Supporting the Development of Smart Cities using a Use Case Methodology

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ABSTRACT

Urbanization grows steadily, i.e. more humans live at one place and rural areas are more unpopular. Urbanization faces challenges for city planning and development. Cities have to deal with large crowds, high energy consumption, large quantities of garbage etc. Thus, smart cities have to meet many requirements of different areas. Hence, realizing smart cities can be supported by linking different smart areas, such as smart girds and smart homes, to one large area. The linking is done by information and communication technologies, which are supported through a clear definition of functionalities and interfaces. Smart cities and further smart areas are under development, so, it is difficult to depict an overview on their functionalities, yet. Therefore, the two approaches, use case methodology and integration profiles, are introduced in this work, which are also realized by a web-based application.

Categories and Subject Descriptors

• **General and reference~Metrics** • *General and reference~Cross-computing tools and techniques* • **Computer systems organization** • **Computer systems organization~Heterogeneous (hybrid) systems** • **Hardware~Power and energy** • **Hardware~Smart grid** • *Hardware~Energy distribution* • **Software and its engineering~Software organization and properties** • **Software and its engineering~Domain specific languages** • **Software and its engineering~Unified Modeling Language (UML)** • **Software and its engineering~Requirements analysis**

General Terms

Management, Documentation, and Standardization.

Keywords

Use Case Management Repository, Architecture Model, Use Cases, Integration Profiles, Requirements Engineering, and Web-Application.

1. MOTIVATION

The urbanization is accelerated by the rapid economical development of cities and by the rising immigration into cities [1]. Large crowds of the limited space in cities make it difficult to meet all requests and requirements of people living there. Therefore, new solutions need to be found to keep the human quality of life in cities. One idea is to make cities smarter using new information and communication technologies, which combine different systems. A combination, connection, and integration of systems and infrastructures in cities, which improve the human quality of life, describes the concept of smart cities [2].

Systems, which should be connected and integrated in smart cities, are smart grids, smart building, and electrical vehicles, etc. to penetrate all areas of life and to improve them. For example, smart grids facilitate the integration of distributed energy resources, and smart buildings support people in daily activities, such as air conditioning and switching on the light [3]. These systems are currently under development just as smart cities. Hence, a possibility is needed to describe the complete functionality of systems and their connections to guarantee the interoperability between them.

Interoperability is an important topic for standardization, because one objective of standardization organizations is to enable a smooth and seamless collaboration between systems and their components. Hence, the German standardization organization DKE tries to collect the complete functionality of systems under development, such as smart grids and ambient assisted living, to create a basis for new standards [4], [5], [20].

Due to the large number of functionalities and involved actors, a structured form is needed to describe these systems' functionalities. The *use case methodology* depicts such a structured form. Use cases describe systems' functionalities through a number of scenarios which depict the interaction of actors and system components in single steps. In agile software development, *user stories* are the well known equivalent to use cases [3]. With a complete system description from use cases, the standardization process of systems and their interactions can be coordinated [6], [7]. Furthermore, the use of use cases enables analyses, e.g. to check the consistency of described functions and further requirements. Moreover, the use case methodology can be extended by *integration profiles* to get a more detailed description of systems' interfaces and possibilities to combine systems [8]. The description of use cases and integration profiles can be done as a collaborative work between different experts or organizations. To facilitate the collaborative work, a web-based tool, a use case management repository (UCMR), can be helpful for supporting the collection and exchange of use cases and integration profiles.

The paper is structured as follows: First, an overview on related work is given in Section 2 to demonstrate further approaches for supporting the planning of systems under development. Second,

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the methodology of both the use case template and the integration profiles are introduced in Section 3, to explain how these support the development of smart cities. In Section 4, a web-based tool, a UCMR, is presented to provide a platform, which realizes the described methodologies. Section 5 gives an overview on future work and Section 6 concludes this paper. In Section 8, a brief glossary can be found.

2. Related Work

The use case methodology is one semi-formal approach for collecting and analyzing requirements for large infrastructure systems. Due to the use of the Unfied Model Language (UML) and a standardized template, the use case methodology contains formal parts for the functional description [9]. Further approaches are summarized in [10], such as goal trees, checklists, mind maps, hierarchical and weighted requirements' lists, etc. Some of these approaches are used in product or software engineering.

Goal trees visualize systems' specifications through the definition of system's goals that can be subdivided into sub-goals and so forth [11]. A goal has to be an object or a state of the system which must be reached. Sub-goals are operational goals which must be fulfilled to reach the goal. Thus, a directed goal tree results from subdividing the goal into sub-goals. The goal and sub-goals can be compared with requirements which must be met. Hence, goal trees support the description and structuring of requirements similar to the use case methodology which depict requirements and allows the creation of further requirements through considering involved actors. Also, analyses can be done on goal trees with known static analysis techniques [12]. However, smart cities, smart grids, etc. are large systems and the requirement specification via goals and sub-goals are very complex. In addition, the assignment of requirements to actors in goal trees is more difficult than the assignment through the use case methodology which has a requirement's library to assign requirements to actors in special use cases.

Checklists, mind maps, and hierarchical, weighted requirements' lists are known techniques to get requirements from users and to visualize requirements in a structured way [13]. However, these approaches have the same disadvantage as the goal trees: clarity and the assignment to actors. These techniques can only be used to visualize requirements and their relations which are described in a non-formal way.

However, the brief described visualization techniques for requirements can be used for supporting the use case methodology to visualize the relations between uses cases. But for a single visualization of the requirements of large systems, these techniques should not be applied to receive clarity. In the next section, the use case methodology is described and in Figure 1, the used tree structured of the uses cases can be seen.

3. USED METHODOLOGIES

This section gives an overview on two methodologies which can be combined to support the development of smart cities. These are the use case methodology which is already used by the German standardization organization DKE for describing the functionalities of smart grid and ambient assisted living systems [4], [5], [14], and the integration profiles which are already used for describing ambient assisted living systems [16].

3.1 Use Case Template

One particular way of structuring the development of systems is the concept of use cases from software engineering .

In software and systems engineering, a use case is mostly a list of scenarios and steps, typically defining interactions between a role (known in UML as an *actor*) and a system, to achieve a particular goal (e.g. a function). The actor can be a human, an external system, or time. In systems engineering, use cases are mostly used at a higher level than within software engineering, often representing missions or stakeholder goals. The detailed requirements may then be captured in systems modeling language (SysML) [15] or as contractual statements.

In this way, documenting the relations between functions, processes, and systems has proven to be rather successful for systems engineering. The so called IEC 62559 template provides an adopted version of this concept for the smart grid domain and has been the first domain-specific initiative to document domain-specific functional and non-functional requirements.

As early as 2009, the existing IntelliGrid template became more and more popular as smart grid demo projects realized that both technical and procedural standards are necessary for a successful development of smart grid technologies and systems. Within the M/490 mandate from the European commission from the European standardization bodies, the need to identify standards to be applicable for certain functions became apparent. In order to simplify and structure this way, standards for smart grid projects could be identified. The so called sustainable processes group developed a platform to track, document, and collaborate the development of smart grid standards. One particular issue was the re-use of the IEC/PAS 62559 IntelliGrid template to document smart grid use cases. Within the mandate, the template was further extended to cover relevant aspects of non-functional domain requirements. Additionally, different maturity levels were developed to cope with the problem of initial granularity for the documentation. A thorough overview as well as an extensive introduction can be found in [9].

The main focus of the IEC/PAS 62559 is on the so called use case diagram which provides a simple graphic representation to visualizing system boundaries, actors, and data exchanged for fulfilling the goal. Based on this very brief description, process sequences, requirements, trigger events as well as to other aspects can be refined further. In general, the template provides a proper way to use a standardized set of vocabulary, definitions, process sequences, and non-functional requirements. However, the first version is limited in use, results are depicted in form of a word document in a non-collaborative environment, e.g. on a local network drive [21]. This proved to be inefficient for the large scale M/490 collaboration.

Therefore, a web-based tool based on this template was developed and put into context with an alignment to the SGAM domain and zone model from the M/490 architecture group. Overall, the application in the mandate for both, the template and the web tool, showed potential to use the methods and tooling in different scenarios than just smart grid. Within this paper, we show potential for the application of the methodology in the context of smart cities.

3.2 Integration Profiles

Integration profiles are used to expand the description of use cases, by describing systems' interfaces more specific. The integration profiles are applied in ambient assisted living (AAL) systems, which also apply the use case methodology in the AAL Joint Program [16]. Integration profiles define all interfaces needed for all systems and their components (alias actors) for one specific use case [8]. If standards already exist for an interface, they will be linked to the description of integration profiles. Unless standards do not exist, a standardization gap will be detected and can be closed. This detailed description and the linking with standards are needed to expand systems over a long period of time without jeopardizing system interoperability. A more detailed description and an example of the structure of integration profiles is demonstrated in [3], [16].

4. SUPPORT FOR SMART CITIES

As mentioned above, smart cities are systems, which are under development, i.e. it is difficult to set the complete functionality of components and to produce them. For example, the development of smart meters has shown that functionalities such as the communication with virtual power plants, which are not standardized, yet, are realized in different ways by different producers [17]. This means, that smart meters' producers have to update their devices in the future when a communication with virtual power plants is deemed necessary. Hence, the UCMR should support the standardization organizations and producers of smart city's components to develop new standards which are important in the future to avoid the production of devices with unused interfaces. In the next subsections, the main functionalities of the UCMR are described.

4.1 Applying the Use Case Management Repository

The UCMR is a web-based tool which shall support the management of use cases and integration profiles in large systems, such as smart cities. The management contains the creation, editing, exchange, analysis, and persistent storage of use cases.

The web-based solution was chosen to allow a simple collaborative work between different experts without installing additional software. The used structure of use cases in the UCMR based on the template IEC/PAS 62559 [9] and the results of the AAL Joint Program [16].

Figure 1 shows a screenshot of a web-based solution of the UCMR. The depicted data is taken from the AAL Joint Program [16]. On the right side, it shows the description of one transaction which is part of an integration profile. At this point, one interface between two systems or system components (alias actors) is explained in detail. The explanation includes a description, a diagram, references, information about data which is exchanged between these two system components, and a requirement's list.

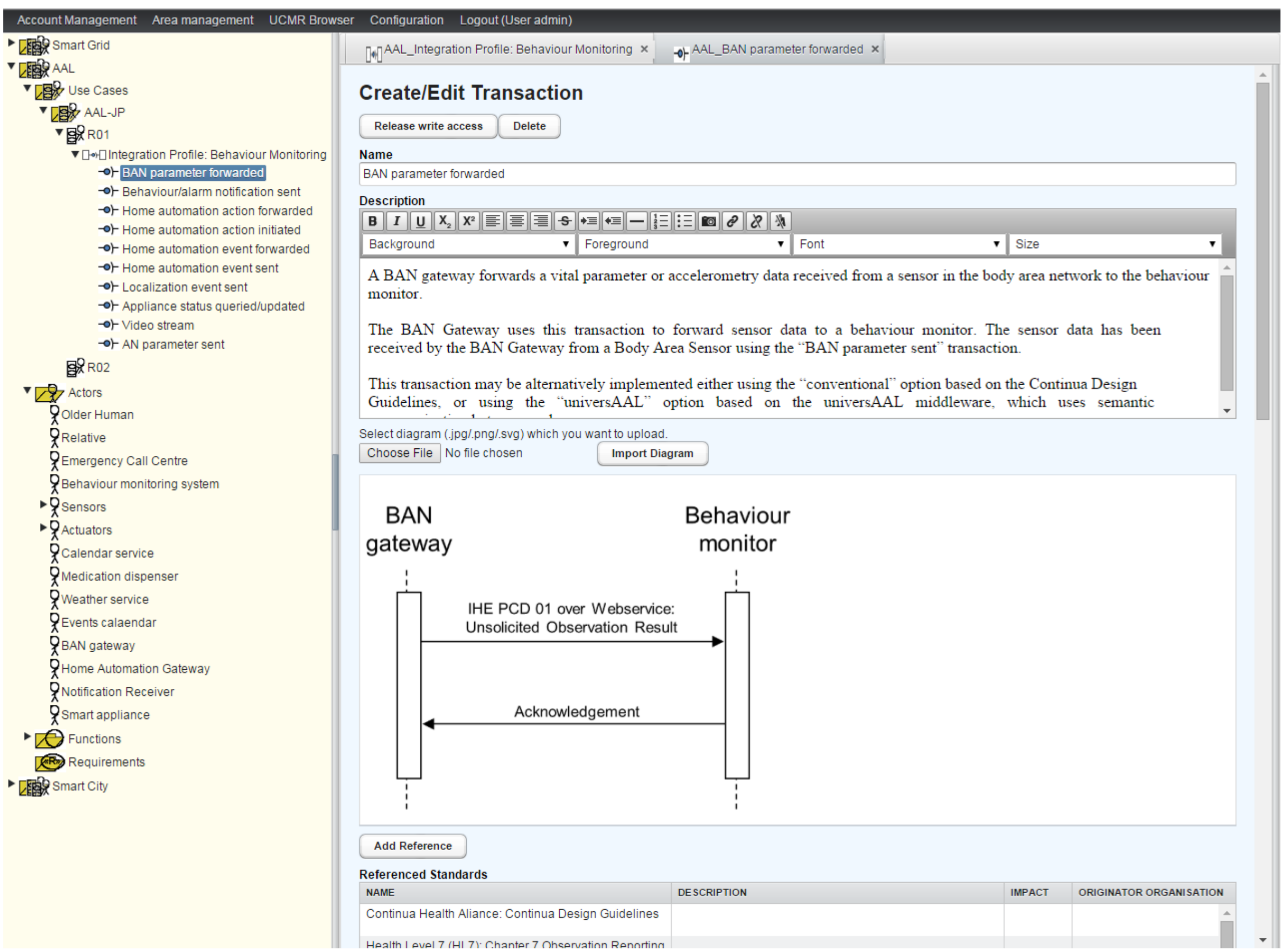

Figure 1: Use Case Management Repository (UCMR)

When all system components' interfaces, which are part of a use case, are considered in such a way, the development of new components is easier and the interoperability remains in the system. On the left side of Figure 1, a tree shows connections between use cases, scenarios, integrations profiles, actors, etc. Also, the tree is used to navigate between different areas. The top level of the tree is the area level, the system type is defined here for which use cases are described, such as smart grid, AAL, or smart city. Each area contains four folders to collect use cases and to define elements which can be re-used in different use cases; these are actors (alias systems or system components), functions, and requirements. Elements can be included via drag and drop into use cases. Due to this structure, it is possible to create separate use cases for different areas with their own definition of actors and functions. But, the UCMR also provides the functionality to share use cases, actors, functions, and, requirements with other areas. For example, the area smart city receives the authorization to use use cases and elements of the areas smart grid and AAL. This enables the extension of existing use cases, so that they meet the ideas of smart cities. Due to this, the same use cases and elements can be used across systems, and a uniform description results [3].

First, it is necessary to standardize actors, which are used in different systems, so that everyone has the same idea of these. Afterwards, a uniform description of use cases and their systems' interfaces can be created which are valid for smart cities, smart grid, AAL, electrical vehicles, etc. With the UCMR, it is possible to share definitions of actors, etc. with many associates. In addition, different definitions of the same actor can be mapped to get one consistent definition. Thus, the collaborative work between experts and organizations is supported, and the development of smart cities can be facilitated.

4.2 Consistency Check

The use case methodology and the integration profiles illustrate the first step for a consistent and traceable development of large systems. However, many parts of the template in the UCMR are filled manually, and due to the large number of use cases, it is difficult to check the consistency of requirements. Though requirements are part of the element folders of an area, they can be re-used. But users have the possibility to change some values of a requirement, which is not re-used. To prevent failures in requirements' lists, an automated consistency check would help to call the attention of users, when inconsistent requirements are created. The automated consistency check can be done by different techniques, such as formal specifications [18], or requirements diagrams from the OMG SysML [15]. This would be a third part, which is included to the UCMR, against the description of functionalities (by use cases) and their interfaces (by integration profiles).

5. FUTURE STEPS

In addition to the presented approach, more and more application cases are triggered from the perspective of standardization, such as electrical devices [19]. As the corresponding templates and repositories have proven to be useful in the context of smart grid and AAL, the extension for different systems seems to be logical.

For the smart grid tool chain, use cases provide a proper way to construct the SGAM (smart grid architecture model) models for the corresponding architecture documentation and security analysis. As the SGAM with its interoperability stack dimension, value chain dimension, and internal organization dimension can also be transferred to other infrastructures when dimensions are changed. For example, in German standardization the described methods have developed into a paradigm, which is also used in the context of smart cities and transport infrastructures, e.g. electric mobility [14], [19].

With experience gained and feedback from projects and participates, more and more integration profiles can be defined and models, like the SGAM, can be developed. The method is now common with the different domains, inter-domain specific exchange e.g. between the transportation, healthcare, and energy sector, which can be facilitated in a better way. In the context of smart cities, it enables a better understanding of the mutual shared infrastructure, e.g. in terms of communication technologies and interdependencies of failures of infrastructures [22], e.g. the aspect of a power blackout and its relation to the water distribution system in cities.

6. CONCLUSION

This paper provides an overview of the current development of a UCMR which combines the use case methodology with integration profiles to get a detailed description of systems and their interfaces. Currently, the UCMR is used to collect use cases and integration profiles for smart grid and AAL systems. The characterization for further systems is planned in the same way, so that the development of smart cities can be supported by already described systems. In addition, the UCMR will serve as a basis for an extension to the SGAM model from smart grids and its corresponding tools [23], [24].

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8. GLOSSARY

[**AAL**]: Ambient Assisted Living describes a system at home which supports people for an independent life. **[DKE]:** German commission for Electrical, Electronic, and Information Technology supports the standardization process for DIN (German Institute for Standardization)**.** [**Integration profile**]: Integration profiles give a detailed description of systems' interfaces. [**SGAM**]: Smart Grid Architecture Model visualizes different viewpoints and interfaces of smart grids. [**UCMR**]: Use Case Management Repository is a web-based tool to collect use cases and integration profiles. **[UML]**: Unified Modeling Language is a modeling language for software systems in the software engineering field. [**Use case**]: Use cases describe systems' functionalities in a structured way.

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