Towards a Platform Architecture for Digital Content

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Abstract: Digital platforms are currently being studied from different angles by information system scientists, software developers and economists, since they have shown their potential to disrupt business domains and create novel approaches for various business models. Nevertheless, the formal definition and the technical description of the platform as a digital infrastructure remain heterogenous among the disciplines as well as users. In this paper, process and methods used to derive technical and governance requirements for a digital content platform are described. Being rooted in the participatory action design research, the results provide a focused definition as well as realization suggestions for the digital artefact that can be used to be mapped on other disciplines as well as to the management of technical and governance-related aspects on digital infrastructures.

1 INTRODUCTION

Digital infrastructures offer a space for connecting content, data, hardware and software that is generally accessible over the online network. A digital platform is one specification of such an infrastructure with the focus on creating and making specific content usable by interested parties. As such, it has the potential to generate network effects as well as discussion-based, i.e. open, innovations as defined by (Chesbrough, 2003), in the context of information services creation or digital support. Principles and discussions on how such an infrastructure can be designed and governed has been one of the rising research topics in Information Systems Research in the last decade, confirming the status of digital platforms as marketplaces as an essential part of the future technology and economic development.

In this paper, we focus on the description of a digital platform that acts as a content intermediary with the goal to combine information applications and services for the electricity and mobility domains, thus providing a marketplace for the accordant actors and a common ground for open innovation of information services. The energy and mobility domains are increasingly getting into focus in the context of the environmental and governmental debates. Nevertheless, they are mostly considered separately, despite the growing number of topics that require their conjoint analysis. Furthermore, both domains are increasingly important in the context of urban development and emerging services and technologies. For the design and realization of the envisioned platform, it is assumed that providing a digital space for combining these domains will benefit the development and sustainability of the resulting information services. The engineering problem addressed here is thus about how to systematically develop a digital space that allows content provision and its usage in urban context considering multiple stakeholder groups including technology, government and private industry. To address these issues the Participatory Action Design Research (PADR) approach is chosen. PADR provides a framework that addresses the cross-disciplinary challenges of the urban informatic research (Bilandzic and Venable, 2011). This research area is known to consider a multiplicity of stakeholder groups into the development of the IT artefact.

The presented artefact is a result and a digital space for further participatory content development in the urban mobility context. The platform is designed to provide governed access and content curation for the system users. The process of the architecture development is outlined. It is based on the classic process known from the systems analysis domain (Satzinger et al., 2015) and structured software design. Furthermore, a stakeholder and actor structure is provided and the governance decision matrix is described. Other methods used for platform realization are use case and process design that serve

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as basis for the actual technical realization. This approach was chosen as the digital content platform is an information technology (IT) artefact as well as a user-centred solution requiring a multi-disciplinary view on its development. Therefore, it is suggested that the described approach can be applied within different domains where a marketplace for information exchange needs to be developed. The paper is structured accordingly. First the state of the art on the current understanding of digital platforms and infrastructures are established, then the design process for the platform as well as the results are described. Discussion of the applicability and current experience with the design as well as the conclusion finish the paper. Hence, the main contributions of this paper are twofold: first the design process and its results are described as a part of the participatory action design research. Then, the applicability of the design decisions is reflected on providing a starting point for the development of reference architectures in the area of digital infrastructures.

2 DIGITAL PLATFORMS- STATE OF THE RESEARCH

A digital platform is defined by Tiwana et al., (2010) as an extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate. The authors also point out that different notions of the platform definition exist in different disciplines and outline why the digital platform should be considered as an Information Systems (IS) artefact: “platforms offer the IS discipline an unusual opportunity to bring the IT artifact into the core of theory development about how platforms evolve and to contribute unique insights distinctive from strategy, economics, and software engineering” (p. 677). Digital platforms are often positioned in the context of a digital ecosystem (Ghazawneh and Henfridsson, 2011; Manner et al., 2013; Rickmann et al., 2014; Schreieck, 2016; Tiwana, 2013; Uludag et al., 2016). An ecosystem in the ecology studies is defined as a dynamic complex of communities and their environment that interact with each other as a functional entity (Schulze et al., 2005). In the context of a digital platform the other communities are: the platform provider, platform owner, platform user, i.e. consumer, as well as technology, application and data providers, i.e. developers of the platform content.

Another understanding of a digital platform includes its consideration as an Internet intermediary that not only provides a technical infrastructure and the information management of the applications run on it, but also presents the content that satisfies all the active groups, i.e. actors, at the platform. The provided content can originate from different sources such as third parties, users or from the platform provider (Perset, 2010). This is also the view that is taken in this research. The goal of the platform as an intermediary is to bring two sides of the information market, i.e. the information suppliers and information seekers, together and thus to create an added value. Similar to the physical marketplace, a digital platform needs to provide a functional environment to facilitate the transactions as well as to create an environment for trust. Additionally, catering to a specific community requires definition and governance of the chosen focus and community.

The ecosystem elements are interacting towards the preservation and advancement of the success of the platform. As platforms are affected by network effects, the success of a platform is determined by having enough participants on the development side to attract the customer side and vice versa. These stakeholder interests need to be aligned by the platform governance. The definition of the digital platform as an ecosystem provides valuable insights into the potential stakeholder and governance structure. Therefore, the existent research was reviewed to derive these aspects. The abovementioned platform content developers can be detailed in sub-groups such as service providers, data providers and application providers (Levina, 2016).

In the following, the design process of a technical architecture for a digital platform that addresses the domains of electricity and mobility information services are described. The stakeholder structure as well as the resulting requirements are presented. The content construction is addressed in the works by [blinded for review].

3 DESIGN PRINCIPLES

The presented artifact is the result of the Participatory Action Design Research (PADR) approach that stems from the urban informatics (Bilandzic and Venable, 2011) approach. This research method provides valuable support when new technological means to support everyday life in urban environments, e.g. using mobile and ubiquitous computing, need to be developed. Such research needs to recognize the urban hybrid space as an ecology of people, place and technology, thus handling multiple stakeholder groups. Following this paradigm, we suggest a digital

platform that has been developed using open sources technologies and that provides a digital open space for urban content related to the mobility and electricity issues.

From an engineering standpoint "a platform design consists of a basic architecture, comprised of sub-systems or modules and the interfaces between these modules" (Meyer et al., 1997), (p. 91). For a platform to provide added value for the implementing domains, the modules need to profit from the emerging network effects and be able to embed different actor roles. Thus, the design and governance structure of the envisioned content platform described here are based on the four major principles:

- compatibility and adherence to the existing (open) standards in the related domains,
- privacy- and security-by-design,
- user focus,
- content suitability.

While the technological standards describe the general requirements towards the software and hardware architecture, remaining aspects are directed at the multi-disciplinary environment. Privacy and security issues, often regarded as part of the IT governance, are strongly dependent on the definition of the actor roles that are involved into the design and operation of the platform as well as the data that is being exchanged, provided or stored in the platform context. The platform is to be designed as an interaction environment that supports informational needs but also respects the prerogative of the purposeful data transfer. Thus, privacy- and security-by-design principles are realized by performing several security and privacy related analysis. The analysis processes were based on the existing security and privacy requirement analysis approaches such as SQUARE (Chen et al., 2004) and PIA (Wright and De Hert, 2012).

To be able to provide end-users with information from multiple sources it is important to define the management of the produced and retrieved data. Here a provider-based data management is suggested. User-related data are stored and managed by the application provider, while the platform delivers user and developer authetification and identification. As a result, the information is stored and accessed in silos constituting a decentralized access to user data.

As for the information supply side, the platform backbone focuses on the infrastructure provision, developer management and on the accordant quality of service aspects such as availability and reliability of the technical infrastructure. To adhere the design principles, a middleware was chosen that can be adjusted and changed according to the requirements. Such a realization can be achieved using a service-oriented approach or, in our case, an agent-based approach to the provided information services (Luetzenberger et al., 2015) was taken due to the practical considerations within the project partner structure.

4 PLATFORM DESIGN: PROCESS AND METHODS USED

Figure 1 shows the platform development process, adopted from the domains of systems analysis (Checkland, 2000), software design (Curtis et al., 1988) and urban informatics (Bilandzic and Venable, 2011), with regard to the different stages of the solution development (top-down) and to the different platform dimensions of each step (left-to-right). The process is shown as a sequence of steps to allow its formal description. In the implementation phase, the process was realized as an iterative heuristic, which steps were defined by the feedback from the preceding steps.

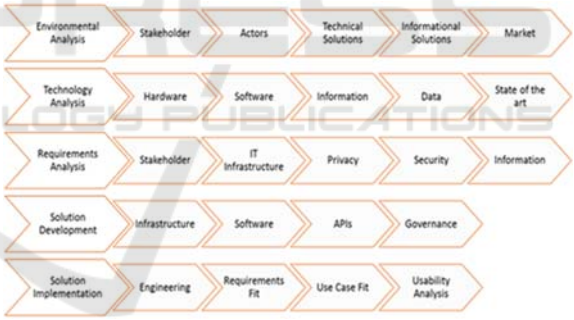

Figure 1: Process of the Platform Design.

Before the actual design, an environment analysis was performed to identify relevant stakeholders for the content platform, the entities interacting on and with the platform, potential technical solutions for the envisioned infrastructure, existing informational services and applications addressing the content domains in question as well as the general market for content platforms in energy and mobility domains. The artefacts of this first step of diagnosing and problem formulation, was an actor and interaction diagram (see figure 2) as well as the coarse technical architecture. The informational solutions that were already developed by the project partners and on the market, were included into an accordant portfolio and released on the platform during the architecture test

phase, as elements of the action planning and action taking phases of PADR. The stakeholder definition laid the first step towards role-based security and privacy modelling that was crucial for the developer guidelines and governance definition. Also, stakeholder definition allowed for the first summary of the requirements and expectations towards the digital artefact. From the stakeholder analysis, main roles interacting with the platform were defined. The definition of roles within a platform ecosystem is an important factor of the ecosystem design (Schreieck, 2016) and covers different aspect of the interactions on the platform, such as ownership regimes (Bakos and Katsamakas, 2008) and distribution of power between the stakeholders (Bullinger et al., 2011).

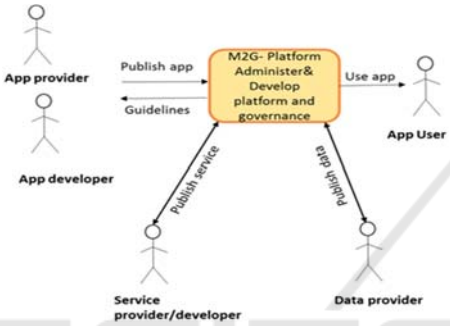

Figure 2: Roles and Interactions on the content platform.

Figure 2 shows the roles involved and their possible interaction with the platform. Data and service providers, i.e. energy or mobility provider or accordant devices, upload their content on the platform for the application provider to access. Application and service providers can use the data and enhance them to derive useful information and present it in a software application that is used by the end-user, i.e. application (app) user. Given this scenario and the assumption that the value of the platform increases with the number of members for each role, network effects are created justifying our platform approach.

Governance Aspects	Decision	How: Possible actions	Activities: Who, How?
Support growth	Yes	Motivate developers/ users	Partner 1, Partner 2
Profit orientation	No		
Agree to in-app buys	No		
Allow paid apps	No		
Allow Ads	No		
Technical Architecture		Open standards, open technologies	Securiy protocols, open web standards
Copy right		Data privacy, Terms of use, Governance	
Support user generated content	Yes	Registration as data provider possible	

Figure 3: Excerpt form the governance decision matrix.

A decision matrix was created and is shown in its excerpt in figure 3 to define the responsibilities and requirements from the actors involved, also serving as a rough governance outline that was later specified in technical, legal or user requirements.

A UML use case diagram (Simsion and Witt, 2004) was constructed using actor roles defined in the stakeholder analysis and the fist requirements towards the platform. The use case diagram also allowed a first review of the required versus already realized functions that were set to support the interactions on the platform. These functions were realized using the JAVA agents, but other similar realizations such as using (web) services or libraries are also possible. The use cases also enabled the definition of the core modules and accordant security measures required by the actors. Thus, the responsibilities were able to be divided between the platform provider and platform owner.

Once the core use cases for the actors and the platform were defined in workshops with future users and developers, the core processes on the platform were modelled according to the use cases using the UML activity diagram that was later transformed into a BPMN diagram as shown in the example in figure 4.

After the technical architecture was set up, the frontend development was started. Here, methods form the UX domain such as interviews, surveys and storytelling were used to define potential information services and their realization.

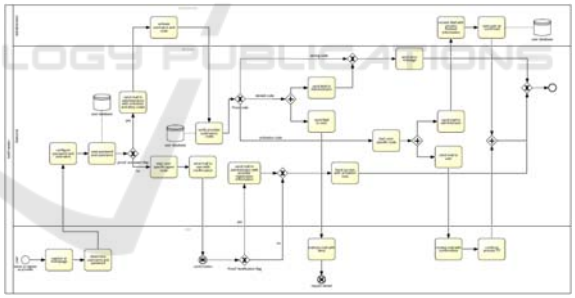

Figure 4: Process for the use case developer registration.

Technology analysis included collecting and discussing the requirements for the hardware and software that were needed to realize the digital content platform on the planned scale. Here, the technological approaches for the realization of a distributed architecture as well as distributed applications were reviewed. Technological approaches such as frontend development frameworks were reviewed to include the application development and integration in the search. The results were obtained via market and technology analysis as well as the inventory of the current resources among the project partners. The platform itself consists of

both, the network and storage components as well as the regulatory content such as application programming interface (API) description, developer guidelines and the general governance statements. The service and application providers submit their artefacts to the platform using defined APIs and adhering to the design, usability and security settings documented in the accordant governance guidelines.

Building on the gathered picture of the state of the art technological potentials, the requirements on usability and content from the main stakeholders and actor groups were collected. Here interviews and workshops were applied as methods to derive the requirements. The meeting minutes were then examined towards the feasibility, focus and redundancy of the mentioned aspects. The remaining content was then mapped on the state of the art definition as well as the realization potential in the given context. Additionally, further use cases were designed and discussed with potential users and developers that were then matched on the found informational solutions. A criteria matrix was designed to capture the technological requirements, stakeholder requirements as well as the requirements stemming from the design principles and their realization potential. These requirements were then ranked according to several criteria, such as their realization potential, originating stakeholder role, future maintenance potential, openness (e.g. for standards), and their sustainability for the further course of the project.

The phase of the solution development in figure 1 included the final technology selection. Hence, a server was chosen instead of a virtualization solution, agent-based middleware was adjusted to the needs of the web development technologies and a web development framework was chosen for the implementation and presentation of the platform. Communication protocols were implemented as well as the security-related aspects introduced according to the derived actor model as shown in figure 2.

As a digital content platform needed to be developed, the content design was a large part of the governance definition beside the guidelines and the privacy and security aspects. Finally, the use case and requirement fits were conducted to determine further steps in the platform realization.

One of the main challenges for the platform design is to aggregate and present the manifold content and make it securely accessible for the user in the intuitive and manageable way. To adhere to the informational needs of both of the domains as well as to the stakeholders, a requirement-based governance structure was developed. Here, the definition of platform governance by (Tiwana, 2013) as: “partitioning of decision-making authority between platform owners and app developers, control mechanisms, and pricing and pie-sharing structures” is adopted. Schreieck et al., (2016) summarize the tasks of the governance structure as being the combination of technologic and marketing views on one hand and integration and description of the main concepts on the other hand. Hence, besides the directly related content on electricity and mobility, several EMAS sustainability indicators (EMAS, 2015) such as pollution, greenhouse gas emissions, waste and water usage were taken as example, providing information support for a more sustainability conscious behaviour. For the derivation of potential content for the envisioned platform, a systematic approach based on classification development of digital services was chosen and described in [blinded for review]. To derive an approach for content curation and selection the current literature on mobile service design (Golding and Donaldson, 2009; Stanoevska-Slabeva and Hoegg, 2005; Walravens, 2013), platform design (Rui and Whinston, 2011; Schreieck, 2016; Selic, 2008; Tiwana, 2013) as well as modularization approaches for mobile services (Schreieck et al., 2016) were reviewed. The insights are implemented in the creation of the content governance concept for a real-life digital platform that is created to unify the domains of electricity and mobility as described in [blinded for review].

5 REALIZING A DIGITAL CONTENT PLATFORM FOR ELECTRICITY AND MOBILITY

Here, the realization of the digital content platform based on the design principles and technology described above is outlined. The realization focused on an efficient and secured communication, scalability and application integration. The platform is aimed at providing an interaction environment that supports informational needs but also respects the prerogative of the purposeful and secure data transfer. To be able to provide end-users with information from multiple sources it is important to define the management of the produced and retrieved data. Here a provider-based data management approach is suggested. User-related data are stored and managed by the application provider, while the platform delivers user and developer authentication and identification. As a result, the information is stored

and accessed in silos constituting a decentralized access to user data. Beside the hardware infrastructure, the platform consists of a homepage that shows the available information services as well as provides the possibility to register or login for personalization of the shown content. This frontend was realized as a progressive web application (Google Developers, 2017) to provide a better usability on mobile devices.

As the platform is supposed to bridge the electricity and mobility domains through information, content offered by the applications needs to be closely observed. It does not only comprise usage of electricity, CO2-footprint or mobility related services, it also opens the possibility to gain insights on other factors of sustainability such as community life by realizing discussion and news forums as well as gamification.

By adopting these principles for our design approach, we affiliate with the research by (Checkland, 2000) and (Curtis et al., 1998), who state that to follow the primary objectives of an IT-platform such as establishing a large user base or being profitable, a formalized and authority-based governance structure is needed. Whereas the secondary objectives can be fulfilled by trust-based and informal control.

5.1 Applications

The software applications are the focus of the considered platform. While the technical and hardware infrastructure serve as enablers, the applications are the focus of the interaction and the raison d'etre of the actual platform. Their quantity and quality are crucial for the platform success that is defined by the involvement of the users and developers. Therefore, an extended effort to define the information services needed or envisioned by the end-users from both of the domains was made with the assumption that this first set of applications would trigger open innovation in term of combination and realization of further information need. Although, this assumption remains to be proven over the course of the project.

After conducting the literature review and a workshop with a group of potential future users, all the categories for the mobility domain identified by Schreieck et al., (2016) were deemed as relevant for content provision on the platform. Furthermore, using the morphological box for mobility (Levina and Kranich, 2016), the categories were integrated into the domain specific classification. Thus, a more thorough analysis of the potential content or information use would be possible. Also, building on a short review of electro mobility digital services, it became clear that a straightforward consolidation of the identified categories of the two domains electricity and mobility would not provide any substantial benefit for the consumer of the mobility and electricity content. They focus on the navigation and payment functionalities for electric cars, which are being one representative of the mobility domain using electricity in one specific way [blinded for review]. After the workshops with future users that included story telling sessions, slightly modified mobility and energy services emerged. These were preliminary described as "special logistics management tool", "mobility coach tool" as well as "multi-modal navigation tool". The latter included the navigation possibility from the charging station to the point of interest as well as the inclusion of the autonomous shuttle service into the route calculation emerged. Building on these insights, a first set of services and for the platform was designed and uploaded for the prototypic use.

5.2 Middleware

The middleware provides auxiliary functions for the connectivity between the technical infrastructure and the application software. It is also used to implement security and other general features, such as analytics and interfaces, for the platform. The interfaces define the integration of potential devices or applications onto the platform. Here we use the Java Intelligent Agent Componentware agent framework, JIAC V, to implement the middleware functions. JIAC was developed under the premise to narrow the discrepancy between research and industry. Its goal was to provide a robust communication infrastructure beyond the borders of homogeneous computer networks. The modular assembly of JIAC agents allows for multi-agent system solutions that are tailored to the application context (Luetzenberger et al., 2015). Among the industry requirements that the agent-based middleware fulfils are: stability and robustness that support the user experience, deploying and undeploying of new services or agents, managing of large number of nodes and agents without a decrease in performance, third-party service integration, component reuse as well as interface management. These are the same requirements that were identified during the requirements analysis with the stakeholders. Given the availability of the JIAC architecture from our project partner as well as its application in distributed architecture context, we adopted the agents to the web-based frontend

development therefore allowing its integration into the planned architecture. We used Bootstrap 4.0 as a CSS framework as well as jquery UI for the frontend development. The APIs were realized using representational state transfer (REST) paradigm.

5.3 Hardware Technical Infrastructure

To realize the software functions, a network architecture as well as the database realizations were needed. The rising degree of virtualization of the technical infrastructure allows for an establishment of the server as well as the database in the cloud, i.e. without the purchase and installation of the actual hardware. Nevertheless, we used a physical server with a virtual machine for the platform operation. We use 16 GB RAM and 4 CPUs with 60 GB of memory for the virtual machine. MySQL was used to integrated and communicate with the database. Each of these layers requires a thorough analysis and definition of the governance rules. Their distribution among the actors is dependent on the business and role models chosen for the platform realization. The communication with the backend was realized using jquery and direct AJAX requests and JSON formatted replies.

6 CONCLUSION AND OUTLOOK

A design approach and guiding design principles for a platform that joins information needs for mobility and electricity domains were introduced here. The design as well as the requirements analysis were grounded in the process of systems analysis and classic software development. By describing the design principles, the process as well as the methods used to derive the final digital platform design, a contribution to the body of knowledge on platform realization and operation is made. Building on these insights, platforms from other domains can be constructed. Urban informatics engages in understanding and analyzing a wide spectrum of issues from the everyday context, needs in the urban setting as well as targets the public as end users of the created artefact. Therefore, the research method from this domain was chosen to develop the presented content platform.

Coming to full realization, the platform is expected to fuel the use of the district-scale experimentation environment among the researchers, service providers and end-users. This digital infrastructure joins context specific service and application developers with end- consumers. Bridging the two domains towards a common goal provides the first coarse definition of a common ecosystem.

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