. Nevertheless, in this work the term service provider is changed to service operator and service consumer is changed to service provider. The reason for the change is that the actual service consumer is the end-customer who accesses services via interfaces provided by his service provider. Table 3 shows that the roles rely on each other and therefore should trust each other. Trust is an important factor within an eMarketplace [15].

1. end-customer: The end-customer wants his requirements to be met [16]. Thus he might registers with as many service providers as possible to satisfy his demands and to retrieve the most suitable result. However, multiple platform registration is perceived as inconvenient [17]. The services have to be available whenever the end-customer requires them [18]. To use a service the end-customer has to register with at least one service provider and has to invoke the offered service.
2. service provider: The service provider lacks and thus requires certain capabilities to satisfy its business demands [16]. This lack can be for example access to charging infrastructure. The service provider has end-customers. It is feasible that a service provider contracts as many service operators as possible. This might increases the service quality for the end-customers who want to access the services at any time [11]. End-customer satisfaction can have a positive impact on the service provider's profit and market share [19]. Service providers and service operators conduct business via the eMMP on a contract basis. The contract defines the Service Level Agreements (SLA) as well as other terms and conditions of the service usage. Examples are system performance, system availability, system redundancy or response time. The contract ensures that the end-customers receive the promised service quality [18].
3. service operator: The service operator is the original owner of the services which are contracted by the service providers. The service operator provides the capabilities accessible via services, for example to search a charging station, to unlock a car-sharing vehicle, to reserve a parking lot or to obtain information about a bus schedule. The service operator's goal is to

increase profit by increasing service utilization through the service providers' end-customers who are charged for their service usage [20]. This implies in turn that the service operator aims to bind as much service providers to its services. The service operator's responsibility is to guarantee the service availability [18].

A role's abbreviation differs from domain to domain. For example, CPO and EMP are used in the charging domain while Car Sharing Provider (CSP) and Car Sharing Operator (CSO) are used in the car-sharing domain. Another example is a Service Consumption Charging Operator (SCCO) There is currently no standard available that defines how roles should be named.

At this juncture it is important to understand the three roles introduced above to understand how an eMMP operates. Once an eMMP develops it can be the case that other roles are also of interest. The *Zachman Framework*[5] can be approached to determine involved roles and their characteristics.

3.2. eMMPs for Value Added Services (VAS)

In contrast to the previously presented platforms which have implemented the charging domain only, an eMMP is supposed to host services from various different domains. Numerous different service operators can market their services within an eMMP. VAS can be of vertical nature like charging, parking and routing services but also of horizontal nature like service charging (clearing) or weather services.

The VAS provided by service operators via an eMMP can be used by service providers either (i) as individual or single services or (ii) as service compositions which aggregates service functionalities to new services. The more services available via an eMMP, the more service compositions are possible. A service provider that uses services offered via an eMMP (i) increases its flexibility, (ii) reduces its development costs and (iii) decreases its services' time to market. All this is possible without being concerned about the services implementation [21] or used technology [22].

3.3. Service contracting method

The marketplace paradigm has been identified to be of high potential according to contracting and service conducting [10]. Therefore well elaborated service contracting is considered as a key factor for eMMP success. A contract between two business parties makes an eMMP to a real marketplace where services are traded like goods. In Goldkuhl's six business phases [23] signing a contract is part of the forth phase. In the last of Goldkuhl's phases, the completion phase, the contract partners have to (i) deliver the service functionality and (ii) pay for the service consumption.

Green eMotion, Hubject, CROME and Open Mobility Berlin use a contracting approach. A service operator and service provider can only conduct if (i) they have a valid contract and (ii) this contract has been closed via the eMMP. The digital contract is used by an eMMP to process business transaction. An expired contract is not a valid contract. The former business partners can re-establish the business relationship once they sign a new contract. If a business partner entitles a third party to access business relevant data of its business partner then this must be part of the contract.

For example, service operator A (SO-A) offers a service-consumption-charging service. Service operator B (SO-B) offers charging infrastructure services and does not want to send invoice to contracted business partners for their service consumption. Thus SO-B instructs SO-A for doing so. They both sign a contract. SO-A is now entitled to access contract data of its client SO-B and SO-B's business partners (for example service provider A (SP-A)). That third party relationship (contract between SO-A and SO-B) is part of the contract signed between SO-B and SP-A. Thus SP-A cannot forbid SO-A to access necessary eMMP data as long as the contracts between SO-B and SO-A and SO-A and SP-A are valid. The data processing performed by SO-A has to comply to the terms and conditions given in the contract signed between SO-A and SO-B. This scenario does not include end-customers and is therefore considered as a minimal transaction relationship.

4. Interconnectivity towards an eMMP ecosystem

4.1. Lack of interconnectivity

Service marketplaces are emerging [24] and already offer various services. Nevertheless, current solutions lack the capability to communicate with each other. Missing communication channels are assumed to neglect future business cases and also limit end-customers in their operation area. Platforms use their own protocol to interact with their participants. Until today, none of the used protocols is finally standardized by International Organization for Standardization (ISO) or DIN (Deutsches Institut für Normierung).[6]

The CROME platform uses the *CROME* protocol and the Green eMotion platform uses the *Green eMotion* protocol. The e-clearing.net platform uses the *Open Clearinghouse Protocol* (OCHP) to enable the communication between their platform and their participants. The *Open Intercharge Protocol* (OICP) is used by Hubject to communicate with Hubject participants. The Open Charge Alliance provides the *Open Charge Point Protocol* (OCPP) which is used to connect charging stations to management systems. The Open Mobility Berlin project uses its internal *Open Mobility Network Interface* (OMNI). Chargepoint and

[5] Developed by John Zachman Framework in 1980s at IBM.
[6] The German Institute for Standardization.

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the Open Charge Map use Application Programming Interfaces (API) for the communication with their participants and their management system.

All these protocols and APIs provide capabilities to establish the communication either between the platform and the platform participants or between the platform and the charging infrastructure. The table in Fig. 1 depicts that the protocols have no capabilities to enable access at internal data. Internal data is for example contract data, transaction data or information about available services or participants.

The lack of missing communication methods between the eMMPs endangers the vision and objective of an interconnected eMMP ecosystem.

The following example demonstrates the problem of missing interconnectivity among eMMPs: CPO-A offers services via eMMP 1 and CPO-B offers services via eMMP 2. EMP-A joined eMMP 1 and has a contract with CPO-A. Thus an end-customer (ED)-A of EMP-A can access services provided by CPO-A. However, end-customers of EMP-A cannot access services provided by CPO-B because eMMP 2 cannot contact eMMP 1. The scenario is depicted in Fig. 2.

	Author-ization	Start charging	Search by	Publish charging station	Validate authorization	Reserve	Reservation options	Notification	Operations	Charge session record
	local 4,5	local start	address 1,5	push data 1	push data 1,4	station	block x minutes	status 2,4	firmware 3	pull 1,4
	remote	local stop	coordinates 1,3,5,6	push data list 1,3,4,5	push data list 1,4,5	plug 3,6	block for fix minutes	heartbeat 2	availability 4	push 1,2,3,5,6
		remote start	ID 1	online database	whitelist 2,4,5		block for time slot 3,6	boot 2	diagnostic	delete 4
		remote stop	list of Ids	real time 1	real time 1,2,3,6			charge	status 4,5	modify
			operator		download data 1,4,5			reservation 3		
All	1,2,3,6	1,2,3,6								
N.a.		4,5	2,4	2,6		1,2,4,5	1,2,4,5	1,5,6	1,5	

Fig. 1. Overview protocol capabilities. OICP v1.2 (1), OCPP v2.0 (2), CROME v1.2 (3), OCHP v1.2.0.18 (4), GeM D.3.5 (5), OMNI (6), N.a. = Not applicable.

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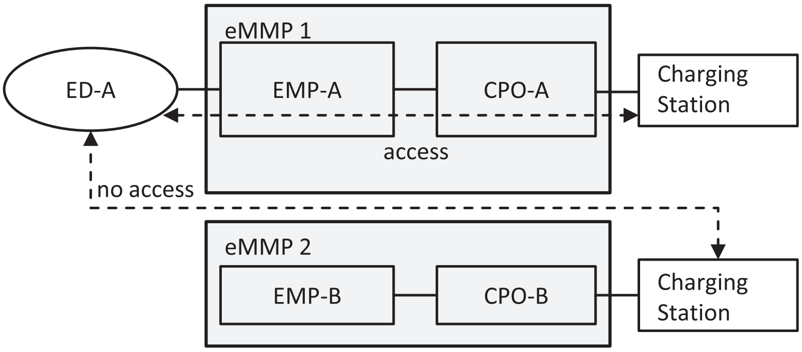

Fig. 2. End-customer service access via eMMPs.

To enable ED-A to access functionality of CPO-B, it is necessary for ED-A to register with any EMP-X which has a contract with CPO-B via eMMP 2. That results in multiple registration which is considered as inconvenient. If appropriate eMMP interfaces for interconnectivity would be in place, eMMP 2 can contact eMMP 1 on behalf of CPO-B and ask if ED-A is known. If interconnectivity would be possible then (1) EMP-A confirms ED-A, (2) eMMP 1 forwards the confirmation to eMMP 2, (3) eMMP 2 forwards the confirmation to CPO-B and 4) CPO-B allows ED-A to access the charging infrastructure. Because an end-customer is involved in this scenario it is considered as a maximal transaction relationship.

Another example presents the business case of service-consumption-charging: A SCCO offers a service-consumption-charging service via an eMMP. This service is a horizontal service. Once a SCCO has settled a contract with another service operator, the SCCO is able to access data of its business partner via special interfaces. These interfaces are used to gather transaction data and contract data of the contracted service operator and its respective service providers. With both data sets the SCCO is able to create an invoice and to request the payment for the service consumption according to the contract. Service-consumption-charging should also be possible for cross eMMP service consumption as explained in the previous example. The instructed SCCO of CPO-B needs to be able to send an invoice to EMP-A to charge the service consumption of ED-A.

An obstacle of today's platforms and their registered service providers is that being a member of one eMMP is not sufficient. Table 1 and the table in Fig. 1 have revealed that there are (i) a lot of platforms available, (ii) most platforms operate in one domain only and (iii) platforms use different protocols.

If an end-customer is registered with one service provider only which in turn is registered with one eMMP only, it might happen that not the best outcome is delivered according to the end-customer's request. The outcome will only consist of the results returned from the contracted service operators within the same eMMP. In worst case the contracted service operators of the same eMMP do not provide any suitable or satisfying result according to the end-customer request. Fig. 3 depicts eMMPs with their system boundaries to demonstrate their separation.

The dilemma of eMMP separation implies that end-customers should register with several EMPs (which in turn are registered with several eMMPs) to derive the best possible outcome. The services offered via each eMMP are currently only available for those EMPs who (i) are registered with the respective eMMP and (ii) have contracts with respective CPOs.

From an end-customer perspective, it is feasible to demand the best suitable outcome according to a service request. Therefore it is proposed that the eMMP (i) forwards the request to all contracted business partners and (ii) forwards the request to other eMMPs if the internal forwarding did not succeed. This approach is assumed to satisfy all involved parties because (i) the service operators' services are used frequently, (ii) the end-customers get suitable service results and (iii) the service providers' have satisfied end-customers. To the present day, request forwarding is not possible because the platforms are separated and no interconnectivity is in place. Therefore overall satisfaction will not be achieved.

To overcome eMMP isolation and to establish eMMP communication, appropriate interfaces need to be in place. Interconnectivity is believed to create a sophisticated ecosystem with positive effects and benefits for all involved parties. An interconnected eMMP ecosystem is believed to pave the way for eMobility by offering special service capabilities. eMMPs can also be used by other domains like intermodal routing or autonomous driving. Both domains require a significant amount of information for their service operation which can be obtained from services offered via eMMPs.

4.2. Towards interconnected eMarketplace ecosystem

To reshape the way of todays mobility towards eMobility and mobility services it is important to convince potential end-customers of its benefits. These benefits, for example easy access to mobility services, increased operation area or reduced carbon dioxide (CO2) footprint, need to outbalance the current shortcomings like long charging hours [25] or range anxiety [26]. Even though eMobility experience various challenges, it is believed that appropriate business models and especially the usage of information and communication technology (ICT) can help to overcome these challenges [20]. ICT

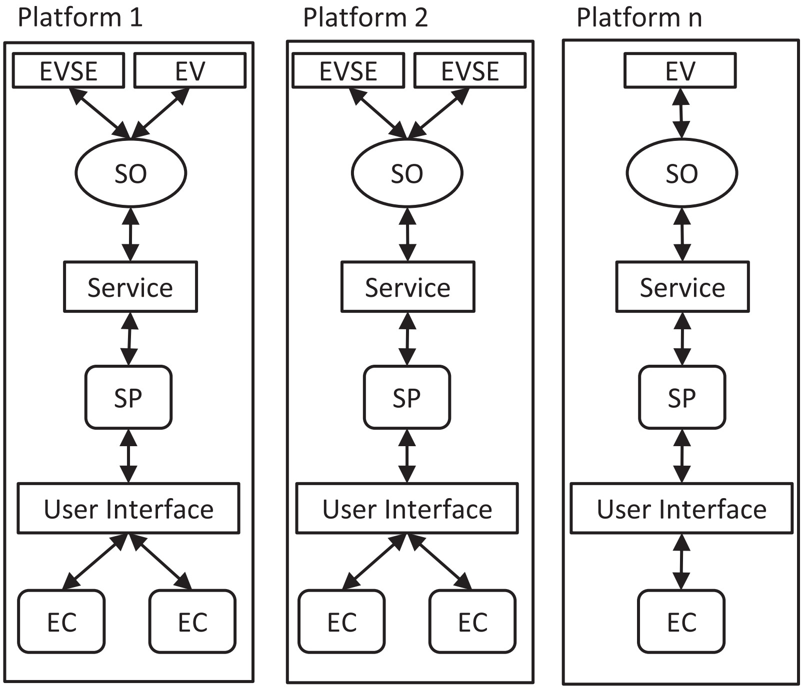

Fig. 3. Separate platforms without interconnectivity. EC = End-Customer, SO = Service Operator, SP = Service Provider, EV = Electric Vehicle, EVSE = Electric Vehicle Supply Equipment.

provides possibilities to develop exact tailored eMMPs for mobility services which are able to deal with various mobility domains but also to establish interconnectivity among eMMPs.

An open eMMP, which offers all kind of services is therefore assumed to be the reloading point for eMobility and fosters the vision of an eMobility ecosystem [27]. Once end-customers perform different actions without multiple registrations, interconnected eMMPs have helped to increase the attractiveness of eMobility by making its usage easy and convenient. A convenience provided to end-customers could be for instance to reserve a car-sharing vehicle and a parking lot with a charging station with only one registration and one user interface.

4.2.1. Request-routing through eMMP interconnectivity

The SotA and the protocol analysis confirm the statement of [11] that existing platforms lack the possibility to communicate with each other. However, interconnectivity is required for service or end-customer roaming among eMMPs. That roaming is similar to what is known from the mobile-phone-roaming.

Below are two concrete scenarios which demonstrate what positive effects interconnectivity can have on service roaming.

An end-customer A (ED-A) is registered with a local service provider A (SP-A). SP-A has a contract with a local charging station operator A (SO-A). In the current scenario, ED-A drives with an electric vehicle from city X to city Z. Once ED-A arrives at Z, the battery is empty and needs to be charged. The charging stations in Z are operated by a local charging operator SO-B. The problem is now that the ED is not known by SO-B. Therefore the charging process will not be authorized at first. But because of eMMP interconnectivity, ED's request is sent from the eMMP of Z to the eMMP of X. SP-A retrieves the request and identifies the ED as his customer. SP-A responses and SO-B authorizes the ED-A to use the charging station.

ED-A is registered with SP-A. SP-A offers car-sharing services. If ED-A wants to use a car-sharing vehicle from car-sharing operator SO-A, ED-A's request is rejected by SO-A. With eMMP interconnectivity ED-A's request is broadcast to other eMMPs. Then SP-A can answer and act as a trusted entity which the requesting SO-A can trust. An important difference to the previous described charging service example is, that using a car-sharing service requires a driving license by ED-A. Thus it is necessary for a SP to check whether a requested service has any imposed restrictions or does require special permissions. A car-sharing provider requires a valid driver license of each end-customer to complete the registration process. A car sharer cannot verify an end-customer's driving license on site and thus any end-customer without a registration will be rejected. However, the car-sharing provider can forward the request to contracted partners. With interconnectivity, the eMMP can also forward the request to other eMMPs. A SP response can consist of (i) an acknowledgment which indicates that the ED is registered, (ii) information about what services the ED has registered and (iii) what evidence has been provided during the registration. Latter information can be used for permission checks to prevent service misuse. Service misuse is for example if an underage end-customer without a driving license wants to use a car-sharing service.

In summary, interconnectivity increases the end-customers operation area and avoids multiple end-customer registration. As an example, an end-customer is using the same mobile phone app for (i) searching and opening a charging station, (ii) reserving a parking lot or (iii) opening a car-sharing vehicle from different providers with one single registration. This easy access may attract new end-customers to register with a service provider. The end-customers who have been roamed through the eMMP ecosystem also increase the usage rate of the service operators' resources.

4.2.2. Requirement for eMMP interconnectivity

In order to realize the communication between eMMPs, missing communication interfaces need to be identified, designed and implemented. Once appropriate interfaces are in place and frequently adjusted according to the eMMP and its participants' requirements, they can provide a solid foundation on which interconnectivity can be built on. Fig. 4 presents a high level overview of the identified missing communication channels. These channels need to be analyzed and later established to create a reliable and sophisticated interconnected eMMP ecosystem.

As B2B service usage will be charged [19], service-consumption-charging is considered as one of the main functionality within an eMMP. Therefore future work will develop a set of interfaces to enable access at general eMMP data. To test and evaluate the interfaces, the respective service-consumption-charging service will be developed too. Interconnectivity between eMMPs can be accomplished only if all eMMPs provide the same interfaces. That implies (i) that the same protocol is used by all eMMPs or (ii) a protocol-adaption method is required.

Below is an extract of requirements which an eMMP has to meet to enable interconnectivity. The requirements have been identified through the research carried out in various projects. The list of requirements does not claim to be complete. It is assumed that additional requirements will be identified once the service-consumption-charging service is developed, tested and evaluated.

- Interfaces for eMMP participants:
  - To enable business partners to access their transaction data.
  - To enable business partners to access their contract related data.
  - Certain participants (e.g. SCCO) require special treatment.
    - to access business partners', transaction data,
    - to access business partners' contracted data.
- Interfaces for eMMPs:
  - To receive and response to eMMPs requests.
    - To forward other eMMP requests.
  - To access foreign eMMP data.
    - to determine hosted domains,
    - to determine available services and service descriptions,
    - to determine available participants and respective contracts.
- Data interfaces require:
  - A standardized communication protocol.
  - A mechanism for protocol-adaption.

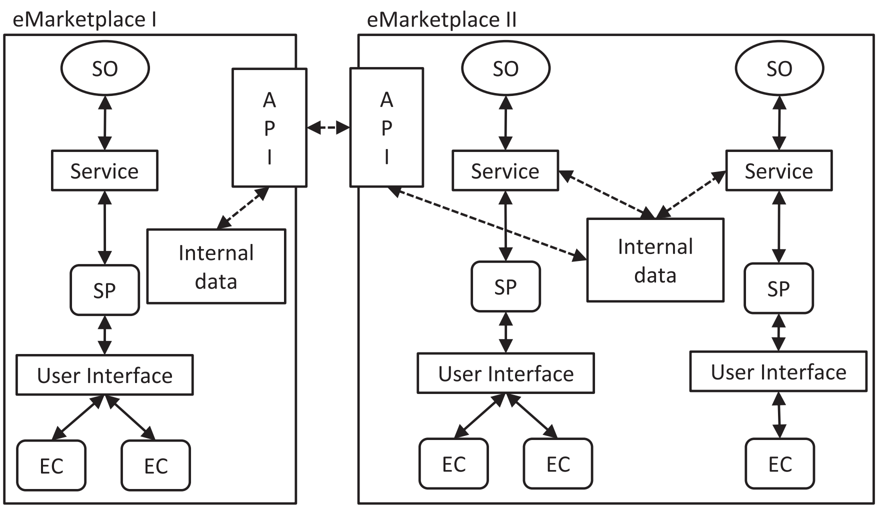

Fig. 4. Missing internal and external communication channels. Dashed lines depict missing communication between marketplaces and internal communication.

Service-consumption-charging is the last action within a business relationship and is done after the service has been delivered [23]. A business transaction is deemed successful once the service operator delivered the service functionality and the service provider paid for the service consumptions of its end-customers.

4.2.3. Architectures for eMobility Marketplace interconnectivity

The architecture of future eMMPs needs to handle various service domains, enable data exchange between eMMP participants but also enable eMMP to eMMP communication. Various architectural approaches are capable of establishing eMMP interconnectivity [11]. Some identified architectures are presented in Fig. 5. All presented approaches currently exist in theory.

The first two architectural approaches in Fig. 5 consist of a direct communication between eMMPs.

Service requests are (i) forwarded to all eMMPs in case the service is not known by the original eMMP or (ii) always forwarded to all partner eMMPs and all eMMPs can return their results. These two architectural approaches have been elaborated in Green eMotion [11]. However, both architectures require that the eMMPs know each others' services and additionally have to have capabilities to merge or filter possible duplicates in the responses.

The approaches three to six in Fig. 5 have been elaborated based upon features identified in Green eMotion and Open Mobility Berlin. All four architectures have integrated a broker entity that performs request-routing and protocol-adaption. A broker can could also merge responses retrieved from different resources. The third approach shows the scenario where a broker receives a service request, determines a suitable eMMP, performs protocol-adaption and forwards the request accordingly. The response is sent back on the inverse way.

The fourth approach is similar to the third, except that the broker does not forward the service request to the determined eMMP but returns the eMMPs endpoint. The requesting eMMP sends the request directly to the eMMP endpoint which forwards the request to the identified service operator. The response message returns as depicted. In this approach, the requesting eMMP has to perform the protocol-adaption in case the destination eMMP uses a different protocol. The broker has to point out which protocol need to be adapted.

The broker in the fifth approach forwards the request to all eMMPs. In best case one eMMP identifies the respective service operator and sends back the respective service operator endpoint. The service provider contacts the service operator directly, thus protocol-adaption needs to be done by the service provider. The broker has to determine what protocol needs to be adapted.

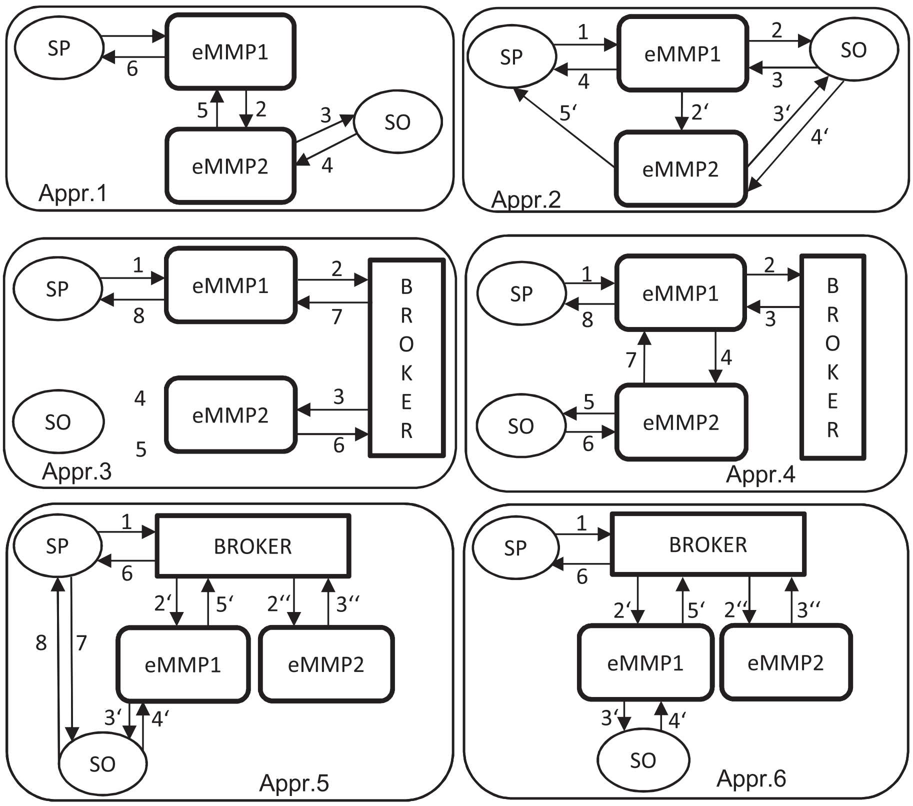

Fig. 5. Interconnected eMarketplace approaches. SO = Service Operator, SP = Service Provider, eMMP = eMobility marketplace.

The sixth approach proposes that the broker receives the request and forwards it to all eMMPs. The eMMPs receive the request, perform protocol-adaption and forward the request to the service operators. In best case only one service operator responses. The response is sent back on the inverse way. In this approach the broker does the protocol-adaption.

Protocol-adaption requires knowledge about the protocol as well as administration and implementation work. In case protocol-adaption is not done by a central entity, a small change in the protocols lead to a lot of individual changes. To the present date, the last four architectural approaches in Fig. 5 are not yet analyzed in detail nor are they implemented. The list of possible approaches can be stressed further. The presented approaches should stimulate and start discussions about how interconnectivity between eMMPs can be achieved.

5. Conclusion

The evaluation of currently available service platforms in respect to the identified criteria unveiled that no service platform currently exists which has implemented all identified criteria and functionality. The fundamental criterion of interconnectivity is not yet implemented by any platform. However, it is considered to be a key asset of future marketplaces and probably has a major impact on a marketplace's success. The disadvantages of missing marketplace interconnectivity have been adequately discussed. The presented examples have pointed out the advantages of interconnectivity for each involved role in the transaction process.

One of the main challenges for eMMP interconnectivity is that currently no standardized protocol is available. The used protocols have been evaluated according their capabilities. The result has shown that no protocol provides capabilities to access internal eMMP or platform data relevant for service or customer roaming. An eMMP approach for, but not exclusively, eMobility services has been elaborated. This approach has incorporated all identified criteria and is assumed to meet all future requirements of an open and sustainable service provisioning eMMP.

Various architectures for marketplace interconnectivity are feasible. Architectures which are considered to have capabilities to establish interconnectivity among eMMPs have been explained. Some of the explained architectures look promising on paper, but are in respect to their implementation not sufficient for eMMP interconnectivity. Even though the architectures are not yet implemented and their capabilities evaluated only in theory, they can contribute to discussions about eMMP and broker functionality as well as protocol standardization and protocol-adaption. Interconnectivity is not yet top priority for platform or marketplace operators. It is assumed that this will change when the number of such provisioning systems as well as the amount of available services increase. Once that happens, interconnectivity can be considered as an advantage over competitors.

6. Outlook on further research

Communication interfaces for marketplace interconnectivity need to be designed, implemented and evaluated to prove their feasibility for eMMP interconnectivity. A sophisticated role model should be developed. Suitable architectural approaches need to be exemplary implemented to determine their feasibility and contribution to eMMP interconnectivity. These reference implementations should consider protocol-adaption as well as request-routing and performance and security. To achieve interconnectivity, it might be feasible to adopt certain capabilities from the smart-home domain as well as from service discovery protocols or file sharing approaches. More research needs to be undertaken to determine how service marketplaces can discover each other and how they establish a communication on demand.

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