universAAL – An Open and Consolidated AAL Platform

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Abstract. Due to the demographic development towards an ageing society AAL technologies will play an important role in the future. There has been a lot of work done in the field of AAL, but most of the project outcomes are proprietary and thus impossible to be combined. Accordingly, there is a need for an universal and open platform, which can be used as a starting point for further developments or just as an integration and standardization tool. For future service platform related research projects reference use cases as well as a reference tool set and framework would help to ensure a reusable and expandable platform, which is wide spread and therefore ensures a quality of service. The aim of the universAAL project is to combine the advantages and strengths of still ongoing or already finished research projects to create an universally applicable platform. The focus thereby is on interoperability and standardization to ensure a broad range of applicability and to develop an open platform that will make it technically feasible and economically viable to develop AAL applications. There are two tools for spreading the outcomes and ideas of the project planned: On the one hand the establishment of a store providing plug-and-play AAL applications and services that support multiple execution platforms and can be deployed to various devices and users, and on the other hand the AAL Open Association (AALOA) with the mission to create a platform for identifying key research topics in AAL, and to reach agreement on prioritization of these and to design, develop, evaluate and standardize a common service platform for AAL.

Keywords: AAL platform, interoperability, open source, reference architecture, platform consolidation.

1 Background and Motivation

Recent European population projections have underlined demographic developments towards an "ageing society". A challenge of the future is "ageing well at home" assisted by technology, while maintaining a high degree of independence, autonomy and dignity. Ambient Assisted Living (AAL) technologies try to follow this objective by integrating intelligent assistance-systems in people's homes.

Looking at the AAL solutions currently offered, one can find different proprietary and non-standardized solutions. There are solutions like home emergency call systems designed as capsulated alarm systems, domotic sensors for in house light control or very specified interfaces to single devices. A lot of these proprietary and single solution devices and applications can only be combined to a more comprehensive solution with a lot of technical development effort. Data formats as well as protocols are mostly incompatible and simple adaptations and integrations need the knowhow of an IT specialist or system integrator. which leads of course to high costs for the user himself. Often components like sensors or different functionalities have to be installed and paid multiple times, because systems are proprietary and only work if distributed as complete package [1].

Additionally, AAL is an application domain with a lot of overlapping subdomains, like the eHealth domain, the home entertainment domain, the home automation domain, the household appliance domain, the energy control and saving domain and many more. Accordingly, the AAL domain has to deal with conflicting versions of standards as well as conflicting implementations thereof. Furthermore, existing standards, like the ISO/IEEE 11073 standards for domotic sensors, have so far not been used and implemented in many applications and cases. Thus, there is little experience regarding missing parts and, overall, not many lessons have been learned from usage. Consequently, there are not many examples to show how to implement these standards in practice. Of course, there is also a lack of standards in some fields of AAL applications like remote maintenance, terminology and ontology, emergency and alarming calls and procedures and in some extend middleware architectures etc. This lack of standards is also amplyfied by the lack of certification and also labelling processes of devices and modules in the AAL domain [2].

Ideally, AAL applications and technologies should be based on a middleware, which is open to the public and which works as an intermediate layer between the operating system and the application itself. The middleware has to be adaptable in terms of services that can be implemented. Furthermore, it should be flexible and freely configurable to consider user needs in the development of applications and user interfaces. Moreover, it should be a good starting point for rapid development of applications and services; making the development process more cost- and time-efficient. A realization as an open source project would help to spread it in a big community, with the benefit of increased reliability and security in all development stages. To ensure the usage of the platform, the architecture should be open and adaptable to other overlapping domains of services and applications. This would overcome interoperability problems of many stand alone solutions currently available. Furthermore, all services must be able to be

easily controlled and maintained, which could be achieved by running them in one defined framework. This will also ensure a better interoperability and quality for the user. On the other hand, a combined platform for services will also lead to a cost sharing for the different services. As an example leisure services can be financed by the end user itself, health related services through health insurances and energy controlling services through a public grant. Lastly, the platform should provide an ecosystem for a lot of different stakeholders including developers, application and service providers, research groups as well as end users of the application.

The aim of universAAL[1] is to establish exactly such a cross application platform for AAL, health, home automation, entertainment, energy efficiency applications and services. Any service based application, which is thinkable, should be realisable on this platform. Beyond that, universAAL will also provide combined and validated reference use cases, and a tool chain for extending platform capabilities. Additionally, with the universAAL Developer Depot and uStore, two tools are available that will support different stakeholders in creating AAL services and applications.

universAAL's development approach for such a platform is described in the next section; including an overview on the input projects that have been considered. Distinctive features of the universAAL platform compared to existing solutions are summarized in Section 3. Section 4 gives a concrete example of the consolidation work and establishes, as a first result, universAAL's layered architecture. In Section 5 the consolidated Reference Model is described, which is another result of the first iteration of the universAAL consolidation process. Section 6 introduces the AAL Open Association (AALOA), which is universAAL's idea to establish a technical AAL community and ecosystem. The last section concludes with a summary and outlook. Since universAAL is an ongoing project all results presented here must be considered as intermediate results that might change during the course of the project.

2 Development of an Open AAL Platform

Fortunately, some already finished or nearly finished mostly public-funded AAL projects have already tried to tackle some of the issues derived above. Apparently though, no solution has been able to overcome all the relevant issues including the initiation of an active technical AAL community. Therefore, universAAL's goal is to tackle all of these issues resulting in a combined flexible, interoperable platform based on standards, which can be adapted and extended through a modular architecture.

In order to do so the universAAL platform will be based on different approaches from various input projects (either still running or already terminated) combining several aspects, advantages and learned lessons that emerged so far [5]. Some of these input projects are described in the following sections.

[1] `http://www.universaal.org/`

2.1 The Input Projects

AMIGO

The AMIGO[2] architecture follows the paradigm of Service Orientation, which allows developing software as services that are delivered and consumed on demand. The components in the AMIGO Open Source Software can be divided into three main parts (the Base Middleware, the Intelligent User Services and the Programming and Deployment Framework).

The aim of application development has been to extend the home environment for both interpersonal communication and shared activities, using the generic AMIGO platform (Middleware and Intelligent User Services). Two subdomains have been addressed: the Ambience Sharing, Social Radio and parts of the Feeling @ applications are oriented towards new forms of interpersonal communication, whereas the Activity Sharing, Board Game and Feeling@ sketch sharing applications provide means for sharing activities with remote people.

The main benefit of the AMIGO project for universAAL can be the provision of seamless interoperability of services and applications. Furthermore, user requirements study results could be used as an input while AMIGO OSGi bundles and some service components can potentially be used for the universAAL platform implementation.

GENESYS

GENESYS[3] [6] has been a FP7-STREP project, which has provided a cross-domain architectural framework for embedded systems development that can be instantiated for different application domains (e.g. consumer electronics, mobile systems, automotive, avionics, industrial control). As a candidate for the ARTEMIS European Reference Architecture for embedded systems it has been designed to meet the requirements and constraints that are defined within the ARTEMIS Strategic Research Agenda [7]. The development of GENESYS has been driven by a list of challenges of embedded systems design: composability, networking, security, robustness, diagnosis, maintenance, integrated resource management and evolvability.

The design principles of the GENESYS architectural style facilitate the development, certification and integration of robust systems that are composed of several individually developed subsystems. The main benefit for universAAL and the specific concerning the other projects is solid formal specification of requirements for distributed systems.

OASIS

The characteristic of the OASIS[4] platform is an architectural development based upon ontologies and semantic services, which allow plug and play and cost-effective interconnection of existing but also not yet existing new services domain comprehensive.

[2] http://www.hitech-projects.com/euprojects/amigo/
[3] http://www.genesys-platform.eu/
[4] http://www.oasis-project.eu/

The approach of OASIS is simple in conception: direct reusability of information is to be provided across heterogeneous services and devices. In order to achieve interoperability of services and sharing of contextual information between different services and objects, it is necessary to model them first, by extracting each services individual structure up to its most primitive level. In current approaches, this can lead to more or less ad hoc solutions. The OASIS solution is to provide foundational ontology components, specifically tailored to the requirements of the applications to be covered and the services provided.

The benefits for universAAL can be that OASIS can provide a comprehensive view of the interoperability between services and applications as well as an excellent background in the integration of different application domains.

MPOWER

MPOWER[5] is based on service oriented architectures (web services, WSDL and SOAP) and uses no semantic services or ontologies. That in itself is an interoperability enabler, as the web service front ends allow heterogeneous platforms to interoperate (e.g. .NET and Java). The platform consists of several middleware building blocks with coordinated interfaces based on the IBM Service-Oriented Architecture (SOA) approach.

MPOWER has done a lot of work in applying software engineering methods and tools. The architecture is based on a good described method by IBM. The modelling and software creation follows defined processes based on tools and established technologies like Enterprise Architecure, Netbeans and the Glassfish application server. The aim has been to not only provide the platform but making it also feasable for developers to reuse and extend the platform with new services through a Model Driven Architecture approach. A lot of this toolchain can be reused in universAAL.

MPOWER has also tried to integrate standards. Thus the medical and information data sharing has been implemented through HL7 and the sensor connection has been realized with a so called Frame Sensor Adapter which has implemented the ISO/IEEE 11073 standard.

There is one central database for each MPOWER platform. These specifications lead to the fact that there is only one physical server for a particular MPOWER platform installation where all components are hosted and provided. This coordinated approach avoids many interoperability problems which automatically arise when different systems are used in a distributed environment. In contrast, a central installation on one server makes it difficult to adapt the modules to their special requirements in runtime, e.g. the hardware or software environment. For installation and integration of course the all in one installation is a benefit and makes it easier to setup.

PERSONA

The requirements of PERSONA[6] have been to put the platform focus on an open distributed selforganizing system that evolves over time according to individual

[5] `www.mpower-project.eu`

[6] `http://www.aal-persona.org/`

needs as they arise. Therefore PERSONA also uses semantic services. The platform modules have been structured in a way that individual parts can be improved and substituted. The PERSONA platform is based on a distributed architecture based on a bus communication system.

The PERSONA platform comprises the PERSONA middleware and a set of mandatory functional components consisting of a context history storage, a situation reasoner, a profiling component, a dialog manager, a service orchestrator, a gateway, and at least one I/O handler.

Benefits for universAAL can be the whole conceptual design of AmI systems as self-organizing systems with the appropriate UI framework and a set of mandatory platform components.

SOPRANO

The SOPRANO[7] technical core is SAM, the SOPRANO ambient middleware, which is installed in each home and provides its intelligence by receiving user commands and inputs from sensors, enriching them semantically and providing appropriate reactions via actuators in the house (more on SAM can be found in [9]).

SOPRANO uses a very straigth forward reflection of *sensing* ⇒ *reasoning* ⇒ *acting*. This has been achieved through a scalable but still configurable solution and an intelligent and modular approach of configuration. Accordingly, SOPRANO works on different layers of abstraction. This enables devices to work on a rather low semantic level, whereas administrators can set up procedures on a fairly high semantic level. The SOPRANO ambient middleware mediates between these abstraction layers.

Additionally, SOPRANO is an ambient system, i.e. it primarily works in the background by understanding the current situation in the house via the connected sensors and influencing it via the connected actuators. Thus, the focus of SOPRANO is different to many design projects, since it assumes that the system is not necessarily driven through user input. Ambient system behavior is achieved by a set of procedures that provide the intelligent reactions of the system to certain situations. These procedures are defined by domain experts. Therefore, the behavior of the SOPRANO system does not stem from a black-box inside the system, but the system will deterministically react according to the rules that are manually entered. As a consequence, SOPRANO is self-learning only in well-defined borders (i.e. it does not change its rules autonomously) to ensure its reproducible behavior.

2.2 The Consolidation and Development Approach

In order to achieve a high acceptance of the emerging open AAL platform, the results of several input projects and standards are consolidated into the universAAL platform. Most suitable architectural designs and components are selected for universAAL to obtain an optimal solution and to reduce the effort of development compared to implementing a completely new platform. Unaddressed open

[7] `http://www.soprano-ip.org/`

issues within the input projects are identified and can be solved by the adaption of solutions of other projects or by finding a new solution. The process of consolidation and development in universAAL - presented in figure 1 - is an iterative approach that consists of four phases: Analysis and Consolidation, Design, Implementation and Standardization, and Evaluation. These phases are described in detail in the following:

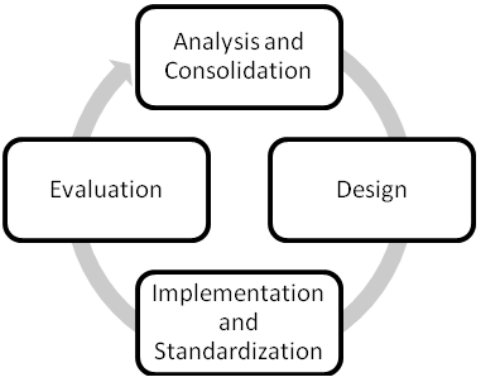

Fig. 1. Process of consolidation

- In the *Analysis and Consolidation* phase existing AAL platforms from the input projects and standards are analyzed and compared. Architectural designs of the different platforms are mapped to the universAAL reference model. This allows a conceptual comparison of heterogeneous architectures, while strengths and weaknesses of different concepts are determined. Furthermore, use cases covered by each platform are merged and the implementations of software and hardware components are ranked based on the requirements they fulfill.
- During the *Design* phase the universAAL reference architecture is designed. Architectural decisions are based on the results of the analysis step, while the obtained ranking criteria for components help to select existing components for the reference architecture. This phase especially targets interoperability between platforms and components.
- The *Implementation and Standardization* phase implements the platform middleware, services and tools. It has a special focus on the reuse of existing implementations from input projects. Thus, the main effort can target at the development of new innovations.
- Within the *Evaluation* phase the reference architecture and the implementation of universAAL services and tools are verified and validated in order to comply with the requirements. The results of the evaluation are input for the next iteration of the consolidation process.

3 Benefit of the Project

The vision of the consortium of the universAAL project is that it should be as simple for users to download and setup AAL services as it is to download and install software applications on a modern operating system. universAAL will establish a store providing plug-and-play AAL applications and services that support multiple execution platforms and can be deployed to various devices and users. Finally, the allocation of local human resources is also supported in the store.

Seen from the end user's view, universAAL provides the uStore, which gives the end user (elderly users or their care providers) a simple way to find and acquire AAL services. The uStore provides a service that can consist of software, hardware, and human resources (service providers). By acquiring an AAL service, required software (applications and device drivers) will be deployed to the user's hardware, access will be provided to required remote software services, and agreements will be made with (local) service providers to reserve required human resources both for deployment and use of the service. If necessary, new hardware will be ordered and installed in the end user's residence. While in some cases the end user or their care providers can download and install the services themselves, in more complex cases (typically involving hardware installation) the service provider will be involved in the installation (either guiding the installation remotely or at the installation site).

Seen from the developer's point of view, universAAL produces several results, which simplify the development and marketing of AAL services. Through the Developer Depot, the developer can find development tools, reference architectures, and guidelines which simplify and streamline the development of AAL services. Also, the depot links to facilities for hosting the development of AAL services in teams, and for sharing models of (public parts of) the AAL services in the wider community. Through the uStore developers can deploy and sell their AAL Services or make them available for free to the users.

Considering this, universAAL is different from other AAL platform projects, since it focuses on dedicated tool support for different stakeholders as well as on building of communities and provision of an open service platform.

4 Consolidation of universAAL's Layered Architecture

Towards consolidation of the universAAL's layered architecture, universAAL compared the layer models of the input projects along with the universAAL Description of Work (DoW) [10] in a common diagram (see figure 2).

This work revealed that the model used in universAAL DoW and the models introduced by GENESYS and PERSONA are very similar. Furthermore, most of the other layer models have a good mapping to these models. The alignment lines in the figures were added to help to visualize this mapping.

Based on the mapping between the layer models of the input projects, the consortium has designed a first version of the universAAL layered architecture

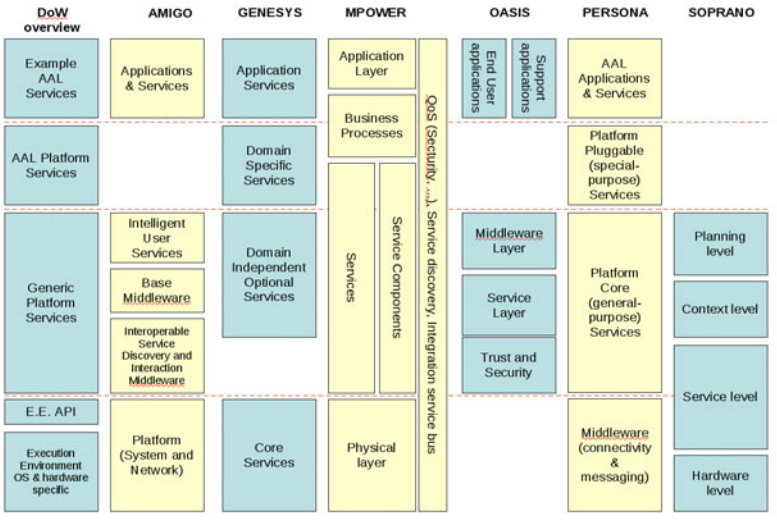

Fig. 2. Consolidation of layer model

mostly based on the GENESYS and PERSONA project. The platform is divided into four layers, namely the Middleware, the Generic Platform Services, the AAL Platform Plug-Ins and the AAL Applications and Services.

The Middleware layer is assumed to extend the native system layer of the different physical nodes participating in an AAL system and hence hide the distribution of these nodes as well as the possible heterogeneity of their native system layers. In addition to that, this layer is supposed to act as a container for integration of all components from the above layers and facilitate the communication among them.

The Generic Platform Services layer provides basic platform services, like context management, service management, and a framework for supporting complex user interactions.

On the AAL Platform Plug-Ins layer special platform services can be introduced to extend the basic functionality. This might be needed in case high-level services have specific demands on, for example, data-mining of context reasoning.

The AAL Applications and Services layer encapsulates all applications and services that directly provide support and assistance to the end user.

5 The Consolidated Reference Model

To understand the consolidated Reference Model the universAAL project team has created graphical representations of concepts and their interrelationships within concept maps which are assumed to help different types of stakeholders to quickly learn about the understanding of the AAL domain based on which universAAL started to work. The set of concept maps representing this understanding reflects the "spirit" of the input projects.

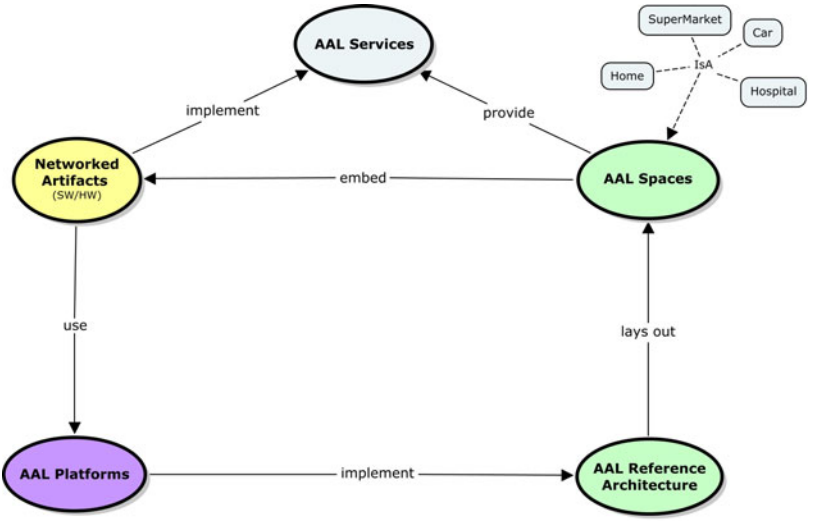

Fig. 3. The Root Concept Map of the universAAL project

The *Root Concept Map* - see Figure 3 - presents the consolidated understanding of AAL systems in a single picture using the fewest possible set of concepts. AAL systems are all about the provision of *AAL Services*. The importance of ambient technologies in the provision of such services is highlighted by putting the concept of *AAL Spaces* and the underlying technologies (*Networked Artefacts*) right in this top level. The *AAL Reference Architecture* and the compliant *AAL Platforms* incorporate the engineering challenges beyond single technologies towards reconstructable infrastructures. The *AAL Reference Architecture* identifies the basic building blocks necessary for constructing an *AAL Space*, such as *Home, Supermarkets, Cars or Hospitals*. Such an AAL Space provides *AAL Services* with the help of embedded *Networked Artefacts* that implement (or contribute to the implementation of) those AAL Services. The cooperation between Networked Artefacts distributed in an AAL Space is facilitated by an *AAL Platform* that implements the previously mentioned reference architecture in order to provide resource sharing and let users experience an integrated world easy to interact with based on natural communication. The concepts from the root concept map are further detailed in six second level concept maps.

One of these concept maps tries to clarify the notation of the term *service* and the relation to an AAL service and the *Service Component* which is a software component, e.g. a Web service or a plain old Java objet, which provides a set of service utilities in the virtual realm. And on the other hand the *Service Utility* which represents a utility in virtual realm, such as an exported method of an object or an exported operation of a Web service, which makes it possible to utilize a service from within the virtual realm. A service utility may directly trigger the process of providing the underlying service or just lead to an arrangement for starting the process at a later point in time.

A domain-specific context of AAL service - which is presented in another concept map - helps to better understand the essence of these services as well as the different interests and concerns that various individuals or organizations might have in providing or using such services.

In a domain-specific context of AAL services the stakeholders are of big interest. For universAAL especially the technical stakeholders. For this purpose, we first emphasize that the networked artefacts referred to so far comprise both, networking enabled hardware nodes and software components loadable by certain types of such hardware nodes. This helps to identify manufacturers (as producers of hardware) and developers (as producers of software). We also highlight that setting up a complex AAL space consisting of specialized hardware and software requires certain expertise and knowledge about the available hardware and software. The stakeholders that have this expertise and provide the service of setting up AAL spaces by using appropriate artefacts are called deployers. Manufacturers, developers and the deployers have to work under the boundary conditions defined by the Authorities.

Ambient Intelligence (AmI) is the science of creating intelligent environments. And, as AAL Spaces are supposed to be smart environments, we can make use of progresses made in AmI for further understanding the characteristics of AAL Spaces. These characteristics have been analysed a *Smart Environment*. According to AmI, this setup is expected to result in characteristics, such as context-awareness, personalization, reactivity and pro-activity in smart environments. That is, smart environments must provide support for acting in a context-aware and personalized way so that responses can be considered to be adaptive. Reaction and pro-action are the two examples of adaptive response that must be emphasized in order for smart environments to live up to what AmI requires. Experience shows that the quality of these four central characteristics can be improved if some sort of reasoning backs them. A supplementary concept map highlights the notion of sensor and actuator always referred to in the context of AmI. However, we would like to emphasize that in addition to sensors and actuators, there are also I/O devices realizing channels between the physical world and the virtual realm that aim at facilitating the interaction between smart environments and humans. This helps to highlight natural interaction as one of the major criteria posed by AmI.

The concept of middleware, which is a central concept for the development of the universAAL platform, has been described in another concept map. It highlights the importance of providing for mechanisms that allow distributed and heterogeneous networked artefacts to interact with each other. The middleware is understood as a software component, which ideally resides on all of the networking-enabled nodes. It provides common interfaces that facilitate the integration of other software components and the communication between them. As the middleware hides the distribution and heterogeneity of networking-enabled nodes, developers of software components need not care about the whereabouts of resources they need.

6 universAAL and the AAL Open Association (AALOA)

Since universAAL aims to develop an open platform that will make it technically feasible and economically viable to develop AAL applications it also is in the interest of the project to support the platform after the project end. This can best be done through an independent, non-profit association open to individuals, institutions and industry with a clear process definition to join the organization and to be nominated for the various elective offices. Such an "ecosystem" of users and developers has been established around the universAAL platform with the AALOA (AAL Open Association) to ensure continual support and ongoing refinements.

The mission of the association will include provision of a shared open framework for developers, technology and service providers, research institutions, and end-user representatives to discuss, design, develop, evaluate and standardize a common service platform in the field of AAL, where the framework - as a combination of resources, tools and people - is supposed to facilitate concluding provisions both inside and outside the association. Furthermore it aims to identify key research topics in AAL, and to reach agreement on prioritization of these and to design, develop, evaluate and standardize a common service platform for AAL.

To reach this goal AALOA invites everyone to participate in the activities of the association, to bring fresh ideas, to propose workshops and projects, and to contribute actively to the growth of the association. For universAAL, the role of the association will be to promote, support and continue the work initiated by universAAL - even after termination of the project itself. Since AALOA has been founded as an open association it is serving as a consortium for various projects and involving individuals as well as organizations, and is forming an AAL community with broad involvement from all types of stakeholders. AALOA is intended as an invitation to join in the mission of bringing together the resources, tools and people involved in AAL in a single forum, making it much easier to reach conclusions on provisions needed to design, develop, evaluate and standardize a common service platform for AAL.

The not-for-profit organization AALOA is being structured as a federation of projects. Projects are supposed to be organized by a project management committee that is autonomous with respect to the association's governing board, which uses the best practices of open source communities. Additionally an Advisory Board composed of industry and user communities is organized in working groups whose duty is to advise AALOA's open source community about emerging technical and market challenges. As a not-for-profit organization its costs are covered by donation and sponsorship.

To establish a technology neutral platform AALOA looks for the best technological solution independent of the interest of any technology provider. It should be transparent regarding the technological solutions provided and promoted and in respect to the governance and strategic choices. Member of a research project can release a piece of software using an open source license. Academics can help by proposing PhD theses, or by having students develop and release code for the

association. Industry can advise the adoption of standards, provide marketing insight or contribute with code. All supporters can help by creating liaisons with other communities, organizations and research projects.

The first step in making the Association a reality will be to issue a manifesto. This call for action will declare the intention of consolidating efforts in the AAL field in order to reach real AAL breakthroughs, and call for foundation of an open association - with a first definition of its proposed structure and open source policies. It will invite active participation in formation of the association. As the association grows, the manifesto will be updated to reflect new developments in the AAL field, and evolution of the association itself.

To overcome the problems hindering progress in the area of AAL the signatories of the manifesto consider that the time has come to find a common solution for transcends individual projects or organizations. It needs a long-term approach, with broad involvement from all types of stakeholders. This manifesto is intended as an invitation to join us in our mission, which brings together the resources, tools and people involved in AAL in a single forum that makes it much easier to reach conclusions on provisions needed to achieve AAL progress. All technology providers, service providers and research institutions involved in AAL should either be directly involved in AALOA or aware of decisions it promotes. Especially end user representatives will be involved in all work of AALOA.

As a few projects and standardization bodies have also expressed an interest in joining AALOA, it seems that we have come a significant step closer to the vision of an universal platform. Parallel to working on community building, there is a clear and present need to convince the technological industry of our vision. Only when the industry is ready to develop products and services based on a common platform AAL and AmI will really get their first chance for having success.

7 Summary and Outlook

Today many implemented solutions for AAL applications in residential houses as well as smart home applications are proprietary solutions. Future developments should be developed and designed in a way that they can be integrated and combined with existing solutions and products. Therefore, the interests of the end users but also of the developers and service providers have to be taken into account. Although there have been a lot of AAL projects and a lot of prototypes of AAL applications exist, the integration to adaptable and reusable complete solution has not been found yet.

The universAAL project aims to combine lessons learned from eight FP6 and FP7 AAL research projects and to provide an open and adaptable framework for all kinds of AAL, eHealth, social services and energy saving services. Additionally, the project will establish a community for all relevant stakeholders with the aim of delivering a sustainable platform also over the project runtime itself.

Since universAAL aims at providing the open AAL solution framework to be reused in other projects, all interface descriptions and components are open

source. We hope that the reuse of universAAL results in other projects could ensure a sustainable use of research funding and is able to speed up the process of rapid development of adaptable and individual AAL solutions.

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