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Facilitating Inter-Domain Synergies in Ambient Assisted Living Environments

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Abstract. Current Ambient Assisted Living (AAL) environments lack integration of sensors and actuators of other sub-domains. Creating technical and organizational integration is addressed by the BASIS project (Build Automation by a Scalable and Intelligent System), which aims to build a cross-domain home bus system. The main objective of this paper is to present an overview of design, architecture and state of realization of BASIS by describing the requirements development process, underlying hardware design and software architecture. We built a distributed system of one independent building manager with several redundantly meshed segment controllers, each controlling a bus segment with any number of bus nodes. The software system layer is divided into logical partitions representing each sub-domain. Structured data storage is possible with a special FHIR based home centered data warehouse. The system has been implemented in six apartments running under daily living conditions. BASIS integrates a broad range of sub-domains, which poses challenges to all project partners in terms of a common terminology, and project management methods, but enables development of inter-domain synergies like using the same sensor and actuator hardware for a broad range of services and use cases.

Keywords. Ambient Assisted Living, Health Enabling Technologies, Data Warehousing, Smart Home, Bus Systems Introduction

1. Introduction

Ambient Assisted Living (AAL) proved to be a potential solution to handle rising healthcare costs and sinking independence and self-reliance of elderly in demographically changing countries. Current home centered health-enabling technologies (HET-HC, ref. [1, 2]) are usually posing separate solutions for domain specific problems. They do not focus on interoperability or integration into multi domain environments taking more into account than AAL use cases. Interoperability standards may help closing this gap, but are in most cases restricted to delineated domains like medical systems, power management or technical building management. Critical problems like interoperability, usability, security, reliability, and the quality of the user experience are not solved but – as shown in [3] – addressed isolated. Dealing with all of the aspects needs a broader understanding of the environment AAL is

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embedded into. Back to the original idea of smart houses from [4] we need to include all sub-domains of a home environment complementary to AAL like building energy management (BEM), home safety, smart grid integration and housing industry services. This technical and organizational integration is addressed by the BASIS project (Build Automation by a Scalable and Intelligent System), which aims to build a cross-domain home bus system. Every integrated sensor and actuator is useable by connected domains facilitating evaluation of foreign sub-domain data for AAL use cases. Key requirement is a common domain model and data structure over all sub-domains to implement a home centered data store accessible for all sub-domains. Distinct domain models for AAL like in [5] and [6] do exist. Implementing these models into AAL focused controlling layers like in [7] and [8] turned out to be complicated if the wrong technology is used (ref. [9]).

Structuring complex data is strength of the medical domain with the existence of reliable interoperability standards like HL7 v2, v3, openEHR or the new HL7 FHIR (ref. [10]). The latter focuses on interoperability with strong extensibility and flexibility, which creates some interesting possibilities to extend the scope of FHIR to other related domains.

The main objective of this paper is to present an overview of use cases, design, architecture and realization of BASIS by describing the requirements development process, underlying hardware design, software architecture and implementation at six demonstrator flats. The description is done from the AAL perspective, showing mainly collaboration of other sub-domains with the AAL domain.

2. Methods

2.1. BASIS Requirements

The following requirements were part of the design process of BASIS and directly influence the methodology of defining the architecture. Aiming to a wide distribution, BASIS needs to minimize power consumption as low as possible. Current externally powered systems use between 150 and 450W where link powered systems (e.g. KNX) need about 72W for 100 bus nodes. The smallCAN (SCAN) bus used in BASIS needs about eleven Watts for the same installed sensor and actuator count (ref. [11]).

Using BASIS as technical backbone for multiple domains for a complete building poses the requirement to be as cost-effective as standard electrical systems taking the added value of certain intelligence into account. While equipment costs for business buildings are usually scaled higher providing same functionality in private houses are expensive. Therefor, BASIS needs to be designed with a minimum of cable use and node costs while maintaining reliability.

Typical electrical equipment in buildings is designed for 30 years of utilization. BASIS needs to support such operation times being both robust to failures and easy to maintain and update.

2.2. Use Case Analysis of Related Sub-Domains

First, we defined a set of use cases representing each relevant sub-domain, in cooperation with the project partner. As top down approach, we agreed on a common terminology to describe the system and offered services. Identified use cases were analyzed for contained socio-technical participants and domain related concepts. Second, we listed existing sensors and actuators with their measured data units or actions triggered respectively. Additionally, relevant properties have been collected. This bottom up process ensures to have all sensor and actuator types covered by identified objects in defined use cases.

We identified a range of use cases from every sub-domain. The ones shown in table 1 have been extracted since they list the feature scope for their respective sub-domain. Additional use cases like manually controlling actuators and visualizing the whole systems state address basic requirements and do apply to all sub-domains.

As one result of these phases, an object model representing the main extracted concepts has been defined. An early version has been briefly described in [12]. We explicitly not targeted invention of a detailed ontology to reduce complexity The object model is based on FHIR resources, mainly Device, Location and Observation.

3. Results

3.1. Hardware Architecture

BASIS is build as distributed system for controlling all technical building equipment. The architecture provides one central building manager (BM) on basis of a BeagleBone Black with several connected segment controller (SC) each controlling a bus segment with any number of bus nodes. Power supply is provided over meshed bus cabling and a backbone network between SCs. Every sensor and actuator is controlled by a bus node, containing modular controller code for the specific hardware. The underlying structure is a redundant mesh enabling the BM and SCs to route bus telegrams flexible. An additional integration of wireless bus nodes is possible. Especially body-related sensors in the AAL domain are realizable.

Table 1. Relevant Use Cases identified to build the inter-domain system

Sub-Domain	Relevant Use Cases
AAL	night light switching, tele rehabilitation training including communication with medical staff, filling of medical questionnaires, critical state detection (e.g. stove shutdown), geriatric assessments
Power Management	controlling of different device types like rule based (e.g. refrigerator), program based (e.g. washing machines) or service based (e.g. coffee machine), receiving and evaluating regulations from smart grids, handling local energy production and storage, providing information to the user
Building Energy Management	optimization of heating, ventilation and air conditioning (HVAC) by specific optimization endpoints (e.g. cost minimization, peak load limitation)
Building Service Engineering	visualizing installed devices integrated into the building structure, searching for technical problems guided by an error wizard, storing additional information per device (e.g. manuals, circuit diagrams), integrating new devices with aided configuration, communicating with specific complex devices through tunnels
Housing Industry Services	monitoring status of multiple apartments of a building, reading energy consumption values for billing, discovering and preventing accidents (e.g. fire safety, burglary prevention), controlling access in case of an emergency

3.2. Software architecture of the BM

Isolation addresses reliability and security. The software system layer is divided into logical partitions representing each sub-domain. Partitions are completely isolated and may communicate over abstracted Unix domain sockets with a system layer. To achieve this encapsulation LXC container and later Genode processes (ref. [13]) are used. The controlling system layer holds a current system image of sensor values and actuator states updated in real-time. Every bus node may have an arbitrary number of virtual channels delivering specific metrics following specifications of ISO 11073:10201. While bus telegrams with measured values of virtual channels are routed with respective tables in every SC, partitions on the BM may subscribe to specific virtual channels. Subscription is regulated by a role model and specific access rights to ensure privacy requirements e.g., as strictly necessary in the AAL sub-domain.

3.3. Data warehouse (DWH) partition architecture

A special partition for persisting sensor and actuator values is implemented on basis of the designed object model. All bus telegrams are stored as JSON encoded FHIR Observation resources. References are set to existing Device and Location resources describing the complete installation. The use of the embedded key value database upscaledb (ref. [14]) facilitates logging of up to 130 bus telegrams per second on the embedded BM. A control layer defining a FHIR query interface over unix sockets has been implemented for used resources. Further analyzes and queries are possible over contract based querying utilizing Oder and OrderResponse respectively.

3.4. Demonstrator Flats

BASIS has been installed at six flats in an apartment house. The final implementation phase took place inside these demonstrators facilitating real word tests and ongoing development. The house has about 600 bus devices installed with 200 more to come. There are repeating sensors like presence, gas, luminosity, temperature and humidity in every room and singleton installations like wind or rain. Actuators range from simple switches or controllable sockets to complex devices like blinds, dimmers or smart meters. The house produces about 30 bus telegrams per second. It supports all basic use cases and the flats are already rented since the end of 2015 or are going to be rented during 2016.

4. Discussion

The main challenges arise from the complexity of the project in multiple dimensions.

BASIS aims to integrate a broad range of sub-domains, which poses challenges to all project partners in terms of a common terminology, and project management methods. Regarding the common object specification and domain model a huge number of requirements may lead to an over-complex specification not manageable. We agreed on some compromises in the number of analyzed use cases and the role of the system partition. Since reliability is a key need, the underlying bus infrastructure up to the system partition are regarded as real-time capable and quasi-isolated unity. All non-real-time services may work with the DWH partition to generate more sophisticated services.

Managing the complex needs of structured, high volume data for analysis and research while being limited to embedded hardware needed a thorough selection of the underlying database engine and restricted implementation.

5. Conclusion

Inter domain synergies in home environments need a strong technical basis as well as good project management. Standards may help reducing differences but requirements like management of multi domain, structured, high volume, semantically enhanced data advanced medical reasoning or data provisioning need need further research.

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References

[1] M. Gietzelt, T. von Bargen, M. Kohlmann, et al. Home-centered Health-enabling Technologies and Regional Health Information Systems. An Integration Approach Based on International Standards. *Methods of Information in Medicine*. **53** (2014), 160-166.
[2] O.J. Bott, M. Marschollek, K.H. Wolf, et al. Towards new scopes: sensor-enhanced regional health information systems - part 1: architectural challenges. *Methods of information in medicine*. **46** (2007), 476– 483.
[3] M. Memon, S.R. Wagner, C.F. Pedersen, et al. Ambient assisted living healthcare frameworks, platforms, standards, and quality attributes. *Sensors* (Basel, Switzerland). **14** (2014), 4312– 4341.
[4] D.H. Stefanov, Z. Bien, W.C. Bang. The smart house for older persons and persons with physical disabilities: structure, technology arrangements, and perspectives. *Neural Systems and Rehabilitation Engineering, IEEE Transactions on*. **12** (2004), 228–250.
[5] M. Klein, A. Schmidt, R. Lauer. Ontology-Centred Design of an Ambient Middleware for Assisted Living: The Case of SOPRANO. In: T. Kirste, B. König-Ries, R. Salomon, editors. *Towards Ambient Intelligence: Methods for Cooperating Ensembles in Ubiquitous Environments* (AIM-CU), 30th Annual German Conference on Artificial Intelligence (KI 2007), Osnabrück, September 10, 2007.
[6] X.H. Wang, D.Q. Zhang, T. Gu, et al. Ontology based context modeling and reasoning using OWL. In: *Pervasive Computing and Communications Workshops*, 2004. Proceedings of the Second IEEE Annual Conference on. IEEE; 2004, 18–22.
[7] T von Bargen, M. Gietzelt, M. Britten, et al. Design and implementation of the standards-based personal intelligent self-management system (PICS). *Studies in health technology and informatics*. **186** (2013), 135–139.
[8] P. Wolf, E. Schmidt, M. Klein. SOPRANO - An extensible, open AAL platform for elderly people based on semantical contracts. In: 3rd Workshop on Artificial Intelligence Techniques for Ambient Intelligence (AITAmI'08), *18th European Conference on Artificial Intelligence* (ECAI 08), Patras, Greece; 2008.
[9] P. Wolf, A. Schmidt, M. Klein. Applying Semantic Technologies for Context-Aware AAL Services: What we can learn from SOPRANO. In: Workshop on Applications of Semantic Technologies 09, Informatik 2009. *Lecture Notes in Informatics*. GI; 2009
[10] Health Level 7 (HL7). FHIR Specification Homepage [Internet]; 2016. [cited 12 Feb 2016]. Available from: *http://www.hl7.org/implement/standards/fhir/*.
[11] H. Schrom, T. Michaels, S. Stein, et al. SmallCAN - A Reliable, Low-Power and Low-Cost Distributed Embedded System for Energy Efficient Building Automation. In: *ENERGY 2011, The First International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies* from May 22, 2011 to May 27, 2011. Venice/Mestre, Italy; 2011. 13–18.
[12] J. Schwartze, L. Jansen, H. Schrom,et al. An HL7-FHIR-based Object Model for a Home-Centered Data Warehouse for Ambient Assisted Living Environments. *Studies in Health Technology and Informatics*. **216** (2015), 1060.
[13] Genode Labs. GENODE Operating System Framework [Internet]; 2016. Available from: *http://genode.org* [cited 12 Feb 2016].
[14] Christoph Rupp. Upscaledb – embedded database technology [Internet]; 2016. Available from: *http://upscaledb.com* [cited 12 Feb 2016].