Adaptierung einer SGAM basierten Demand Side Management Architektur für die Realisierung von Ambient Assisted Living
Adopting an SGAM Based Demand Side Management Architecture for the Realization of Ambient Assisted Living

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Kurzfassung

Um die Verbreitung von Smart City Infrastruktur Technologie zu forcieren, ist ein Ausgleich zwischen Kosten und Nutzen notwendig. Ein Ansatz hierzu ist das Ausnutzen von Synergien und die Verwendung derselben Infrastruktur für unterschiedliche Anwendungs-Domänen wie z.B. Energie, Gesundheit oder Verkehr. Die Komplexität der zu entwickelnden Systeme erfordert einen ganzheitlichen Entwicklungsansatz, um domänenunabhängige und skalierbare Systeme zu entwickeln. Die vorgestellte Arbeit beschreibt eine Fall-Studie, die modellbasierte Entwicklungskonzepte und Architekturmodelle aus der Energie Domäne verwendet um ein existierendes *Demand Side Management* System mit *Ambient Assisted Living* Funktionalität zu erweitern. Darüber hinaus ist die Implementierung einer Schlüsselkomponente, des *Home Area Management Systems* beschrieben. Das paper schließt mit einer Diskussion über die durchgeführten Architektur-Adaptierungen sowie der Anwendbarkeit von Smart Grid Konzepten auf andere Anwendungs-Domänen.

Abstract

In order to enable the propagation of Smart City technology, it is necessary to establish a balance between costs and value. A common approach is to make use of synergies and utilize the same technological infrastructure for different application domains, such as energy, health or traffic. Due to the complexity of such systems a holistic engineering approach is necessary in order to develop open and scalable systems. The presented work discusses a case study that applies *Model Driven Engineering* concepts and architecture models from the energy domain to extend an existing Demand Side Management system with Ambient Assisted Living functionality. Moreover, the implementation of a key component, the *Home Area Management System* is described in detail. The paper concludes with considerations about the nature of the infrastructure, necessary for multi-purpose usage. In addition, the applicability of the Smart Grid concepts for developing Smart City systems from other application domains is discussed.

1 Introduction

The realization of Smart Cities affects various different application domains like energy, public health or traffic. Each of these domains by itself is facing major changes and hence, vast research efforts have been made. Especially in the energy and public health related fields "Smart Grid" and "Ambient Assisted Living" (AAL) noteworthy efforts have been made and numerous research- and demonstration-projects have been realized. The research activities in the field of Smart Grids aims at developing an intelligent infrastructure for integration of renewable energy ressources and AAL focuses on improvement of comfort, safety and health with a special focus on emergency situations [3].

The evaluation of present demonstration projects in respect to their potential for real world implementations reveals some major challenges. Most important of all is the balance between costs and generated value for the customers. In the Smart Grid, which aims at a paradigm shift from "generation follows load" to "load follows generation", concepts like *Demand Side Management* (DSM) and *Demand Response* (DR) are deemed crucial. Thus, a certain level of intelligence, like Home-Automation Systems, within the user premises is necessary. At present, the propagation of "intelligence" within the user premises turns out challenging as the value as perceived by the consumer seems insufficient to generate an investment by the end users. Various publications, like [8] advise that it will be necessary to deliver add-on values with Smart Grid infrastructure in order to increase cost effectiveness.

An obvious approach is to make use of the synergies between different application domains, such as Smart Grid and AAL. These application domains seem to have similar requirements like the need for "intelligence" within the user premises, a certain amount of sensors and actuators and a remote operation concept.

Even if there are some obvious similarities, various challenges have to be faced, especially in the field of quality requirements. Intuitively, the non-functional requirements for privacy, security and availability in the field of AAL are more critical than those for applications like DSM or DR. Thus, the development of systems, suitable for usage in different Smart City application domains, requires a holistic engineering approach, based on standards, in order to meet the requirements of all application domains and to allow for a synergetic use of technical infrastructure.

In the field of "Smart Grids" some valuable work concering the engineering task exists. Especially the Model Driven Engineering (MDE) approach as introduced by Dänekas et al [1] is of special interest. This approach utilizes the broadly accepted *Smart Grid Architecture Model* (SGAM) [7], as elaborated among the EU Mandate M/490, for development of a *Domain Specific Language* (DSL). Moreover, the utilization of this DSL for developing Smart Grid Systems is guided by a dedicated engineering process.

The presented work considers how to utilize the existing concepts from the energy domain in order to develop Smart City systems for other application domains. A case study is described that extends an existing DSM architecture for AAL purposes by utilization of the MDE concepts from [1]. Moreover, the implementation of a key element for such systems, the *Home Area Management System* (HAMS), is discussed in detail.

The remainder of this paper is structured as follows: in Section 2, engineering concepts for Smart Grid systems in respect to the SGAM are briefly described. In addition, an overview about various projects that aim at the development of HAMS is given. Section 3 describes the extension of an existing DSM architecture for the usage in AAL by utilization of Smart Grid engineering concepts. The implementation of the HAMS is described in more detail in 4. Finally, in Section 5, the experiences made during this case study are discussed.

2 Related Work

Within this section, existing work which is of relevance to the presented case study is briefly described.

Among the EU standardization mandate M/490, the CEN-CENELEC-ETSI Smart Grid Coordination Group presented the *Smart Grid Architecture Model* (SGAM). This architecture model aims at providing a holistic viewpoint for Smart Grid systems and their functionality. It is based on existing approaches and subsumes different concepts such as the NIST Conceptual Model [5] or the GridWise Architecture Council Stack interoperability categories [9]. Figure 1 depicts the structure of the SGAM, consisting of five Interoperability Layer: *Business Layer, Function Layer, Information Layer, Communication Layer* and *Component Layer*. Each of these layer structures a certain aspect of a system in reference to *domains* and *zones*. The domains reflect a hierarchical decomposition of the energy chain (*Generation, Transmission, Distribution, Distributed Energy Resources* and *Customer Premise*) whereas the zones structure the management of the energy chain on basis of the automation pyramid.

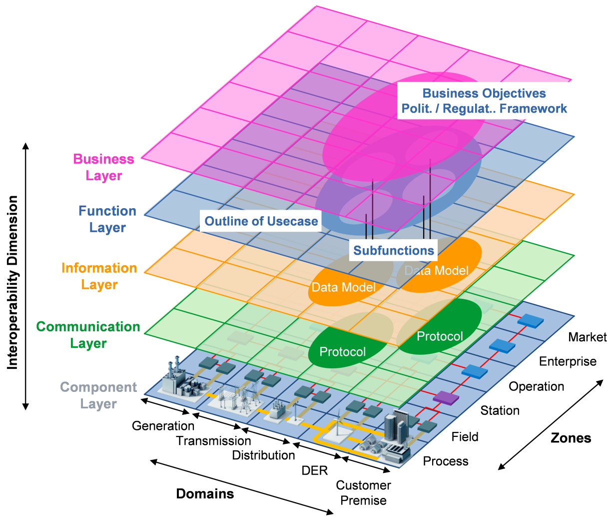

Figure 1 SGAM framework [7]

Besides the structural concepts, the *Use Case Mapping Process* (UCMP) is introduced for modelling systems in context of the SGAM. This process begins with analysing and documenting Use Cases by utilizing a two layer concept comprising *High Level Use Cases* (HLUC) and *Primary Use Cases* (PUC). Next, a step-by-step guidance is given on how to derive an architectural solution for the described functionality.

Even if the original scope of the SGAM was set to standardization issues, it has proven to be suitable for engineering purposes as well as it delivers a good reference for system analysis and architecture.

A specific approach on how to utilize the SGAM for engineering purposes has been proposed by [1]. The authors present a domain specific *Model Driven Engineering* (MDE) concept for Smart Grid systems. This concept proposes an SGAM based *Domain Specific Language* (DSL) together with a compact engineering process. Basically, this engineering process aligns the UCMP with the *Model Driven Architecture* (MDA) concepts as introduced by the *Object Management Group* (OMG) [4]. One of the MDA's key elements is the separation of functionality and technology. Considering the SGAM, the functionality is described within the upper two and the technology by the lower three layer. The presented concepts were implemented as publicly available *SGAM-Toolbox*[1] and can be used for architecting Smart Grid systems.

Besides the overall architecture of Smart Grid systems, the gateway between sensors and actuators in the Customer Premises and external third party services plays a major role. As such systems are discussed in different application domains, the terminology is ambiguous. In reference to the terminology of Smart Grids, (*Consumer Energy Management System; CEMS*), the term *Home Area Management System* (HAMS) is used for further discussions.

Besides different commercial solutions a few open source projects for such HAMS exist. The three most promising approaches, OpenHAB, OGEMA and openMUC have

[1]www.en-trust.at/SGAM-Toolbox

been evaluated with a special focus on supported protocols, application development, security and privacy. All of these systems are built on top of Java and OSGi, which delivers various benefits for the intended usage as described in [2].
OpenHAB supports the most protocols. Actually over 70 different so called bindings are part of the framework. These bindings vary from EnOcean, KNX to Smart TV appliances. OGEMA and OpenMUC do not support such a wide base of protocols. In OpenMUC the focus lies on energy-related protocols like IEC 61850 or DLMS/COSEM.
Only OGEMA and OpenHUB support dedicated application development within the framework. To do so, OGEMA provides interfaces and classes with basic functionality which can be executed. OpenHUB takes it a step further. It additionally provides a DSL to define rules and actions.
Another approach from the field of AAL is the openAAL project that provides an ontology-based platform specific for AAL needs. It represents an OSGi based middleware allowing the integration of different services, products and experiences. The project is based on the research result of the European Integrated Project SOPRANO [6].
However, all of these projects are lacking security and privacy mechanisms. No encryption mechanisms securing measured or configuration data is implemented. Also privacy mechanisms for managing confidential customer data are missing. This allows for example parallel executed applications to access confidential data from other applications. Moreover, all of the considered frameworks are focusing on a certain application domain and thus deliver a huge amount of domain specific functionality that raises the complexity.

3 Approach

As described in Section 1, a synergetic use of Smart City technologies in different application domains is demanded. Our approach realizes a case study that evaluates the extension of an existing DSM architecture to be used in context of AAL. Beyond the extension of the architecture itself, the applicability of the Smart Grid specific engineering concepts from [1] for the AAL application domain are of special interest.
The following subsections describe an existing, SGAM related DSM architecture and the necessary adoptions for utilization in AAL in more detail.

3.1 SGAM based DSM Architecture

The available DSM architecture realizes a scenario in which some consumer appliances, such as a heat pump or an E-Car charging system, can shift their energy consumption in respect to the *Distribution System Operator's* (DSO) needs.
Following the considerations from [1], the development of this system is based on a comprehensive system analysis phase. Starting from a *Business Case* (BC) as original intention, a hierarchical decomposition into *High Level Use Cases* (HLUC) and *Primary Use Cases* (PUC) is done in order to analyse the system's functionality. Basically, the DSM Business Case aims at utilization of load shaping in order to avoid infrastructure investments to the electric network. The presented DSM scenario assumes a customer that is willing to participate in DSM by announcing shiftable loads, such as a heat pump, to the DSO. This simplified example is based on one single HLUC named *Demand Side Management* that comprises various different PUC's related to different actors such as a *DSM Service*, a *Consumer Energy Management System* (CEMS) and a *Home Automation* system.
A key component of this architecture is a dedicated *Consumer Energy Management System* (CEMS) that is able to manage certain houshold appliances. The CEMS is able to detect the houshold's current energy consumption, to calculate the potentially shiftable loads in respect to the user's preferences and to communicate the result to the DSO. Moreover, in case of load shaping is required by the DSO, the CEMS is able to turn the shiftable load on or off.
The simplified, SGAM based architecture of the DSM system is illustrated in figure 2. Due to the limited space, the most important elements for understanding are combined in one single layer.

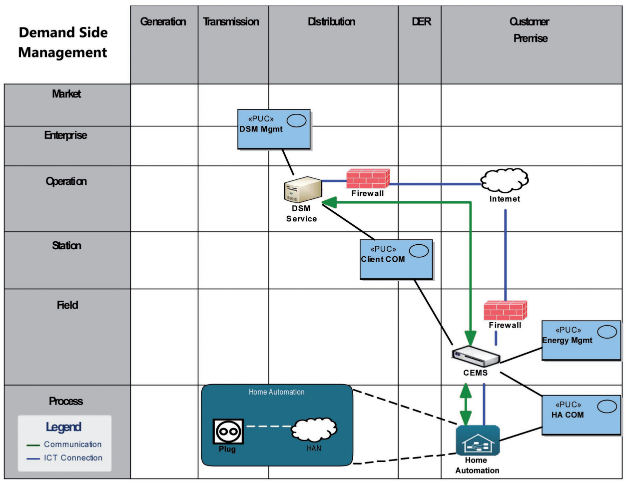

Figure 2 SGAM based DSM architecture

The main task of the CEMS is covered by the PUC *Energy Mgmt* and deals with management of shiftable loads in reference to the user's preferences. Therefore, in a first step it fetches the present state of certain home appliances by invocation of the PUC *HA COM*. Next, it determines the potentially shiftable loads and communicates this information to the DSO by invocation of the *Client COM* PUC. The *DSM Mgmt* PUC, operated by the *DSM Service*, processes this information and provides the announced capabilities to the *Distribution System Management* (DSM). Due to the restricted place, the latter is blinded out in figure 2. Depending on the DSM's needs the command for switching some shiftable load on or off is transmitted from the DSM Service to the CEMS. Thus, the CEMS can take appropriate action such as switching the heat pump on or off.

3.2 Adoptions for AAL purposes

The described DSM system provides a communication infrastructure between sensors and actors from the customer domain (e.g. switchable plug with energy measurement from a Home Automation system) to a remote service. This infrastructure should be utilized for AAL purposes. To be more precise, the system should be used for indication of emergency situations such as elderlies being helpless after falling. This can be achieved for example by integration of sensors that detect a potential fall of an elderly. Another, more passive concept, is the detection of missing interactions between an inhabitant and his environment. For example, if until a certain time in the morning no light is switched on, no movement can be detected and no kitchen equipment is used, the inhabitant potentially is in a situation of helplessness. The detection of such a potentially critical situation can trigger an escalation based alarming mechanism. For example, in case of absence of interactions the relatives or neighbours are informed by a dedicated *AAL Service* and only if none of them is able to respond in an appropriate way, the alarm is forwarded to a professional Emergency Service.

The extension of the existing system is done following the engineering concepts from [1]. Basically, the functionality is extended by the HLUC *Detect absence of interactions*, which is further refined into appropriate PUC's. The key functionality is covered by the PUCs *Emergency indication* and *Alarming*. The latter PUC is associated with a dedicated *AAL Service*. To realize the additional functionality the architecture has been adopted as follows.

First, the infrastructure needs to be opened to allow for the integration of different services. To do so, a dedicated *Gateway* is introduced that serves as mediator between the household and some third party services. This Gateway plays an important role, as it can serve as central entity for Security (e.g. Public Key Infrastructure) and Privacy issues. The basic task of the Gateway is the management of registered services and the management of communication between the third party services and the *Home Area Management System* (HAMS). The HAMS basically represents the CEMS from the described DSM example, but to emphasize the independence from the application domain it has been renamed from *Consumer Energy Management System* to *Home Area Management System*. In the given example, the main task of the HAMS in context of AAL is reflected by the two PUCs *HA COM* and *Emergency Indication*. Keeping the evaluation of interactions local on the HAMS is a crucial part in terms of privacy. Communication to the *AAL Service* only takes place if an emergency situation is indicated by an internal *Rule Based Action* (RBA) mechanism. However, the existence of a remote AAL Service is necessary in order to provide an adequate treatment of potential emergency situations and to keep the operation status of the whole system monitored. At this time it comes clear that the HAMS needs to be able to dynamically extend it's functionality and to interact with different services rather than being directly linked to only one service from a specific application domain.

The second adoption is the implementation of a dedicated *AAL Service*. This service is able to connect to the Gateway and register a certain client, monitor it's functionality and trigger the alarming mechanism. To keep the case study example compact, all these functionality is subsumed within the PUC *Alarming*.

Finally, the Home Automation System is extended by numerous different sensors, such as motion detectors, light switches or others. A simplified illustration of the architecture and the key PUC's, mapped to one single layer, can be found in figure 3

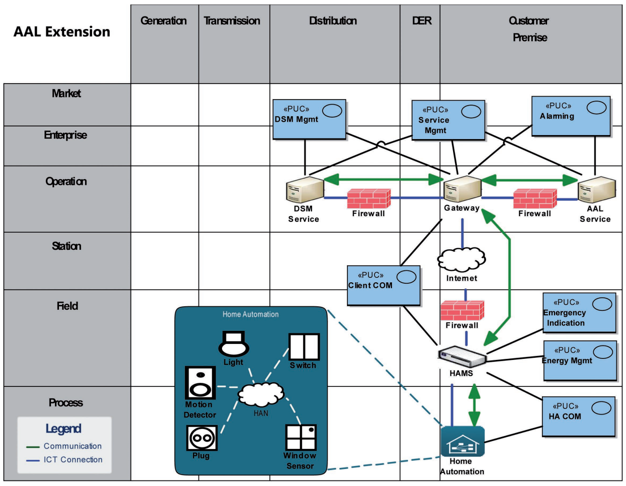

Figure 3 AAL Architecture

Considering the adoptions made, a few things come clear. First, the importance of an open HAMS, capable for interactions with different services is evident. Moreover, in terms of privacy and security, a mediating instance between the HAMS and different third party services is suggested. Assuming such an infrastructure as given, the extension from DSM to AAL can be realized very easy. During the presented case study, such a HAMS, able to be used with different services, has been implemented.

4 Implementation

Following the considerations from Section 3, the gateway and the HAMS need to be implemented as open systems in order to extend the DMS infrastructure for AAL purposes. As none of the existing frameworks discussed in Section 2 meets our requirements, an own implementation of the HAMS has been made. The implementation of the Gateway, which plays a major role in privacy and security considerations, is scheduled for the future as individual project. Both implementations are part of the publicly available *Trust Enhancing Home Area Management System*[2].

The main task of a HAMS is to provide an environment to run different services making use of existing Home-Automation infrastructure within the Customer Premise. As the realization of Smart Cities affects various different domains, the HAMS provides a single point of entry for

[2] www.en-trust.at/TEHAMS

these services. It must be open and capable of different technologies such as EnOcean or XMPP. To meet future requirements it's design has to be expandable and provide methods for installing functionality on demand.

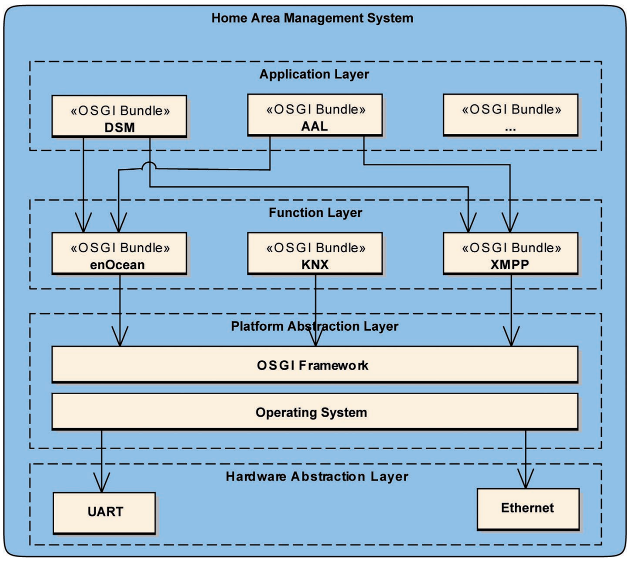

Figure 4 HAMS System Architecture

The implementation of the prototype was done by using a Raspberry Pi as platform and OSGI as implementation framework. Figure 4 illustrates the architecture, consisting of four layer. The *Hardware Abstraction Layer* (HAL) provides access to physical interface like UART and Ethernet. Upon this layer, the *Platform Abstraction Layer* (PAL) covers the operating system and the OSGi framework. It enables the *Function Layer* (FL) to access the interfaces within the HAL. OSGi bundles with generally available functionality are part of this layer. Example bundles are the protocol drivers used for EnOcean (accessible via the UART), KNX or XMPP communication.
The business logic of the system is located within the *Application Layer* (AL) and is designed like a container that hosts different application bundles. These bundles can be installed and executed on demand which enables the HAMS to run a DSM functionality and install some AAL functionality (or others) in addition.
The AAL bundle includes the Business Logic, which analyses activities and triggers alerts based on the evaluation. These activities are generated out of sensor and actuator information accessed through the HAMS. Similar to the AAL bundle, the DSM bundle implements the DSM business logic. It provides methods to control electrical load using the same services provided by the HAMS. Based on the architecture considerations the prototype was built and implemented.
Based on the existing DSM infrastructure the hardware components were given. For the Home-Automation system used by the DSM application, EnOcean was set as communication technology. It is a wireless communication technology, which uses energy harvesting mechanisms to produce the energy needed for the communication. Products from Telefunken SB were selected as actuators and sensor. To enable a communication between the Raspberry Pi platform and the used EnOcean technology an EnOcen Pi was integrated. Table 1 shows the hardware setup in more detail.

ID	Manufacturer	Name
PI	Raspberry Pi Foundation	Raspberry Pi model B r2
EPI	EnOcean	EnOcean Pi
BM1	Telefunken SB	motion detector BM1
TA2	Telefunken SB	rocker switch TA2
FS1	Telefunken SB	switchable power plug FS1
NET	Netgear	Netgear WNR1000

Table 1 Detailed list of used components

Based on the selected hardware a software stack was built. The basic layer is formed by Raspbian, which is a free operating system based on Debian with the possibility to install Oracle Java on a Raspberry Pi [10]. As OSGi middleware Eclipse Equinox is selected and extended with administration bundles from the Apache Felix project. Equinox is a full implementation of all aspects of the OSGi specification [12]. Within this software stack the AAL prototype is executed and able to access all information provided by the hardware stack.
To fulfil loose coupling and a service oriented architecture, as mentioned in [11], the application is divided into different bundles. Each bundle provides interfaces which are exposed to the service registry. The home automation driver is integrated in the EnOcean bundle. This bundle interacts over a serial interface with the EnOcean Pi module. Beside the communication with the EnOcean module it includes methods to register the used actuators and sensors.
The driver bundle uses the EnOcean Radio Protocol (ERP) to communicate with the actuators and sensors. Depending on the telegram type, the user data is defined in EnOcean Equipment Profiles (EEP). Every EEP has an ID and reflects the three basic components: ERP radio telegram type (RORG), basic functionality of the data content (FUNC), type of device in its individual characterstics (TYPE). At the time of writing there are twelve different telegram types defined. These types are identified by a sequence of 8 bit RORG. The developed prototype is built upon the hardware mentioned earlier and corresponds to the following EEP: TA2 = F6-02-01, FS1 = D2-01-08 and BM1 = A5-08-02. The TA2 is part of the two rocker switch family. It supports 4 buttons (A1, A0, B1 and B0) whereas the protocol differentiates between released and pressed state. Within the electronic switches and dimmers with Energy Measurement and Local Control family the FS1 is located. It supports one output channel, switching, local control, energy measurement and more features. The third component is part of the Light, Temperature and Occupancy Sensor group. As part of the group, the BM1 supports the measurement and transmission of this physical parameters. The EnOcean traffic is accessed through the UART of the Raspberry Pi with the bundle inspecting the serial stream

and mapping it to specific objects. The type of the object is determined by package header information. When a package of interest is received, an asynchronous event is triggered that is analyzed by the AAL application which subsequent forms activities. Based on these activities decisions are made, whether an emergency situation is indicated or not. This information can be communicated to the AAL Service that triggers an appropriate alarming mechanism.

5 Conclusion

The presented work describes a case study that investigates the synergetic use of Smart City infrastructure in order to obtain a balance between costs and value. An existing Demand Side Management architecture has been adopted to be used in an Ambient Assisted Living scenario. Therefore, Smart Grid specific engineering concepts and architecture models have been utilized. Focus has been put on the applicability of these concepts to other application domains, such as Ambient Assisted Living, and on the architectural needs of the infrastructure. Furthermore, the implementation of one key component, the Home Area Management System, is described in more detail.

During the work on this case study, different findings were made. First of all, the engineering concepts from Smart Grids have turned out applicable for developing systems from other application domains. However, as the utilized DSL is based on the SGAM, it does not reflect the needs of other application domains. It is necessary, to extend the SGAM to a more generic architecture model that reflects other domains of Smart Cities. To keep a holistic view about technological infrastructure used in different domains, an extension of the SGAM appears more reasonable than developing individual architecture models.

The extension of the architecture for a synergetic usage of the infrastructure highlighted the need for open systems, capable of being utilized in different services from different application domains. For the delivery of a certain third party service, a point-to-point connection between the service and the HAMS as local entity would be a possible scenario. However the presented work proposes an architecture with a remote Gateway as mediator for all communication. This architecture has been chosen by keeping in mind a future *Trusted Instance*, responsible for security and privacy management.

Our future work focuses in a first step on the implementation of the Gateway. Together with the HAMS, it represents a *Trust Infrastructure*. This Trust Infrastructure will be utilized to demonstrate and evaluate various privacy and security concepts developed at the *Josef Ressel Center for User-Centric Smart Grid Privacy, Security and Control*

6 Acknowledgement

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