

Assessment of Reference Architectures and Reference Models for Ambient Assisted Living Systems: Results of a Systematic Literature Review

Lina Garcés, Department of Computer Systems, University of São Paulo, São Carlos, Brazil

Flavio Oquendo, IRISA - University of South Brittany, Vannes, France

Elisa Yumi Nakagawa, Department of Computer Systems, University of São Paulo, São Carlos, Brazil

ABSTRACT

The innovation and development of software systems in the Ambient Assisted Living (AAL) domain have brought huge challenges for academia and software industry as well. Despite the existence of architectural models that can be used as references to build AAL systems, their selection for new AAL projects is a difficult task. In this work, the authors present the state of the art on Reference Architectures (RA) and Reference Models (RM) found through the conduction of a systematic literature review. The authors identified, analyzed, and assessed 24 existing RA&RM for AAL domain, and, as result, the authors spotted interesting research directions that should be further explored to improve existing and future RA&RM and software systems for that domain.

KEYWORDS

Ambient Assisted Living, e-Health, Reference Architecture, Reference Model, Software Architecture, Systematic Literature Review

1. INTRODUCTION

Ambient Assisted Living (AAL) is a relatively new field that has become an increasingly important, interdisciplinary research topic for the governmental services, and the medical and technological research communities (Broek, Cavallo & Wehrmann, 2010). AAL refers to concepts, products, and services aiming at enhancing several aspects of people's quality of life, including autonomy/independence, comfort, safety, security, and health in all stages of their life (Broek et al., 2010). AAL software systems can be seen as super-set of Ambient Intelligence (AmI) that includes concepts and technologies from smart homes, robotics, sensor networks, and eHealth (Buchmayr & Kurschl, 2011).

Considering the relevance of AAL software systems for society, and the diversity of application domains and technologies that AAL embraces, researchers, practitioners, and organizations have advised the importance of creating heterogeneous, interoperable, open, and reusable platforms and standards for the AAL domain. For this reason, several reference architectures (RA) and reference

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models (RM) have been proposed, supported, for instance, by the European Commission under the FP6 and FP7 research calls¹. In short, RA are a generic type of software architecture that presents a well-recognized understanding of specific domains, promoting reuse of domain and design expertise, and facilitating the development, standardization, and evolution of software systems (Nakagawa, Oquendo & Maldonado, 2014). Meanwhile, RM are considered abstract frameworks whose purpose is the domain modelling, representing relationships between domain entities. In a RM, entities can be further mapped into software architecture structures (Bass, Clements & Kazman, 2003).

In the AAL context, it is possible to find different RA&RM, such as UniversAAL (Hanke et al., 2011), proposed to guide the AAL providers and consolidate the AAL market. Nowadays, the selection of RA&RM for developing, standardizing, and evolving AAL systems is a rather difficult task, because the heterogeneity of technologies, and complex purposes of those systems. However, to the best of our knowledge, there is a lack of a complete and detailed analysis and assessment of the existing RA&RM for the AAL domain. The main objective of this paper is to present the state of the art obtained by assessing those RA&RM regarding their completeness and congruence. The identification and selection of RA&RM was made through the conduction of a systematic literature based on well-known guidelines presented in (Kitchenham & Charters, 2007).

The remainder of this article is organized as follows. Section 2 presents the background. Section 3 details related work. Section 4 summarizes the protocol of the conducted systematic literature review. Section 5 reports the results of our review. Discussions about our research questions are presented in Section 6. Section 7 exposes threats to validity. Finally, Section 8 presents our conclusions and future work.

2. BACKGROUND

In this section, the theoretical background containing the main topics embraced in this work, namely, AAL, reference architectures, and reference models, is given.

2.1. Ambient Assisted Living

Aiming at enhancing the quality of life for everyone, the Ambient Assisted Living (AAL) concept emerged in the 1990s, but just from the middle of the 2000s it has received more attention. AAL is a relatively new field and has become an essential, multidisciplinary research topic, aiming at providing software systems and services to assist people with disabilities, chronic illness, or low autonomy, in their every life activities. In this context, efforts in the AAL domain intend to improve autonomy/independence, comfort, safety, security, and health, for everyone (with a focus on elderly persons) in all stages of their life (Broek et al., 2010). AAL is primarily concerned with the individual in his or her immediate environment (e.g., at home, community, or work) by offering user-friendly interfaces for all sorts of equipment in the home and outside, taking into account that many older people have impairments in vision, hearing, mobility, or dexterity (Pieper, M., Antona, M., & Cortés, U., 2011).

Table 1 shows the classification of AAL goals (G) proposed originally by Afsarmanesh (2011). Shortly, AAL systems can be constructed to address three general goals (G1, G2, and G3) depending of the environment in which the system will work (i.e., personal environment, such as home, work, or community). The three general goals can be refined in more detailed objectives (for instance, G1A.b as sub-goal of G1), as detailed in Table 1.

2.1.1. Technologies in Ambient Assisted Living

To develop successful AAL systems, knowledge provided by a heterogeneous set of disciplines (as those showed in Figure 1) must be integrated. AAL software systems can be seen as an evolution of Ambient Intelligence (AmI) technologies, including also technological advances from Smart Homes and e-Health (Buchmayr & Kurschl, 2011). Figure 1 shows relationships between different technologies from the AAL point of view. Smart Homes focus on controlling devices installed at people's houses,

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