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Development of an Ambient Assisted Living Ecosystem

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To my Parents, who never stop supporting me

Agradecimentos

Quero começar por agradecer ao meu orientador, o Professor João Rosas, pela paciência, dedicação, disponibilidade e amizade demonstradas ao longo desta dissertação.

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Resumo

A sociedade em que vivemos enfrenta actualmente grandes mudanças demográficas. Hoje em dia, as pessoas vivem cada vez mais anos, e a tendência é que a esperança média de vida continue a aumentar. No ano 2000, 420 milhões de pessoas (correspondentes a cerca de 7% da população mundial) tinham já mais de 65 anos de idade. Em 2050, estima-se que esse número atingirá os 1500 milhões (cerca de 16% da população mundial). Naturalmente, assim sendo, aumentará também o número de pessoas com limitações físicas.

Este contexto traz novos desafios aos sistemas tradicionais de saúde existentes em Portugal e no resto do mundo. Há necessidade urgente de procurar soluções que permitam às pessoas viver da melhor forma possível nas últimas etapas das suas vidas. Para isso, terão de ser implementados sistemas que permitam aos seus utilizadores prolongar ao máximo a sua estadia no seu ambiente favorito, aumentando a sua autonomia, confiança, mobilidade e bem-estar.

Hoje em dia, as tecnologias de comunicação e informação oferecem novas oportunidades para a prestação de serviços de assistência. *Ambient Assisted Living* (AAL) é um paradigma no qual a tecnologia é utilizada como forma de melhorar a independência e bem-estar de pessoas com algum tipo de limitação, que pretendem continuar a viver nas suas próprias casas.

Esta dissertação tem como objectivo contribuir para dar uma resposta a esta necessidade, mediante o desenvolvimento de um ecossistema de produtos e serviços para *Ambient Assisted Living*, associado a um modelo de negócio, e procurando explorar várias possibilidades de criação de redes colaborativas na procura de soluções eficientes e acessíveis a todos.

Palavras-chave: Tecnologias de Informação e Comunicação, *Ambient Assisted Living*, prestação de serviços, Redes Colaborativas.

Abstract

The society that we live in faces today big demographic changes. Nowadays, people live longer, and it is expected that this trend will proceed. In 2000, there were already 420 million people with more than 65 years old, which correspond to about 7% of the world population. In 2050, it is expected that this number reaches 1500 million which corresponds to about 16% of the world population. Naturally, in these circumstances, the number of disabled people will increase as well.

This context brings new challenges to the traditional health care systems in Portugal and in the rest of the world. There is an urgent need to search for new solutions that will allow people to live in the best possible way, in the latest stages of life. In order to fulfill this need, it is necessary to develop systems that allow to extend their life in their favorite environment, improving their safety, autonomy, mobility and welfare.

Nowadays, information and communication technologies (ICT) offer new opportunities to provide care and assistance. Ambient Assisted Living (AAL), is such a paradigm, in which technology is used as a way to improve the independence and welfare of aged or disabled people at their homes.

This dissertation has the purpose of contributing to providing an answer to this necessity, associated to a development of an ecosystem for Ambient Assisted

Living, associated to a business model and the search for the possibility of collaborative networks creation, in order to look for efficient and accessible solutions for AAL services provision.

Keywords: Information and Communication Technologies (ICT), Ambient Assisted Living, services providing, collaborative networks.

Acronyms

AAL *Ambient Assisted Living*

AAL4ALL *Ambient Assisted Living for All*

BRAID Project *Bridging Research in Ageing and ICT Development Project*

CAS *Care and Assistance Service*

EU *European Union*

FR *Functional Requirements*

FR_e *Functional Requirement for the AAL ecosystem management*

FR_p *Functional Requirement for AAL provider's management*

FR_s *Functional Requirements of AAL services management*

FR_u *Functional Requirements for the AAL user's management*

HL *Health and Care in Life*

IaaS *Infrastructure as a service*

ICT *Information and Communication Technologies*

IL *Independent Living*

MCU *Microcontroller Unit*

OL *Occupation in Life*

PaaS *Platform as a Service*

PDA *Personal Digital Assistant*

R&D *Research and Development*

REST *Representational State Transfer*

RL *Recreation in Life*

RTD *Research and technological development*

SaaS *Software as a Service*

SP *Service Provider*

THM *Tele Health Manager*

UI *User Interface*

U.S. *United States*

WCF *Windows Communication Foundation*

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1 Introduction

The current severe demographic changes faced by most developed countries, lead to a rapid increase of the percentage of aged population and raise tough challenges to our society in terms of supporting them at the latest stages of their life. There is an urgent need to find effective and affordable solutions to provide care and assistance to elderly.

Ambient Assisted Living (AAL) aims at applying technology to help people with specific needs prolong their living in their preferred environments, mostly at home. It aims at constructing and providing safe and adapted environments for people with specific needs, allowing them to live more independently and healthy. The majority of the developments in AAL are focused on assisting elderly.

As mentioned in [1], although the significant research in the area of AAL, many of the resulting ideas and promising pilot cases fail to scale because the adopted approaches have been excessively techno-centric. Many R&D initiatives have been excessively techno-centric. However, a purely technology centered approach, without consideration of the socio-organizational aspects is likely to add only marginal value. In fact, many tools and technologies developed in this area failed to meet the expectations, namely because they were not accepted by users, or could not find a sustainable business approach for wider deployment. As such, the design of AAL infrastructures, services and products requires the consideration of organizational and cultural aspects. Information and communication technologies (ICT), and particularly high-speed broadband connectivity, cloud-computing and web-based technologies, offer new opportunities to provide care and assistance, as well as new ways of working, facilitate social interaction, and reduce limitations imposed by location and time.

During this dissertation, we aim at developing an Ambient Assisted Living ecosystem, which follows the conceptual architecture proposed in AAL4ALL project [2]. The proposed system helps a community of users and services providers to interact in order to better achieve assistance services provision.

1.1 Ambient Assisted Living

As mentioned in [3], ICT offer new opportunities to provide care and assistance. Ambient Assisted Living (AAL), is such a paradigm in which, technology is used as a way to improve the independence and welfare of aged or disabled people, at their homes. Most paradigms develop AAL architectures, which follow techno-centric approaches. The architecture presented and implemented during the AAL4ALL project considers such aspects related to the AAL business model and broader range of AAL services, from welfare to recreation and occupation in life [3]. As such, our work will be focused on the instantiation of the AAL architecture on a Cloud Computing infrastructure, composed of several types of entities, like the users and their homes. Figure 1-1 illustrates a home, which contains a number of sensors and actuators that are remotely operated by a care-center.

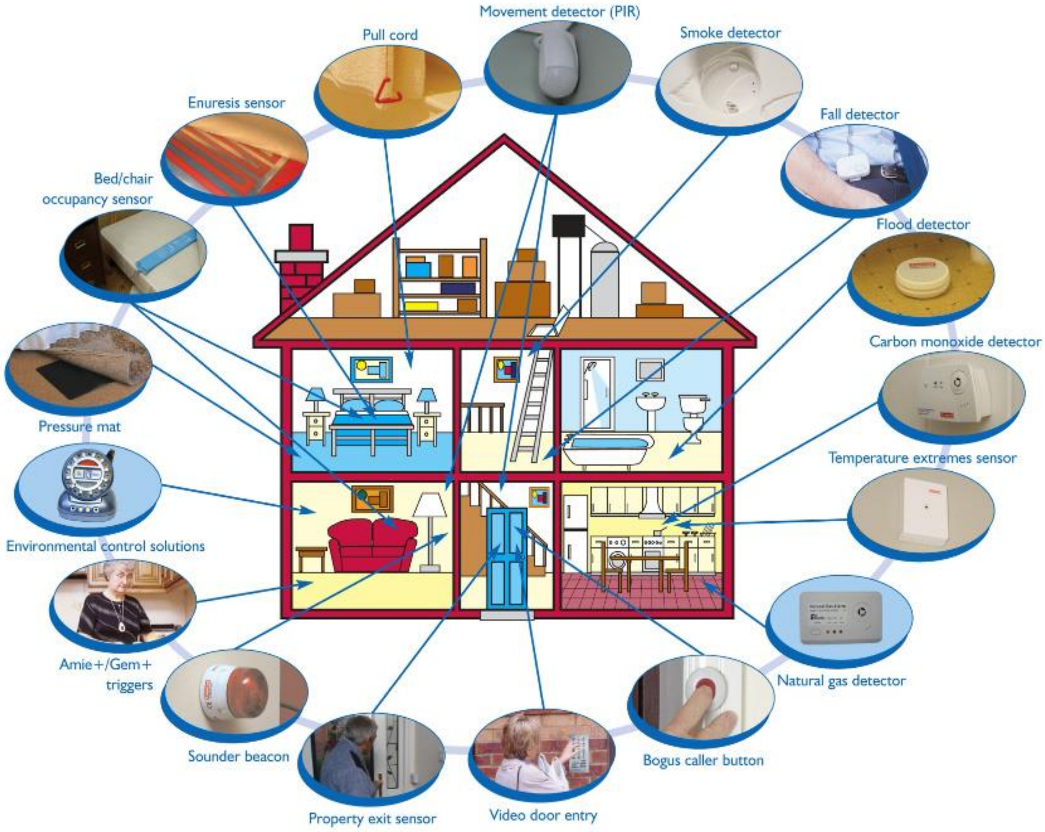


Figure 1-1 – A typical AAL home [4].

Typical services in AAL include Home environment services, like home safety and security, temperature monitoring, gas detection, smoke detection, intruder alert, fall detection. It includes Welfare monitoring, for people that is not ill, like heart rate monitoring, blood pressure, body temperature monitoring and agenda re-minding. It includes Health support for ill people, like behavior monitoring (for people with dementia), chronicle disease management, and so on. It also includes Occupation and Recreation services, which support the involvement of leisure services and the continuation of professional activities.

1.2 Why is it important

As mentioned before, there has been a severe demographic change, faced by most developed countries, which lead to a rapid increase of the percentage of aged population, as illustrated in **Figure 1-2**, which raises tough challenges to our society. This trend of having fewer youngsters, who hang to support growing elderly population, requiring increased assistance, leads security systems to the verge of economical rupture.

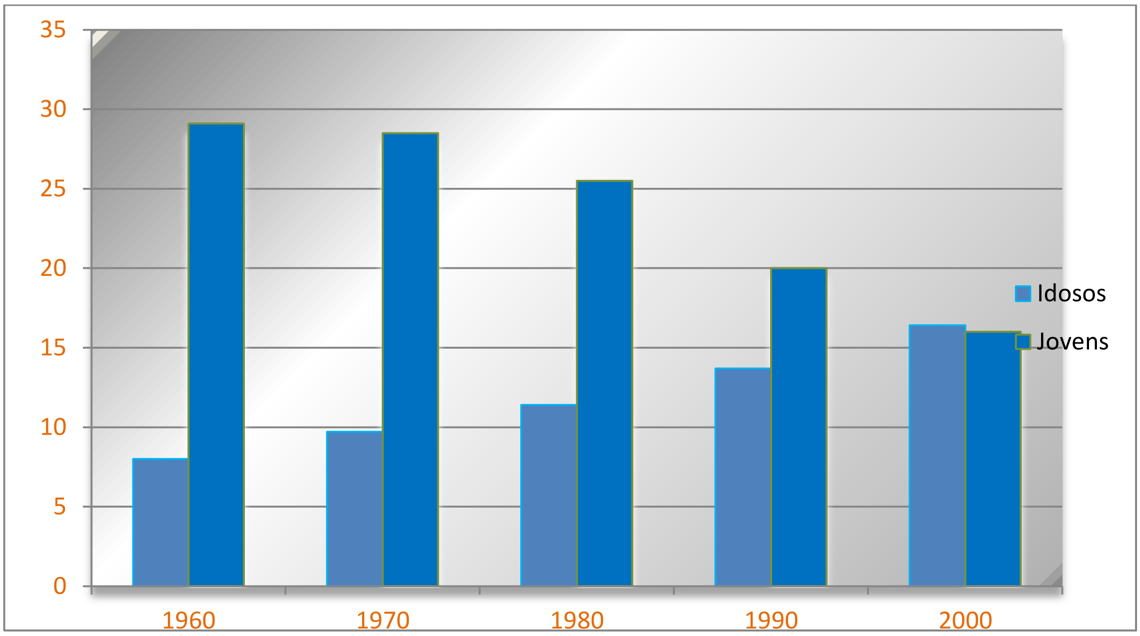


Figure 1-2 - Demographic changes of Portuguese population, considering elders to be with 65 years old (or more) and youngers to be under 15 years old [5].

As such, there is an urgent need to find effective and affordable solutions to provide care and assistance to elderly. In this regard, this work can also be seen as a contribution towards the effective development of solutions that may help to better deal with this demographic trend.

1.3 Followed approach and expected results

In order to adequately handle the mentioned issues, our approach is to instantiate the AAL4ALL architecture illustrated in **Figure 1-3**. We adopted the vision shared in AAL4ALL project of following a more socio-technological approach. As such, we are more focused on instantiating the top layer of the architecture, which is used to assist us in the specification and implementation of the AAL ecosystem that is proposed in this work.

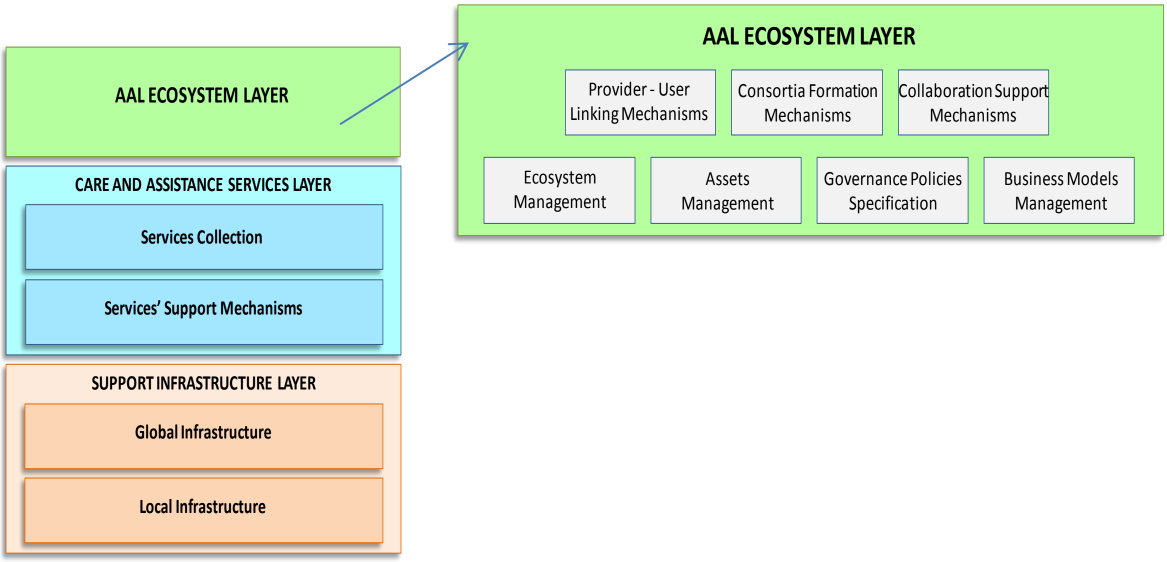


Figure 1-3 - AAL Conceptual Architecture [1].

This architecture is organized in several layers [1], namely:

- **Ecosystem** – at the highest level, the architecture should consider the organizational structure of the support services providing ecosystem to the elders. In this layer, it is important to consider the functionalities of a management system and the governance principles. According to the recent tendencies, such architecture should adopt a collaborative network philosophy, facilitating an effective cooperation between all the relevant stakeholders.

- **Areas of focus** – Given the large scope of the area and the complexity of the involved aspects, which are of a multi-disciplinary nature, it becomes convenient the focus in some complementary perspectives of analysis. AAL4ALL project, 4 different life settings in an elder's life were considered, namely: Independent Living, Health Living, Occupation in life, and Recreation in Life.

- **Services Infrastructure** – This layer has got functionalities, which should allow the services ecology creation that facilitate the fluid services composition/ integration to offer more holistic and adapted answers to the necessities of every elder.

As mentioned before, our focus in on the ecosystem layer of this architecture, the highest level of the conceptual architecture. Nevertheless, in order to broadly address the issues in such level, it is necessary to consider requirements and functionality of the other layers. As such, it is necessary to also develop some functionalities of the local and global infrastructure nodes of the AAL architecture's infrastructure layer. As such, the development of the AAL ecosystem will also include the development of some features from the global and local infrastructure layers

1.4 Structure of this document

We start this dissertation by firstly present an overview of the AAL concept and its most important aspects. At section 2, we present a literature review mostly concerned with introducing and analyzing current aspects about assistance services, users, AAL providers, sensors and actuators, and supporting infra-structure. Section 3 is devoted to establishing the requirements, specification development, verification and testing of the proposed AAL ecosystem. Finally, section 4 provides a synthesis of the work, achieved results and proposes the next steps for future work.

2 Literature Review

2.1 Ambient Assisted Living Overview

The area of AAL can be addressed by several perspectives, as it comprises technological or infra-structure, strategic, economic, social, moral and regulatory aspects. During our literature review, we emphasize some of the mentioned aspects, aiming to provide an adequately general overview of AAL. We start by the technological aspects.

2.1.1 Technological Aspects

Considering AAL, the immediate technological aspects we can think of are the sensors and actuators installed in users' homes, or the local nodes. These devices require an adequate infra-structure, usually of wireless type, for the adequate communication and interaction. It is on top of these devices that AAL services operate in the local nodes of user's homes.

Sensors and Actuators

As illustrated in Figure 2-1, there are many types of sensors, namely: environmental, personal and mobility

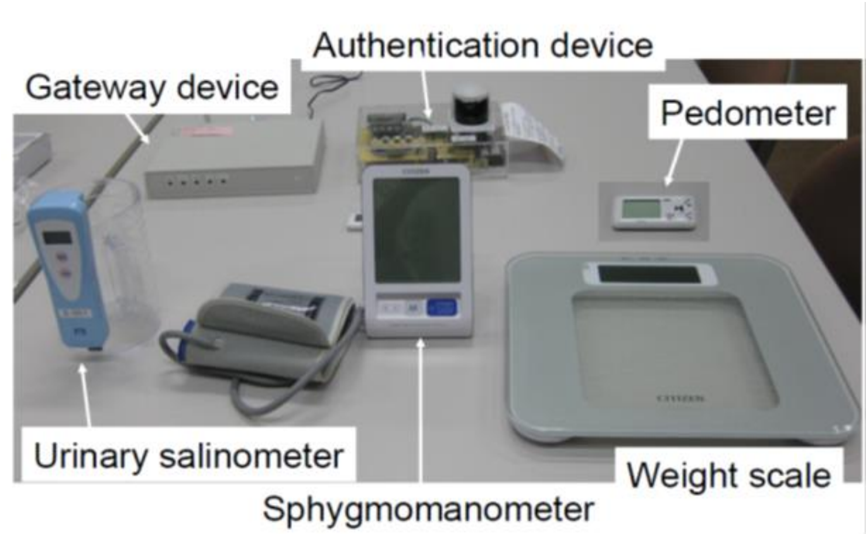


Figure 2-1 – Example of an AAL sensor [10].

These sensors can be usually classified as personal sensors, which are used to monitor and protect from internal threats and ensure that users' homes are in safe conditions, regarding aspects such as temperature, smokes, floods, or gas leakages. There are Home security sensors, which protect from external threats, such as sensors for monitoring intrusion, detection of presence, or doors/ windows open. Home Safety sensors hold a large number of sensor sub-classes, each one devoted to each aspect of users' wellness, like monitoring home temperature, smoke detection, gas leakage, and carbon monoxide. These varieties can be organized in taxonomies, as illustrated in **Figure 2-2**.

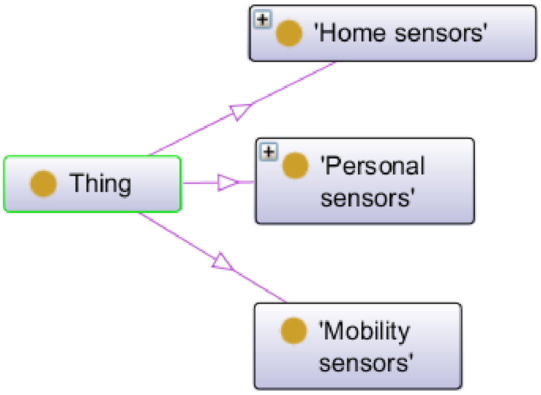


Figure 2-2 – Sensor taxonomy illustrating several types of AAL sensors [10].

Each sensor category can be spit in more sub-categories, as more sensor types appear, as illustrated in **Figure 2-3**.

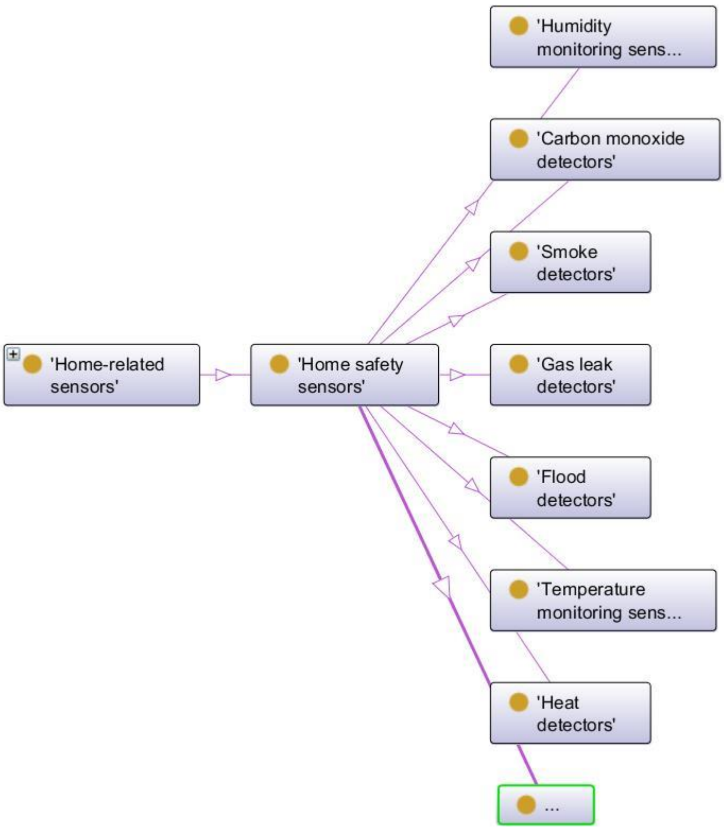


Figure 2-3 – Sensor taxonomy illustrating several types of AAL sensors [11].

Such great variety of type and technologies in sensors raises concerns related to integration and interoperability. This is because of the electronic devices available on the market do not provide standardized interfaces for integration. In a further section, we mention a number of research projects, which deal with integration and interoperability in AAL.

ICT infrastructures

There are a great variety of ICT infrastructures and manufactures. A typical system has got hardware and software components, involving data, processes and people. Information flow includes observations from sensors, user profiles, services providers interactions and treatments. Given that in an environment of variable number of user, preferably growing, we adopt an adequate infrastructure paradigm, which provides better scalability as described in chapter 3.

An AAL infrastructure also requires such ICT components. An example of an AAL architecture is illustrated in Figure 2-4.

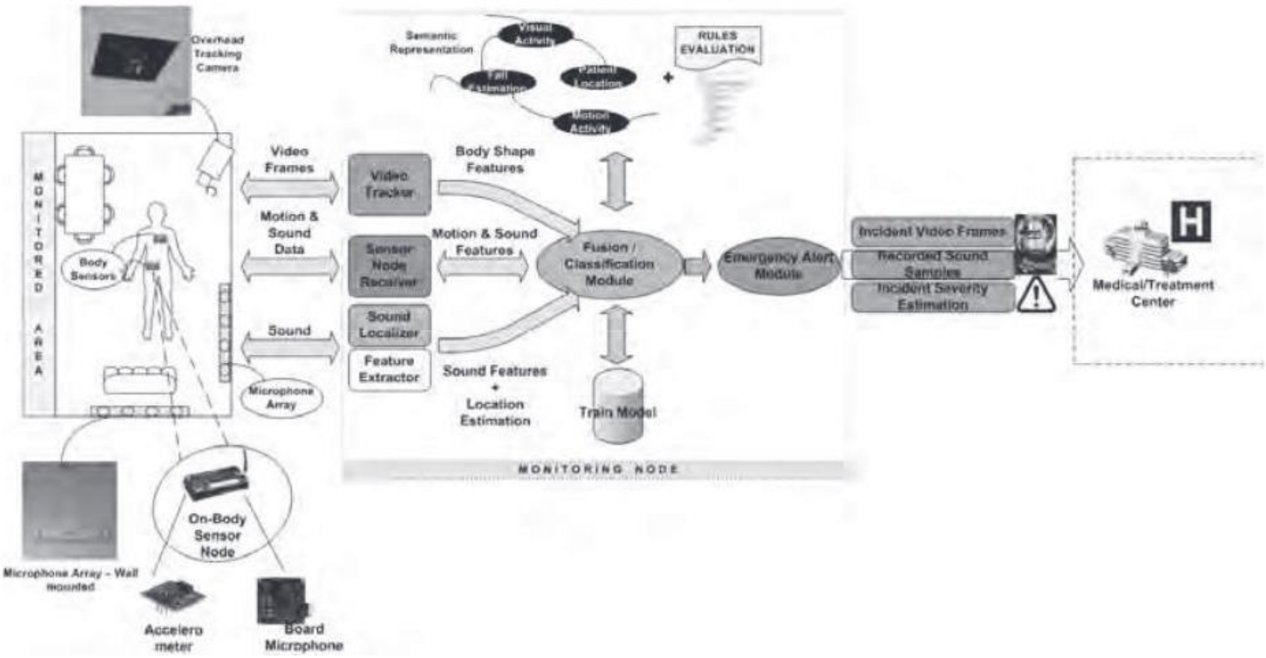


Figure 2-4 – System architecture and data interaction between the movement capturing tools and monitoring node [6].

Additionally, a typical AAL environment includes heterogeneous components of distinct technology, which need to interoperate. A useful approach for such interaction between these components is to rely on a service-oriented approach, such as the Enterprise Service Bus, as illustrated in Figure 2-5, in which elements of heterogeneous nature are able to interact using a standardized protocol.

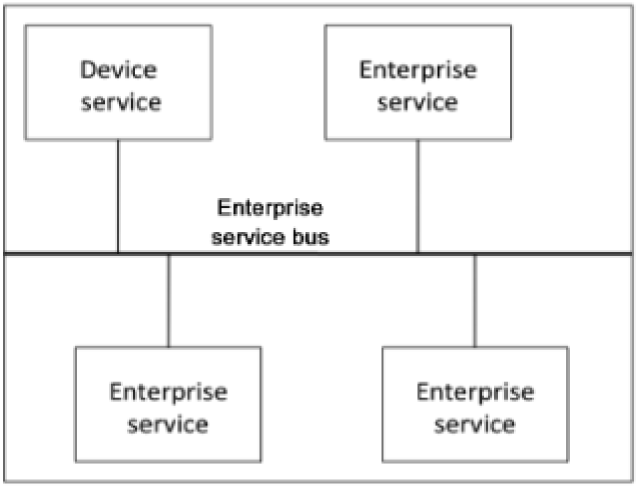


Figure 2-5 – The Enterprise Serial Bus concept [7].

2.1.2 Ambient Assisted Living Services

As mentioned in [1], past research and developments in elderly care services, as well as current market offers, are characterized by some fragmentation. The focus has been predominately put on the development of isolated services - e.g. monitoring of some health related parameters, fall detection, agenda reminder, alarm button, etc. - each one typically provided by a single organization, and often showing an excessive techno-centric flavor [44].

In [1], it is proposed the concept of Care and Assistance Service (CAS), which refers to a category of services, either of a medical or social nature, aiming at helping senior citizens in their daily lives, compensating for the reduction of physical and/ or mental capabilities that comes with the ageing process. Particularly in the context of ambient assisted living, ICT-based technological support is explored in service delivery.

AAL services intend to enable people with specific needs to live an independent and save life. To this end, the services have to cope with a number of *user and environmental challenges*, known from literature as researched in [8]:

- *Low, declining capabilities.* Some of the capabilities of the assisted persons are rather low and thus raise the demand for external assistance. Furthermore the capabilities of the users decline over time.
- *Differing needs of the users.* The capabilities, goals, and habits of the individuals differ substantially, at first between the individuals and at second over time. There is no single solution to fit all situations.
- *Limited resources.* The available human assistance and financial resources are limited these days and will become scarce within the next years.
- *Low acceptance of technical problems.* The assisted persons show only little acceptance of AAL services [9], if they encounter problems with them.
- *Involvement in active life.* Despite of demand for external assistance, the assisted persons want to be involved in active life as long as possible.
- *Keep control.* Although the demand for living assistance increases over time, the assisted persons want to keep the control over the assistance services.
- *Avoid stigmatization.* The stigmatization of the assisted persons through visible assistance devices should be avoided if possible in order raising the acceptance of the AAL services.
- *Keep privacy.* Information about the current and past situation of the assisted person should only be provided to persons and institutions that are actually involved in providing the assistance services.

The execution of a care and assistance service may involve a number of software services and human intervention (manual tasks). The actual structure of such service also depends on the interaction between the provider and the end-user, and may ultimately (and dynamically) vary according to the flow of that interaction.

Similarly to sensors, AAL services exist in multiple categories. In AAL4ALL, four categories of services, named as life-setting, were considered, as identified in Figure 2-6.

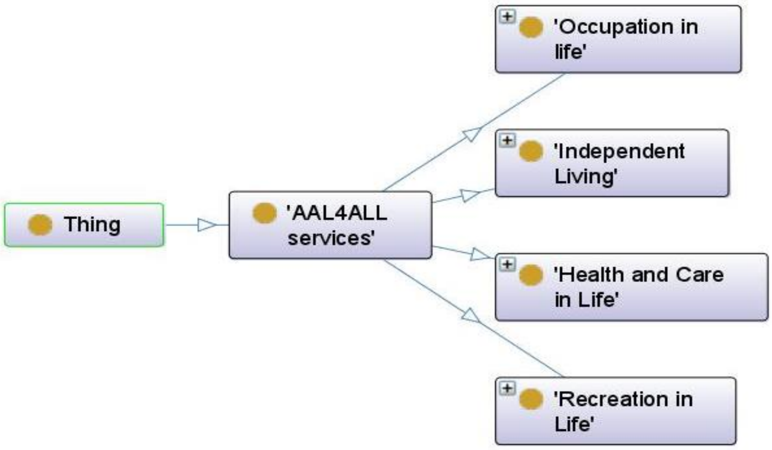


Figure 2-6 – AAL services grouped in four life settings [11].

Figure 2-7 illustrates the services which fall in the "home safety and security services category, proposed in the AAL4ALL project.

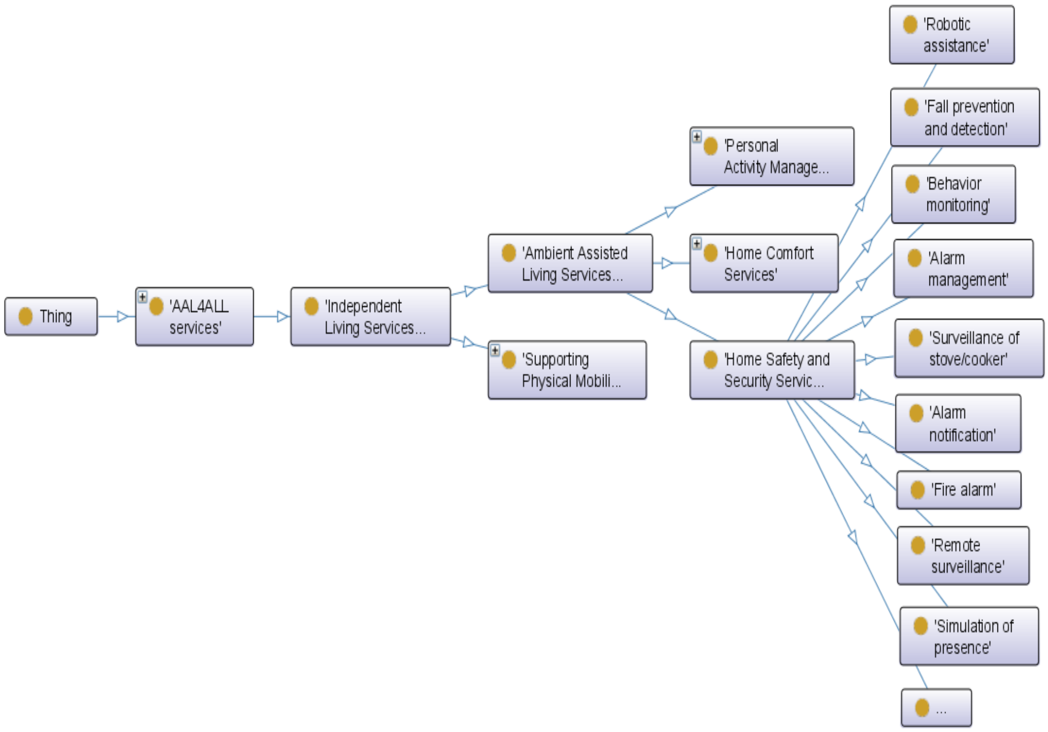


Figure 2-7 – Home safety and Security Services [11].

2.1.3 AAL Providers

Providing AAL services involves the participation of several types of stakeholders, ranging from health care providers, to day care centers, to hospitals and fire departments. The ICT providers, who are responsible for the supply of the necessary technological infrastructures for the AAL services providing, are also included in this group.

In the AAL context, given the heterogeneity of these stakeholders, a single and isolated provider isn't enough to satisfy every concrete need of AAL users. As described in Chapter 3 of this document, the proposed approach is to develop an AAL ecosystem, which allows providers to collaborate and establish partnerships. In such way, they can together be able to provide the adequate services to each user.

Several kinds of service providers can be considered, namely: care centers, security and safety entities, including AAL live ICT providers.

2.2 Existing AAL Systems

2.2.1 International research projects

According to the study in [12], there has been an increase of investment in research and development projects in companies, related to communication and information technologies, on the AAL thematic. For these investments, the EU itself offer several funding programs to encourage business entities, research and development organizations, universities and other kind of partners to form consortiums on projects with a well-defined value chain. This study also reflects the trends and priorities of European policy on the AAL issue.

As mentioned in [13], a considerable number of research projects are focused on the detection of activities and welfare of the elderly based on the use of sensor fusion. The most common architecture is based on a set of sensors, more or less extended, dispersed throughout the housing and allowing the control of a number of activities (for example, opening and closing of doors, stove utilization or the use of refrigerator water consumption / gas / electricity, etc.). By merging all the information gathered by different sensors, it is possible to determine the current activity of the person who is being controlled and identify deviations from their daily routines. These deviations can be used to detect emergency situations or changes in the condition of the person.

Internationally there are several projects that address this issue of AAL. In the table that follows are reported examples of these projects, as detailed in Table 2-1.

Table 2-1 – International AAL projects [13].

Project name	Description
ITALH **[14]**	Intends to develop systems and devices that enable individuals with special needs to live at their own homes longer, with greater security and confidence, using ICT to enable effective use of human and financial available resources. The project explores how to integrate different technologies - motes, zigbee, bluetooth, mobile devices – on a suitable system in order to provide AAL services.
UbiSense **[15**]	Development of a system that is able to monitor the elder's movement and activities in their homes and, through a pattern of daily activities, detect significant changes in their behavior that indicate emergency situations.
PlaceLab **[16**]	Development of a home that can be used as a test for research and scientific studies on the interaction patterns of people with new technologies and the environment that they can provide.
i2Home **[17**]	The i2Home is based on industry standards and existing development. Focuses on household devices (including consumer electronics) for people with cognitive difficulties and older people. Simultaneously, i2Home takes into account that the access strategies, developed and standardized, will apply to areas outside of the home.
OASIS **[18**]	Integrated project with the aim to revolutionize services for the activities of the day-to-day life of the elderly, particularly in terms of interoperability, quality and usability
ROSETTA **[19**]	The ROSETTA project is an ICT platform that aims to improve and increase the autonomy of people suffering from chronic progressive diseases such as Alzheimer's and Parkinson's, both with a strong focus on the elderly. This platform focuses on three areas: non-intrusive monitoring of the environment and the condition of the assisted people, daily activity and behavior analysis and support of the assisted person; support to health care providers by promoting a system that offers them a guide information and additional value.

AWARE [20]	The goal of the AWARE project is the development of a social network integrated into a telematics platform to promote innovative services for both older workers and for retired persons, with the intention of contributing to social inclusion, to which European policies direct for an increasingly aging society and to promote business management needs in aging workforce.
Dreaming [21]	The DREAMING project brings a set of services that, together, allow the extension of the independent life of older people providing them at the same time a level of security in a protected environment as the home of an elderly, offering them a way of being so in contact with their loved ones. Additionally, the services of DREAMING facilitate management of chronic conditions in a home environment reducing the need to use the resources spent in hospitals for a minimum.

2.2.2 Products and Services

As mentioned in [22], at the same time of the research, the introduction of some products, devices and services to start AAL are also emerging. Companies like Philips [23] and GE Healthcare [24] currently have some AAL solutions, targeting mainly the senior population. In addition, GE Healthcare with its product QuiteCare [24] shows to types of solutions: QuiteCare communities for seniors and QuiteCare for seniors and families. For the first solution, the product includes sensors for detecting falls, as well as monitoring the physiological parameters, providing knowledge of less normal situations for the patient. This tool allows the healthcare provider a more quickly and effectively assistance to the patient. The QuiteCare for seniors and families integrates miniaturized wireless sensors and cameras, which are strategically located in buildings. With this type of sensors, the system collects information about the activity of the patient, sending notifications/alerts during physiological activities that do not conform to the situation of the patient. In addition to these products, and in the same line with the detection of falls and ways to assist users in such situations, other companies also begin to introduce some more simple AAL solutions on the market, with a lower cost and also using wearable, wireless and miniaturized sensors [25] [26].

However, the market is very fragmented, so there are still not fully consolidated AAL solutions that meet the needs of all countries worldwide. But, at the international level, it is expected that the products in the AAL area will decrease about 50% of the costs associated with health care services for senior people, envisaging, for example, that the U.S. market of AAL is in 20 million euros per year with a rising trend [13].

On the Table 2-2, there are presented some solutions that can help to realize what exists and what can be implemented as a solution of AAL.

Table 2-2 – International progress on the AAL systems [13].

Name	**Description**
Equivital [27]	It is an integrated monitoring system that has a set of sensors in a wireless module that can be "dressed". The system provides, in a first analysis, the cardio-respiratory state, and also information on the temperature and the activity of the individual. The signals are sent to a PDA, PC or other device to be processed. This product is not yet commercial.
Sensium [28]	It is a platform developed to allow continuous monitoring of the human body based on using non-intrusive wireless sensors, which allow monitoring various body parameters via a PDA, a PC or a mobile phone.
Hallo Monitoring [29].	This system enables the automatic sending of an alarm in case the individual fell down, without requiring any intervention.
Grand Care [30]	Monitoring system of activity daily. Making use of various technologies, it is possible to create a system like "Grand Care", which allows a state of permanent monitoring of an individual's welfare in a non-intrusive way.
HomMed [31]	Platform for remote monitoring of the health status of a patient. The tele-monitoring unit is placed in the user's home, collecting and transmitting data on the state of health of the user to a service center that processes and presents this information to health

	care providers.

2.2.3 International Roadmaps

Considering the international context of AAL, it is important to mention some of the roadmap projects that addressed this issue, including projects like SENIOR, AALIANCE, EPAL, and CAPSIL BRAID.

Table 2-3 – International Roadmaps [13]

Project name	**Description**
AALIANCE [32]	The focus of the AALIANCE project is on creating innovative devices and sensors for AAL based on advanced ICT technologies in the areas of ageing at work, ageing at home and ageing in society.
ePAL [33]	The aim of the ePAL project is to consider and define new ways to promote a balanced and active life for retired people or in the process of retirement in Europe. The EPAL developed a roadmap - a set of actions - that will help to promote the Europe to the forefront of active ageing and direct to the realization of a more positive future for the elderly population.
CAPSIL [34]	The CAPSIL project has three main objectives: • Develop a roadmap • Promote knowledge dissemination • Use the roadmap to help policymakers in Europe, U.S. and Japan to coordinate research agendas and funding efforts in the area of telecare.
SENIOR [35]	The SENIOR project aims to promote a systematic assessment of the social, ethical and privacy that are involved in aging and ICT; understanding what lessons should be learned from the current technology and trend and, planning strategic governance for the future trends in this area

BRAID [37]	The BRAID project aims to develop a roadmap for Research and Technological Development (RTD) for active ageing by consolidating existing roadmaps and by describing and launching stakeholder coordination and consultation mechanisms.

2.2.4 Critics on the existing approaches

As we noticed during this chapter, many of the AAL initiatives are characterized by being too techno-centric, without properly addressing social and strategic aspects. On the other hand, AAL services are too fragmented and provided by different service providers. However, no single AAL provider can adequately fulfill the elderly needs. These providers are also characterized by a deep heterogeneity. Given these factors, and as already mentioned, the best strategy for the provision of AAL is to follow more collaborative approaches.

2.3 Collaborative networks

A trend identified in recent [3], shows the need to move from a scenario characterized by fragmented services, typically provided by single service providers, and often showing an excessive techno-centric flavor, to more integrated care services. These integrated services are likely to be provided by multiple stakeholders, through well-elaborated collaboration mechanisms. Furthermore, the importance of the role of communities and other forms of collaborative networks involving all stakeholders, operating as an ecosystem, is being recognized, as illustrated in Figure 2-8

Figure 2-8 – Identified trend – rational for an ecosystem [1].

This trend was confirmed by the BRAID road mapping project [36]. This European initiative went through an extensive consultation of stakeholders in the AAL area towards identifying the most relevant research actions in this sector for the next decade. When asked to prioritize the identified actions, participants privileged actions such as:

- Establish collaborative environments for independent living
- Establish healthcare ecosystems
- Build collaboration platforms and systems for occupation in life
- Build participatory communities for recreation in life
- Etc.

This confirms the mentioned trend towards integrated services provided through collaborative ecosystems.

In conclusion, there is now a perception that is fundamental, for the success of future AAL support systems, to seek synergies between the areas of ICT and Ageing and Collaborative Networks (Figure 2-9).

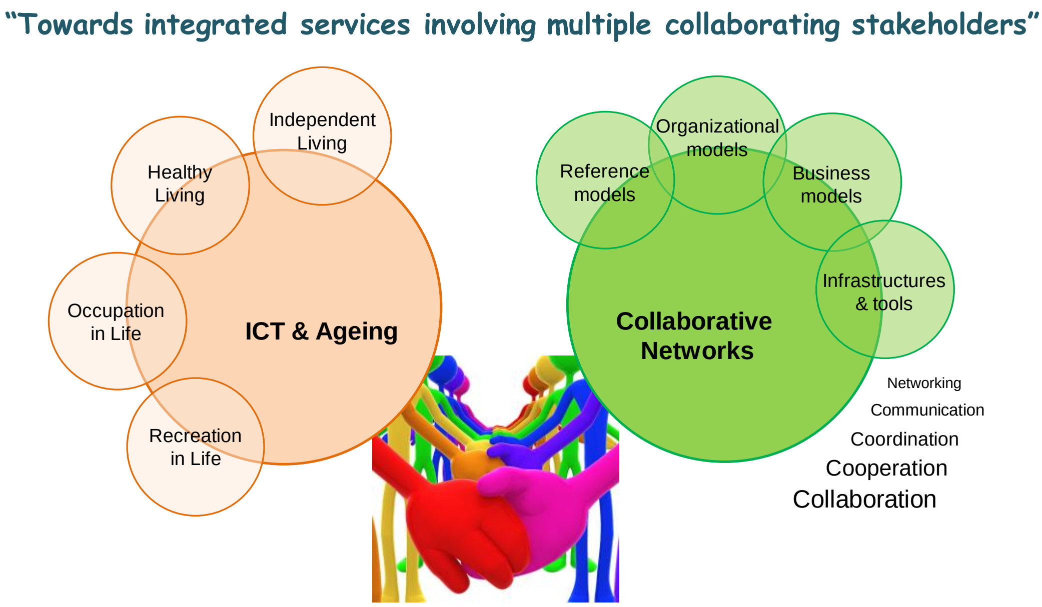


Figure 2-9 – Creating synergies – towards AAL collaborative ecosystems [3]

An AAL ecosystem can in fact involve, in addition to the senior citizens, a combination of formal care and informal care networks, as illustrated in Figure 2-10

Figure 2-10 – Example of an AAL ecosystem [3].

3 Ecosystem Development

Considering the several aspects revised in previous chapters, we describe in this chapter the specification and development of the AAL ecosystem support platform.

As suggested from the international trends, described on the BRAID project [36], the approach is based on the collaborative strategies. The specified and developed models are of canonical nature. This option allows us to model within adequate complexity level, and implementing, through simulation, the various ecosystem components, in order to test and validate its functionality.

3.1 The conceptual architecture

As mentioned before, we aim at instantiating the AAL4ALL architecture, described in [1]. The development starts by identifying the functional requirements of the AAL ecosystem layer that is part of this architecture. As illustrated in Figure 3-1, the architecture is composed of several layers, namely: the Support Infrastructure Layer, the Care and Assistance Services Layer and the mentioned AAL Ecosystem layer, being this one the focus of our work.

Each layer is focused on specific aspects of the intended ambient assisted living environment, and a logical hierarchical structure is established among these layers.

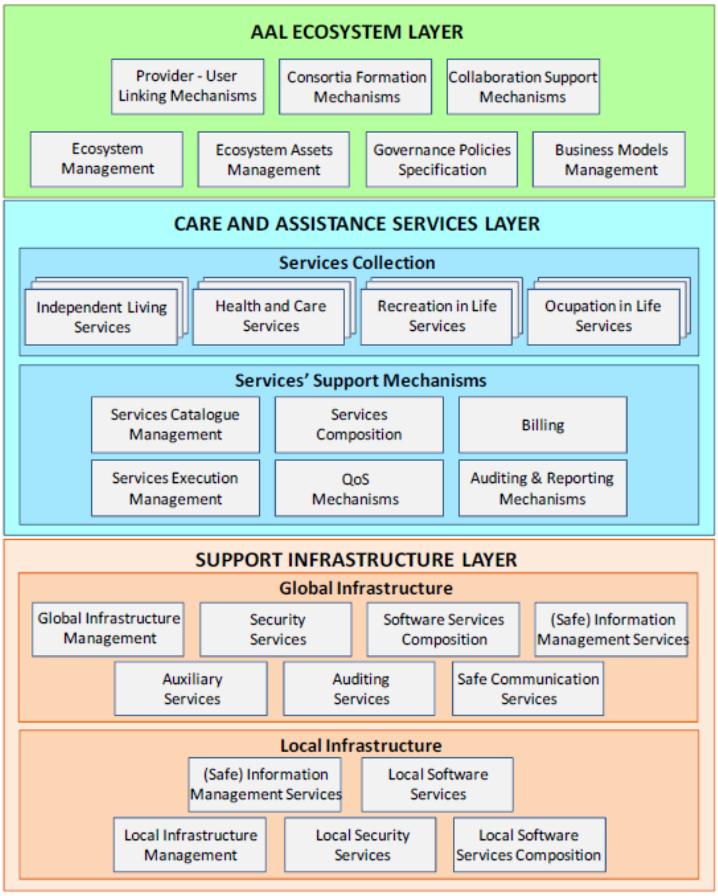


Figure 3-1 – AAL4ALL conceptual architecture [1].

As mentioned in Chapter 2, the **Support Infrastructure layer** plays the role of a facilitator (provides support) for the development and delivery of care and assistance services. Such infrastructure should provide, among other functionalities, channels and mechanisms for safe communications and information sharing and exchange among the members of a given AAL ecosystem. It has two sub-layers, the local infrastructure (Figure 3-2), corresponding to the support infrastructure located in a specific "location", e.g. users' home, care center, health care center, human-centered environment (intelligent cloth, mobile gadgets, etc.); and the global infrastructure (Figure 3-3), supporting the network of "spaces" (or local environments) "inhabited" by the various stakeholders.

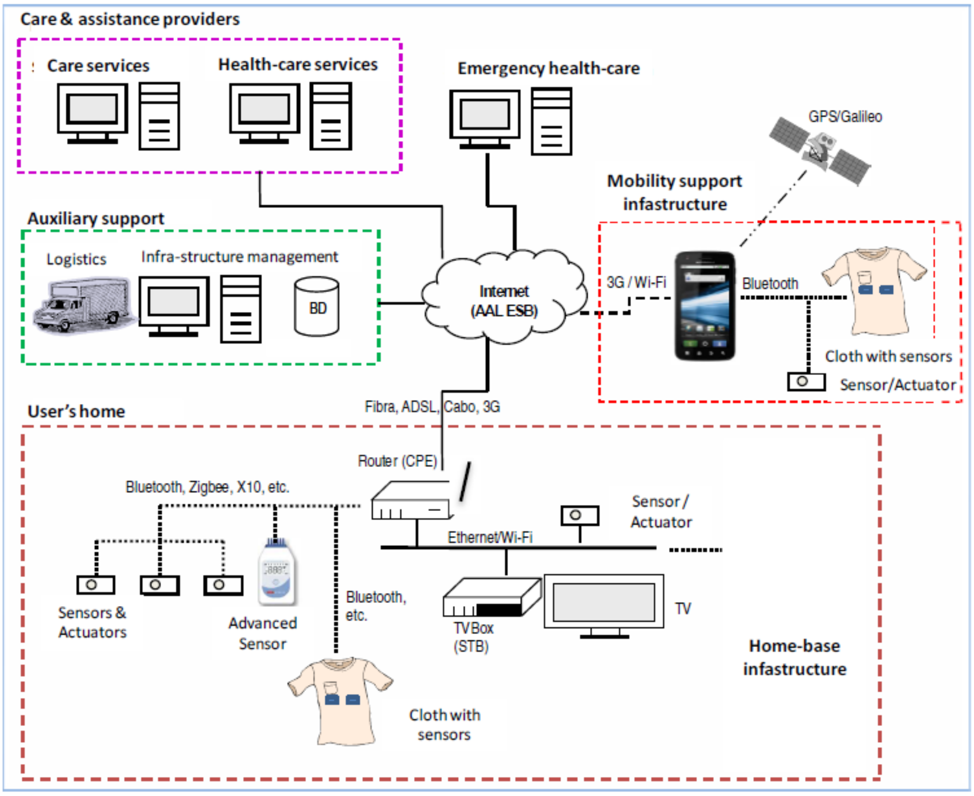


Figure 3-2 – Example of a local infrastructure.

The global infrastructure illustrated in Figure 3-3, supports the interaction between the entities/ nodes engaged in care provision and the assisted people. It supports multi-node services, distributed processes, software services invocation and composition.

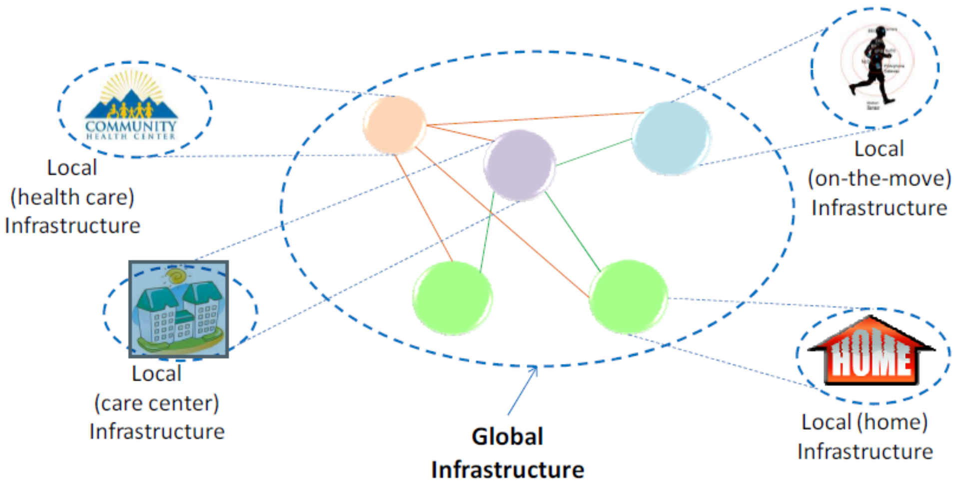


Figure 3-3 – Representation of a global infrastructure composed by several local infrastructures [1].

The intermediate layer - **Care and Assistance Services** - provides functionalities for managing and making available an open collection of services (care and assistance services). This layer of the architecture considers an open and scalable collection of services, allowing for easy plug ability of future developments. As mentioned in previous chapter, to facilitate the organization and management of the collection, services are divided into four groups according to the four life settings of Independent Living (IL), Health and Care in Life (HL), Occupation in Life (OL), and Recreation in Life (RL).

The top layer of the architecture - **AAL Ecosystem** - provides organization, governance, and collaboration support for the AAL multi-stakeholders from a socio-technical perspective.

As mentioned before, our work is focused in the ecosystem layer. Some of the functionality we aim to develop is the assistance services management, service provider's management, and user's management. We start by developing basic use cases for these components, such as:

- Definition and management of AAL services;
- Management of AAL service providers;
- Management of AAL users;
- Contracts and service subscription management;
- Definition of tailored packages of assistance services;
- Partnership formation between providers for delivering tailored packages of assistance services (customized sets of services for fulfilling specific user's needs);
- Service subscription life cycle (e.g.: monthly billing, home interventions, etc.).

The physical architecture that supports our AAL ecosystem is based on the Cloud Computing paradigm, as later illustrated during this chapter, in order to benefit from the advantages of such technology.

Work plan for ecosystem development

Our work is composed of the following phases:

1. Identification of the Functional requirements of the ecosystem level for proposed architecture;
2. Characterization of the local infra-structure nodes;
3. Characterization of the global-infrastructure nodes;
4. Characterization of the AAL Ecosystem platform;
5. Development of both local infra-structure and global-infrastructure nodes;
6. Development of ecosystem platform in a Cloud Computing platform, using windows Azure for the ecosystem components. This comprises the implementation of the data model, architecture components, and adequate user interfaces;
7. Testing, verification and results analysis.

3.2 Requirements identification

Accordingly to what was mentioned before, our approach to the AAL ecosystem development is based on the specification of canonic models. This type of models allows the specification of a system with considerable complexity using simple, yet useful structures. This allows developing the system with in a more limited time frame, but without undermining the fulfillment functional requirements.

3.2.1 AAL Services

Pursuing an approach based on canonical models, an AAL service can be seen as a set of actions designed to provide care to a user. A service can be identified by a name and a pre-established functionality. A service can be also composed for other services in a hierarchical composition structure, as shown in Figure 3-4.

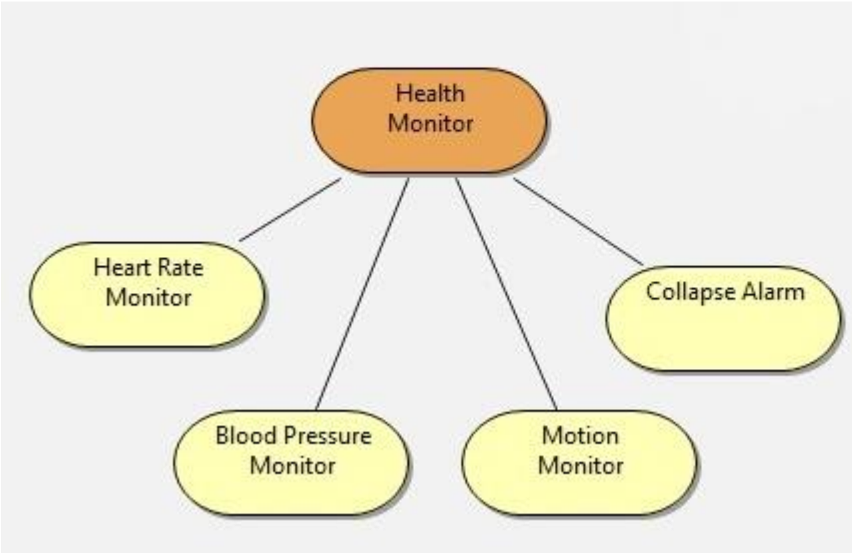


Figure 3-4 – Hierarchical services definition

This complies with the notion of service established in the previous chapters and illustrated in Figure 3-5.

The combination of services results in "tailored / customized packages", as a way to meet particular needs of specific users.

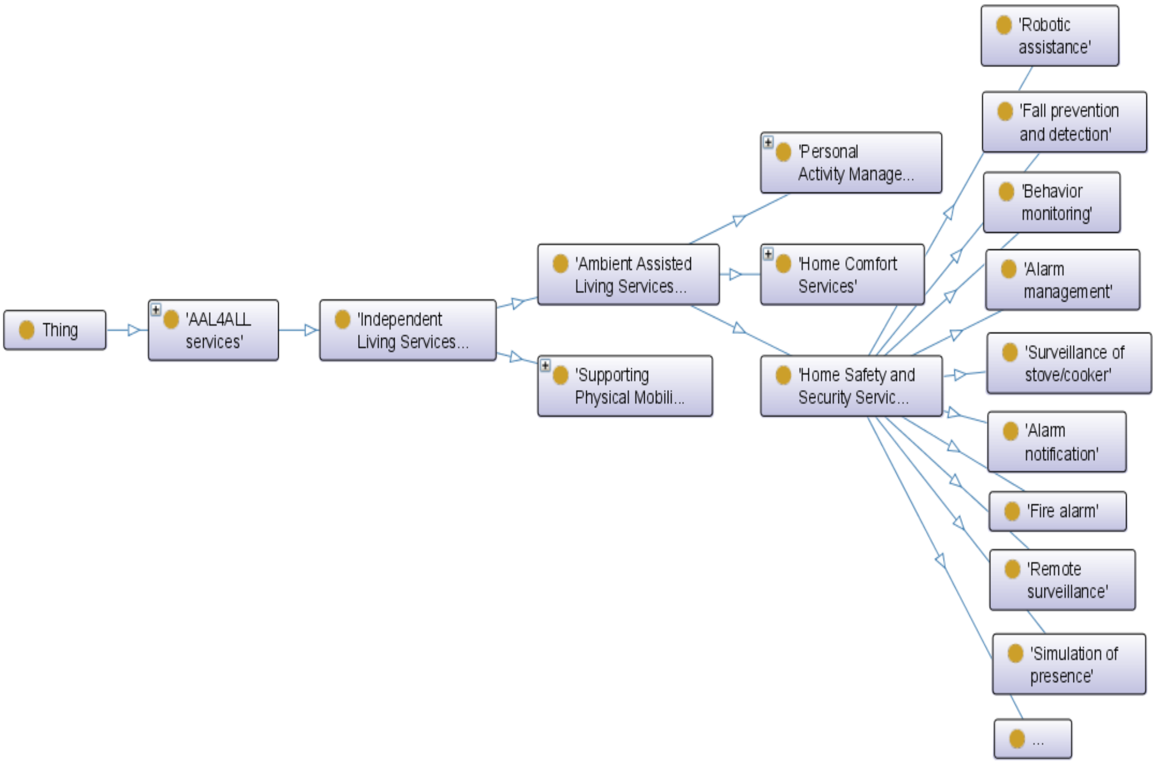


Figure 3-5 – AAL4ALL services definition

The functional requirements for the management of the AAL services are described in the Table 3-1.

Table 3-1 – Functional requirements of AAL services management.

FR	Description
FR_s1	Creation of services, which can be adequately characterized by ID, name and type.
FR_s2	Search, update and deletion of existing services
FR_s3	Creation of services as a composition of other services
FR_s4	Contract of a service by a user
FR_s5	Association of a running service to a user or users' home

3.2.2 AAL users

In canonical terms, a user can be characterized by a name, an address and a set of pre-established AAL characteristics (e.g. in an ontology). The functional requirements for the management of users are listed in the Table 3-2.

Table 3-2 – Functional requirements for the AAL users management

FR	Description
FR_u1	Creation of new users, which can be adequately characterized by ID, name and a set of pre-established attributes for its AAL characterization
FR_u2	Search, update and deletion of existing users
FR_u3	Service contracts establishment with users
FR_u4	Track of AAL relevant events from a users' services
FR_u5	Billing of contracted services

3.2.3 AAL providers

Providers can be characterized by its name, location, and type. (Infrastructures providers, and AAL service deliver, care centers, surveillance and security providers, etc.). The functional requirements of provider's management are identified in Table 3-3.

Table 3-3 – Functional requirements for AAL providers management.

FR	Description
FR_p1	Creation of new providers, which can be adequately characterized by ID, name and a set of pre-established attributes for its AAL characterization.
FR_p2	Search, update and deletion of existing users
FR_p3	Creation of providers as composition of other providers
FR_p4	Association of providers and the services they deliver
FR_p5	Participation of providers in services contracts with users

3.2.4 AAL ecosystem

Some users may require distinct type of services, which comes from particular care needs, which leads to the consideration of customized care provision. As mentioned before, no single provider can fulfill the needs of users, if operating alone. When such situations of customized care arise, partners can organize themselves in partnerships, aiming at creation of composed services. In Figure 3-6, it's represented one composed service (in dark blue), that is composed by other four services (or groups of services) in lighter blue. It is also showed the different Service Providers (Sp) that are responsible for providing them.

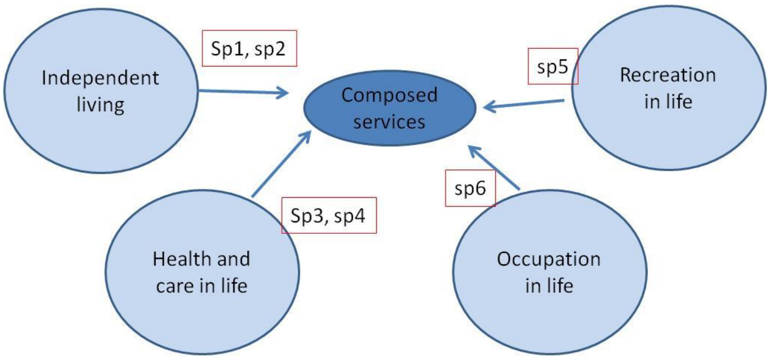


Figure 3-6 - Creation of composed services from providers of distinct types.

Inside a partnership that is composed of providers of distinct type, it is now possible to create such customized services, or service packages, as illustrated in Figure 3-7.

AAL Package 1

- Home security
- personal activity management
- nutritional advisor
- Physical rehabilitation

Figure 3-7 – Customized package of AAL services.

We can assume that a partnership is also a service provide, meaning that a provider may be a single entity or composed by several entities. Some entities belonging to a partnership may already be partnerships. This leads to a hierarchical or recursive definition of service provider, as illustrated in Figure 3-8.

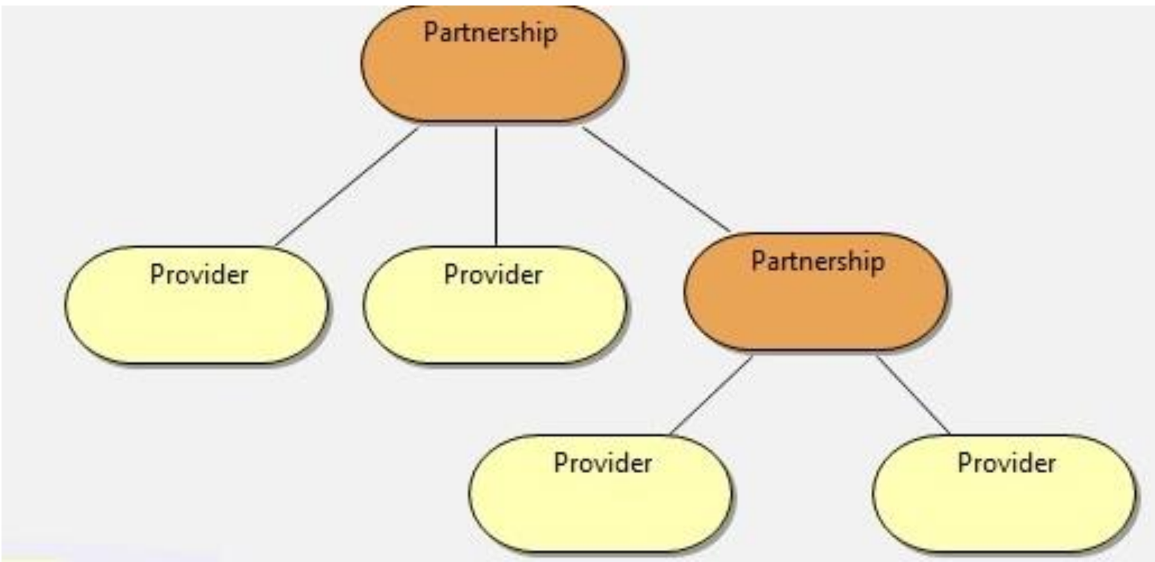


Figure 3-8 – Simple and composed providers.

The AAL ecosystem, illustrated in Figure 3-9, is composed of several service providers, each one delivering their own services. As mentioned before, an ecosystem is a virtual space in which members (service providers) agree to create partnerships as soon good opportunities arise. It facilitates fast, dynamic and on-the-fly partnership formation. As members of the ecosystem, partners remain prepared to engage in partnerships [37].

When a market opportunity for a new customized service appears, they engage in fast partnership creation. The partnership remains while package is being delivered.

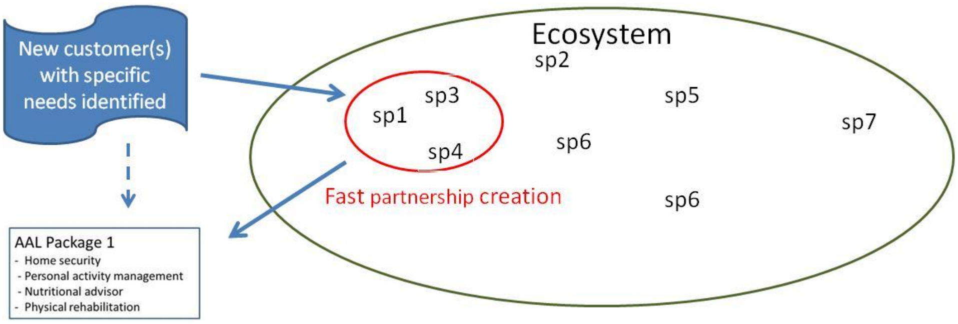


Figure 3-9 – Illustration of an AAL ecosystem.

Considering these aspects, the requirements for the AAL ecosystem are described in Table 3-4.

Table 3-4 – Functional requirements of the AAL ecosystem management.

FR	Description
FR_e1	Registering of users/elders.
FR_e2	Registering of providers.
FR_e3	Partnerships creation
FR_e4	Partnership life-cycle management
FR_e5	Business model (tailored packages, responsibilities, profit sharing approach, etc.).

3.3 AAL ecosystem specification

The specification of the AAL Ecosystem requires the preliminary considerations of four main concepts: Users, Habitations/User's locations, Care Providers, and AAL Services, which will now be defined.

Definition 3-1 (AAL Users) - Can be elders or a people that live alone or with barely any assistance that want to maintain their independence. These users subscribe one or more services for compensating their limitations and aiming to improve their welfare and safety. A user can be abstractly defined as a tuple $u = (IDuser, Name, Uattr)$. The set $Uattr$ represents the attributes that adequately characterizes a user. From now on, let us consider the existence of the set of users $U = \{u_1, u_2, .., u_n\}$.

Definition 3-2 (User's homes) - The environment where the user lives is also an important part of the AAL Ecosystem. If the user has limitations, it's important to monitor its environmental conditions, such as the temperature, smoke detectors, floods and the work of potentially dangerous electric or gas devices, intruders alarm, etc. It can be specified as a tuple $h = IDhome, location\ Hattr)$. The set $Hattr$ represents a set of attributes that adequately characterizes the user's home. For now on, let us consider the set of homes $H = \{h_1, h_2, \dots, h_n)$.

Definition 3-3 (AAL Service Providers) - Entities that are able to provide care and assistance services to elders or persons who need assistance. They can be formal care providers, such as an hospital or a clinic; or informal care providers, such as churches or voluntary groups. One provider has a structure composed by one or several associated providers, forming partnerships, which can be recursively defined as $SP = \{(p_i, \{p_{ij} | p_{ij} \in SP\}, S) | p_i \neq p_{ij} \land p_i \varepsilon P\}$. The set $S = \{s_1, s_2, \dots, s_n)$ in this tuple represents the services the provider is able to deliver.

Definitions 3-4 (AAL Services) – An AAL service can abstractly be defined as a tuple $s = (IDservice, Description, Sattr)$. The set $Sattr$ represents a set of attributes, which adequately characterizes the AAL service. For now on, let us consider the set of services $S = s_1, s_2, \ldots, s_3$.

Definitions 3-5 (Subscription Contract) – A subscription contract associates a user an a service provider by means of a number of services subscription. Each subscription can be specified as a tuple $s = (IDcontract, IDprovider, IDuser, S)$. The set $S = (s_1, s_2, \ldots, s_n)$ represents the services subscribed by the user or delivered by the service provider.

Using these definitions, it is now possible to model mechanisms or rules to identify and select potential services that a user may subscribe.

Definitions 3-6 (Useful services selection) – These are the services that a user might need, according to its user attributes. It can be formally specified as: $\forall_{s \in Services} \forall_{u \in Users}(UsefulService(S,U) \Leftarrow attributes(S,SA) \wedge attributes(U,SU) \wedge SA \cap SU <> \phi$. In other words, the interception between service attributes and user attributes which are variables, results in a non-empty set.

In this definition, SU and SA are free variables, not bound by universal or existential quantifiers.

Using Definition 3.6, it is possible to select and propose services to a user, according to its characteristics or attributes, which can be a step before contract subscription. The mentioned definition can also be improved in order to consider the attributes of the user's home.

Definitions 3-7 (AAL service market opportunity) – Corresponds to an opportunity identified in the market, which may lead to the creation of a new tailored AAL service. It can be specified as a tuple $mo = (ID,\ OPattr)$, in which $OPattr$ represents the set of attributes characterizing the opportunity. For now on, let us consider the set of market opportunities $MO = \{mo_1, mo_2, \ldots, mo_n)$.

Definitions 3-8 (AAL Service provider selection) – Given a Market Opportunity MO (Definition 3.7), we can identify adequate service providers with the following query:

$$\forall_{mo \in MO} \forall_{P \in SP} (UsefulProvider\ (mo, p) \Leftarrow HasService(p, s)\ \wedge attributes\ (s, Sattr) \wedge attributes\ (mo, MOattr) \wedge Sattr\ \cap MOattr <> \phi)$$

Definitions 3-9 (AAL partnership formation) – Given a market opportunity mo, either concrete or abstract, an adequate partnership can be specified as a tuple $partner = (ID, Partners)$ in which partners is a set $Partners = \{pi | pi\ \in SP, useful\_partners(mo, Pi)$.

3.4 Development of the data models for the AAL ecosystem

3.4.1 Global Infrastructure Model

In general terms, the global infrastructure supports the interaction between the entities/nodes engaged in care provision and the assisted people. It supports multi-node services, distributed processes, software services invocation and composition. The main functional blocks are: Global Infrastructure Management, Security Services, Software Services Composition, Safe Information Management Services at Global Level, Auditing Services, Safe Communication Service, and Auxiliary Services (including identification of critical issues, assessing performance, statistics and reporting.

In our concrete specification, we assume that the global infrastructure takes care of a number of homes and users. Each home has got a number of ambient sensors (e.g., temperature, blood pressure, etc.). Periodic observations are taken from these sensors, which might trigger important events. Some events may require an adequate response, like sending an SMS alarm to the user's relatives, or sending an emergency team to the user's home. The conceptual model presented in Figure 3-10 incorporates these requirements.

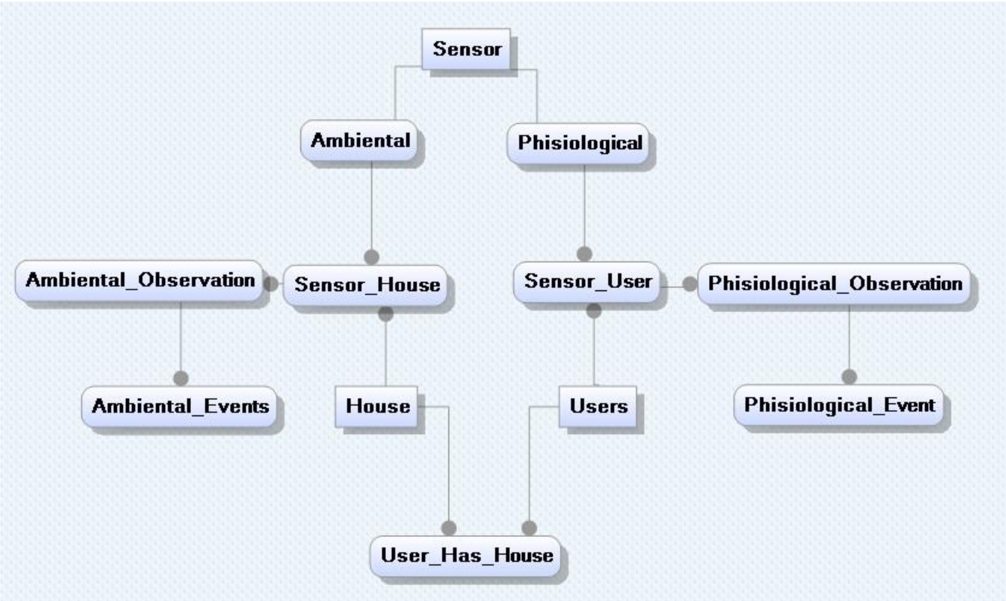


Figure 3-10 – Global infrastructure data model.

The logical detailed Data Model for the Global Infrastructure can be seen in Appendix A.1

3.4.2 AAL ecosystem data model

In general terms, the top layer of the architecture – AAL Ecosystem – has the main purpose of providing, under a socio-technical perspective, organization and collaboration support for the AAL multi-stakeholders, organized as a collaborative community. Members of the AAL ecosystem include the AAL services/product providers, the end users, regulators and other support entities such as governmental entities. This layer supports functionalities for establishing links between providers and users, business models, collaboration processes and governance policies enforcement. Main functional elements of this layer include: Ecosystem Management, Assets Management, Governance Policies Specification, Business Models Management, Providers – User Linking Mechanisms, Consortia Formation Mechanisms, and Collaboration Support Mechanisms.

In our concrete specification, the ecosystem allows the creation of service providers, users, contract subscription, services and services composition, AAL events and billing. The conceptual model presented in Figure 3-11 illustrates these aspects.

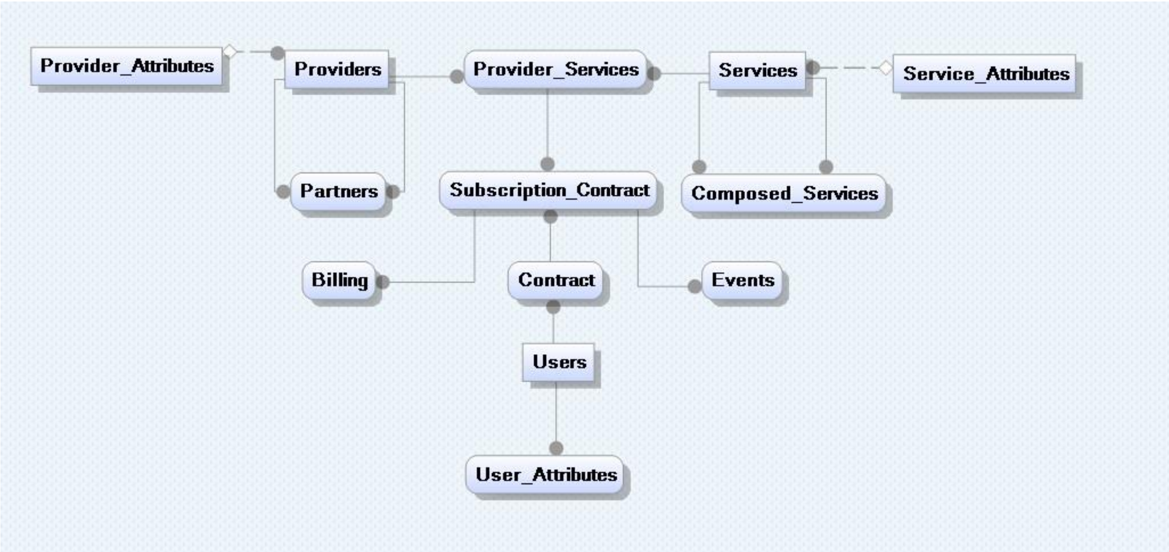


Figure 3-11 – Ecosystem management data model.

Whenever a user subscribes a service, a subscription contract between user and service provider is established. An AAL service can be a simple service or be recursively composed by other services, resulting in tailored packages. Such packages may be supplied by a single service provider. But it also may happen that for completing the package, it is necessary to consider additional partners. In such case, the model allows the creation of service providers that are in fact the combination of other providers, resulting in partnerships formation.

The Events entity encodes the main episodes related to these contracts, like the addition of more services to the contract. The Billing entity encodes the periodic payments resulting from the contract

3.4.3 Adopted technological approach

Ambient Assisted Living is a multifaceted area. It harnesses a diverse range of technologies from various domains. Requirements like remote supervision of elderly, information management and business processes, just to mention a few, are quite demanding in terms of ICT. For the physical architecture of AAL, the choice for adequate infrastructures is very important in terms of the initial budget necessary for launching an AAL ecosystem.

Cloud computing environment is an infrastructure paradigm for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services), which can be rapidly provisioned and released with minimal management effort or service provider interaction (Figure 3-12). This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models [38]

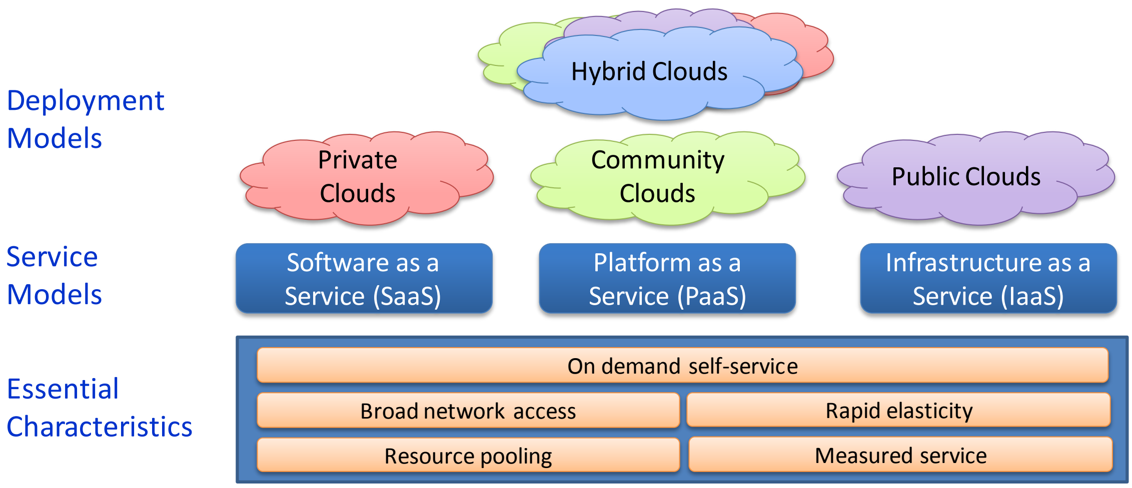
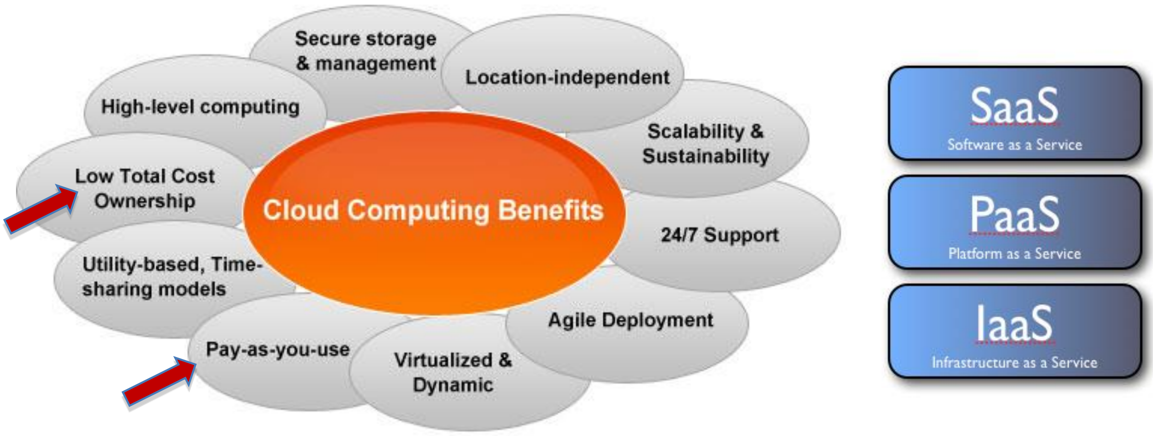


Figure 3-12 – Cloud environment [38].

Typical features of Cloud Computing are summarized in Figure 3-13, from which faster development/ installation time, lower initial capital, and "pay-per-use" can be highlighted.



http://www.dotcominfoway.com/technology/cloud-computing

Figure 3-13 – Cloud computing features

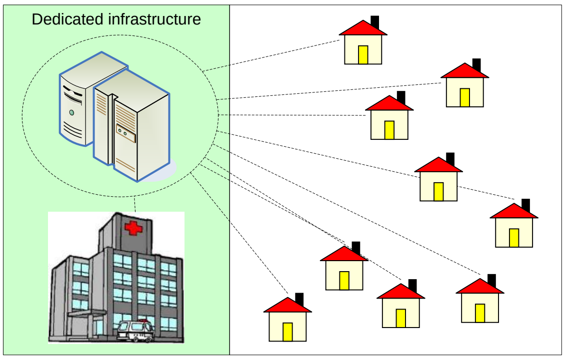
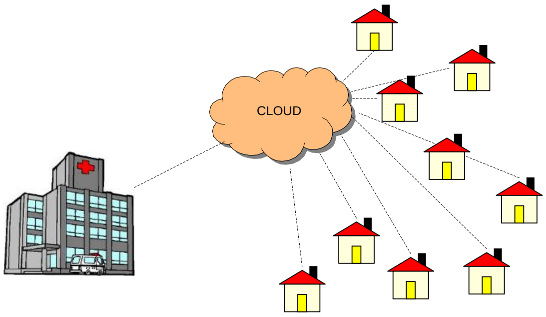
Table 3-5 summarizes the benefits of Cloud Computing versus conventional, non-cloud, infrastructures.

Table 3-5 – Cloud computing benefits [39].

EFFICIENCY	
Cloud Benefits	**Current Environment**
• Improved asset utilization (server utilization > 60-70%) • Aggregated demand and accelerated system consolidation (e.g., Federal Data Center Consolidation Initiative) • Improved productivity in application development, application management, network, and end-user	• Low asset utilization (server utilization < 30% typical) • Fragmented demand and duplicative systems • Difficult-to-manage systems
AGILITY	
Cloud Benefits	**Current Environment**
• Purchase "as-a-service" from trusted cloud providers • Near-instantaneous increases and reductions in capacity • More responsive to urgent agency needs	• Years required to build data centers for new services • Months required to increase capacity of existing services
INNOVATION	
Cloud Benefits	**Current Environment**
• Shift focus from asset ownership to service management • Tap into private sector innovation • Encourages entrepreneurial culture • Better linked to emerging technologies (e.g., devices)	• Burdened by asset management • De-coupled from private sector innovation engines • Risk-adverse culture

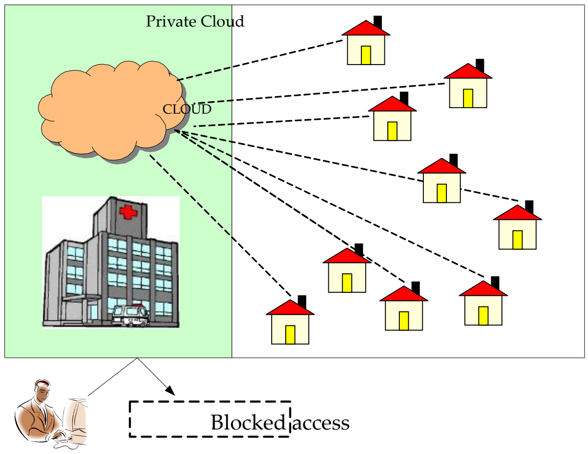
Possible strategies and infrastructures modalities for the development of the AAL4ALL ecosystem with Cloud Computing, together with their main features, are summarized in **Table 3-6**.

Table 3-6 – Cloud computing modalities that are useful for the AAL ecosystem [11].

Modalities	Illustration
Dedicated infrastructure/datacenter • High initial cost. • High development and launch time. • Complex installation and configuration. • The stakeholders are responsible for maintenance. • Some advantages are the complete ownership and control over the infrastructure, services and information.	
Public cloud (provided by third party supplier) • It is probably the fastest option to create and launch the ecosystem. • Many suppliers of Cloud Computing infrastructures are available. • Low initial cost. But if time is long, dedicated infrastructure may become cheaper. • Short Setup/installation time. • Cost is proportional ("Pay per use") to the number of users, utilization time, and used computational and storage resources, which might require some further analysis in face of the specific needs of AAL. • A major issue is that information of users (elders, customers and stakeholders), like the profiles and clinical information, is stored on third-party infrastructures, which raises security and privacy concerns. • An additional drawback is the lack of standards that allow portability. As such, once one provider is selected, solutions get too dependent on that provider.	

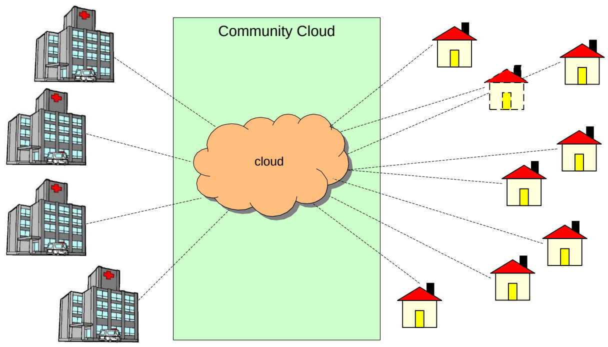
Private cloud (owned by one stakeholder)

- Has similar/same advantages of the public cloud.
- Infrastructure is totally controlled by the stakeholder/AAL services provider.
- Better in terms security and privacy, as management and access to information is performed by the stakeholder.
- The stakeholder may start with a "small private cloud", with a lower initial cost, and scale up the capacity if it becomes necessary afterwards.
- This approach might suit a major services integrator.



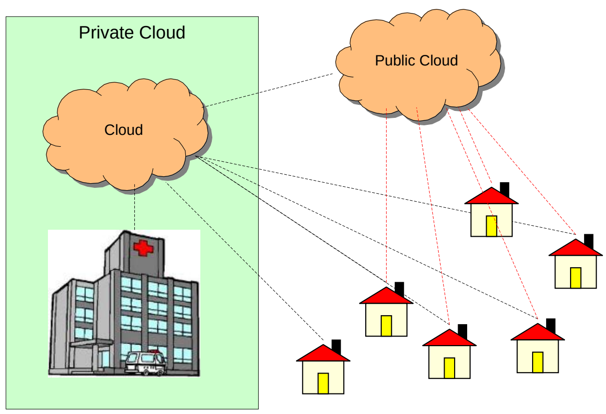
Community cloud

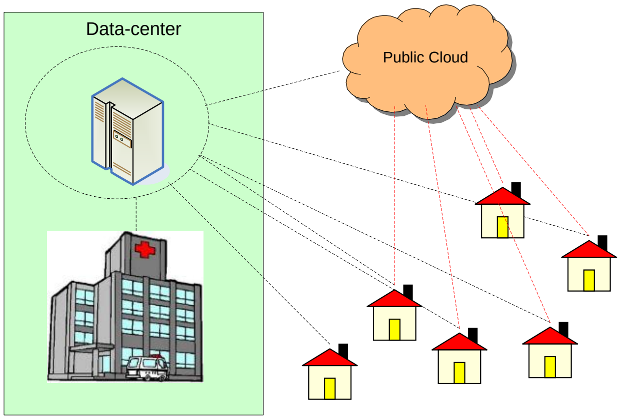
- It has got similar advantages to private clouds.
- Ecosystem acquires Cloud infrastructure to be shared by the stakeholders.
- Ownership and control by the stakeholders of AAL4ALL ecosystem.
- Acquisition, launch, and maintenance costs can be shared by the stakeholders, which means lower costs and reduced business risks for each one.
- Network installation and maintenance role can be assigned to a third-party provider, or rented/"outsourced" to a cloud-supplier, which already belongs to the ecosystem.



Hybrid cloud

- Similar characteristics of both public and private clouds.
- Combination of public/community and private cloud infrastructures.
- Computer load can be balanced between private and public clouds, whenever necessary.
- Stakeholders' profiles and clinical data are stored in the private cloud; information and processes that do not pose se-



curity/privacy issues can be located in the public cloud.	
Combination of a private infrastructure/datacenter with a public cloud • Similar advantages to hybrid clouds. • Some limitations/disadvantages of dedicated infrastructures. • Computer load can be balanced between private infrastructure and public cloud, whenever necessary. • Stakeholders' profiles and clinical data are stored in the private datacenter; information and processes that do not pose security/privacy issues can be located in the public cloud.	

3.4.4 AAL ecosystem cloud computing-based portal

From the available cloud-computing modalities (Table 3-6), we developed the ecosystem portal in a public cloud (provided by third party supplier), as illustrated in Figure 3-14. It was implemented using Microsoft Azure Cloud Computing [40].

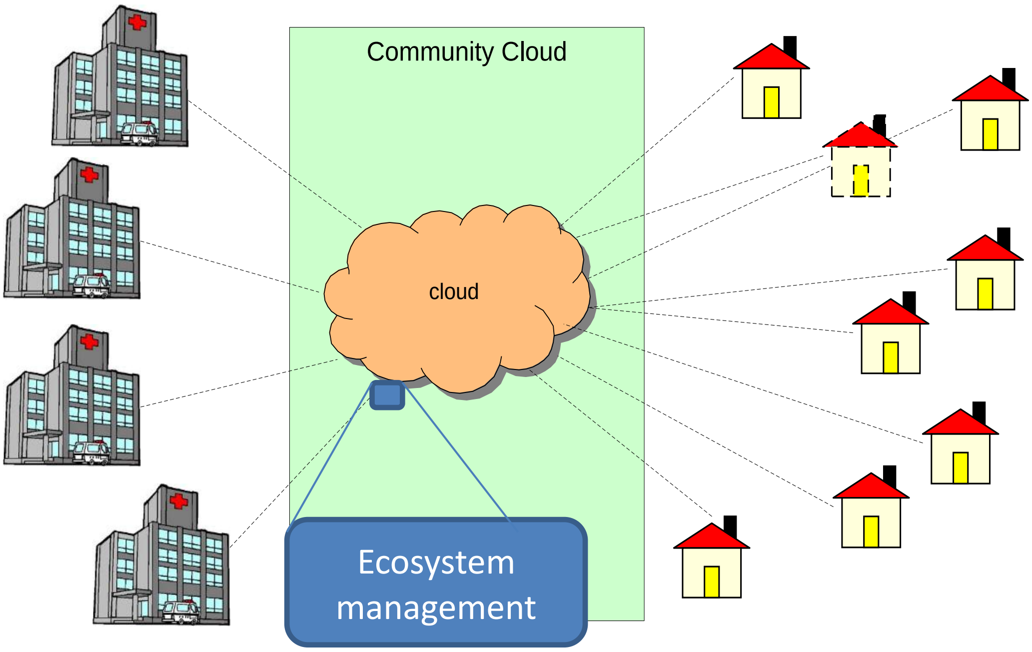


Figure 3-14 – Adopted cloud computing modality for the AAL ecosystem portal

The web portal, illustrated by the initial user interface in Figure 3-15, allows the services providers to register and be part of the ecosystem. It allows partners advertise their services to other partners and create partnerships, whenever an opportunity appears. Global infrastructures, which may be owned by a simple partner or by service provider's partnerships, are also implemented in the Cloud infrastructure. The main advantage is that both ecosystem and global infrastructure nodes can scale as the number of users grow. This way, each service provider can initially commit a lower budget or pay reduced monthly Cloud renting costs.

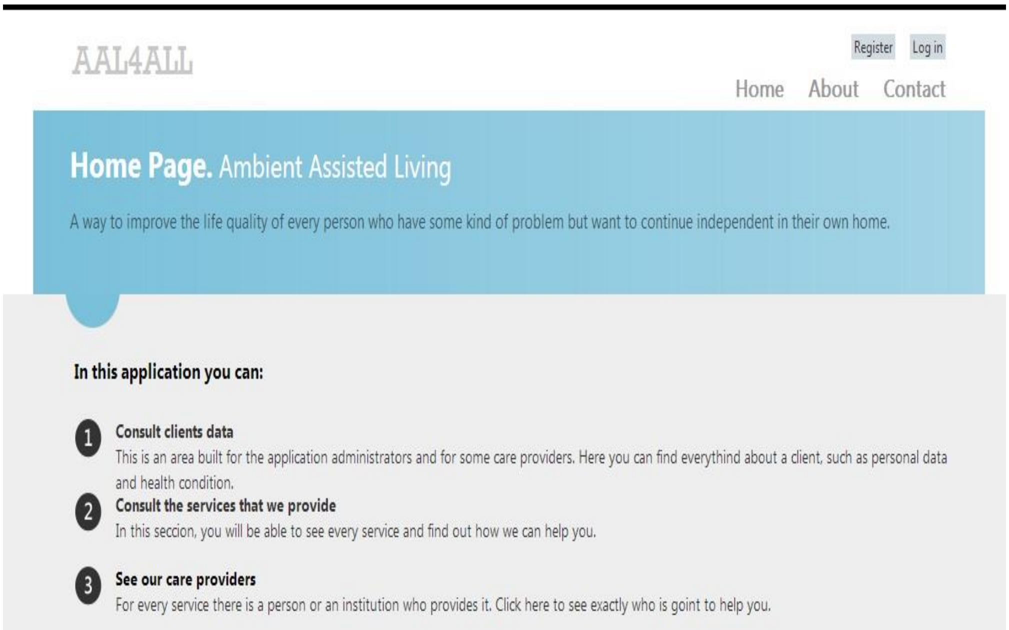


Figure 3-15 – Initial page of the AAL ecosystem portal

Figure 3-16 illustrates the user interface regarding services subscription contracts established between service providers and users.

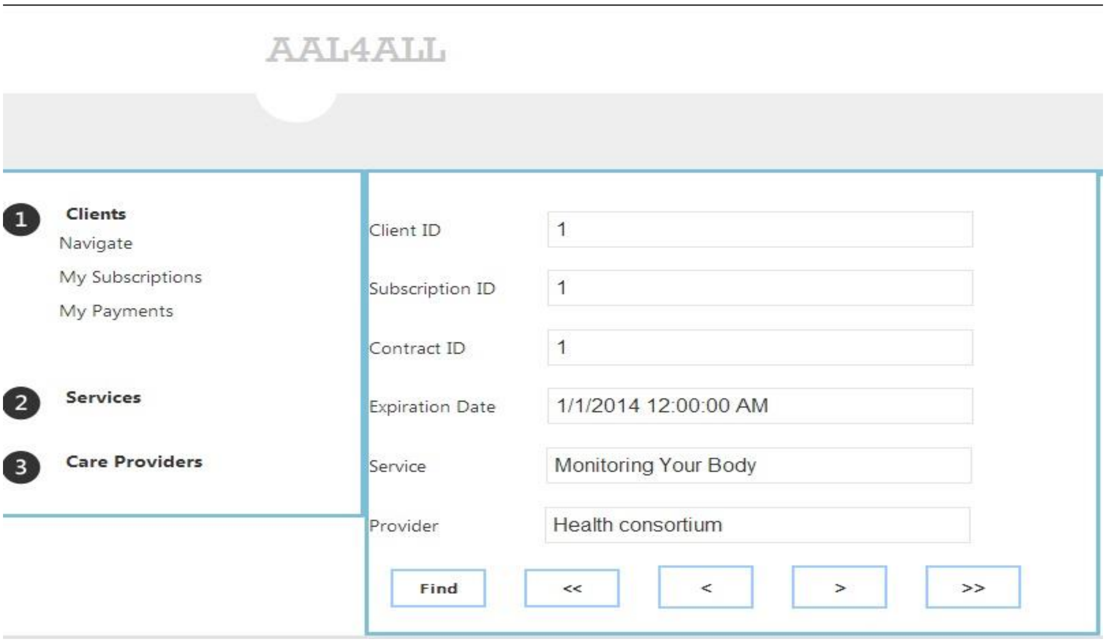


Figure 3-16 – Services Subscription of a user

3.4.5 The Local infrastructure model

As we mentioned before, we designed software models that simulate local infrastructures, which represent user's nodes and homes. As illustrated in Figure 3-17, several AAL services were subscribed, ranging from ambient to physiological monitoring. Therefore, each UI represents a user and its home. Whenever an event is triggered, in this simulation approach performed by a click in the corresponding UI control, the information is recorded in the corresponding table of the data model instantiated in the provider's global infrastructure, illustrated at the right side of the mentioned figure, and more completely in annex A1.

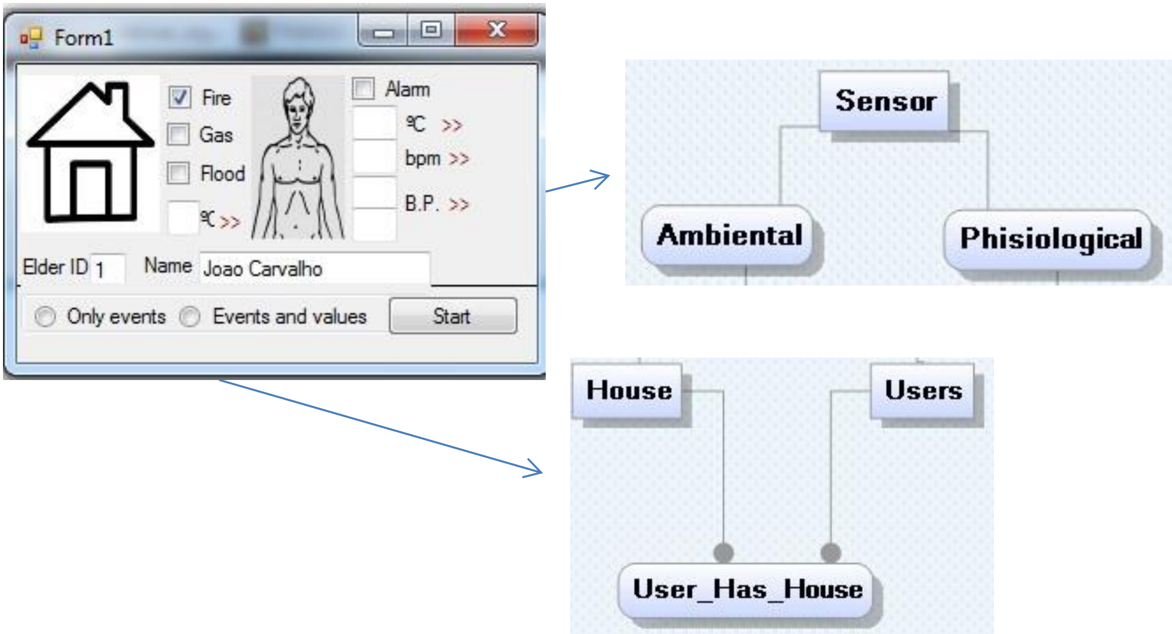


Figure 3-17 – Local infrastructure node (at the user's home) and corresponding data model from global infrastructure

3.4.6 The global infrastructure node

The global infrastructure node was also developed using a simulation approach, as illustrated in Figure 3-10, which also illustrates the corresponding data model. Each observation taken from the local nodes is stored in the database running in the global node. The database complies with the models illustrated in Figure 3-10 and Figure 3-11. Such observations might trigger events that are relevant for the comfort and health of the users. These are the events shown in the user interface of the global node shown in mentioned Figure 3-18.

The set of rules that identify events from observations are hard-encoded in C# inside the application. In this regard, we are planning the development of a knowledge-base, which provides more advanced events detection and corresponding response from service providers with adequate interactions at user's homes. This is scheduled for future work.

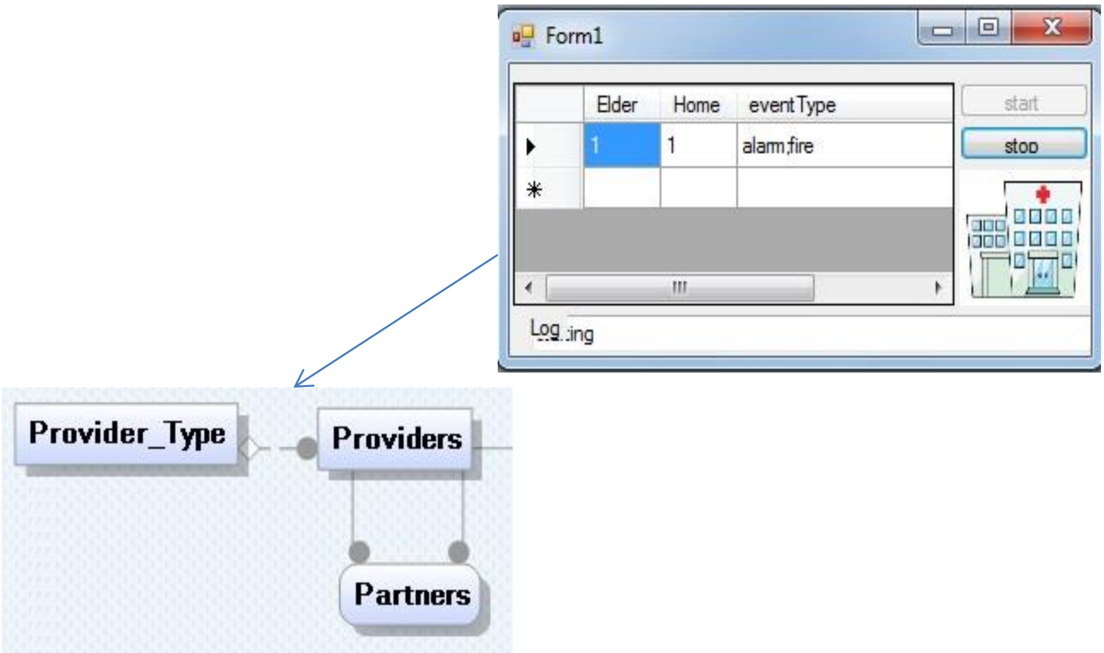


Figure 3-18 – Global infrastructure node and corresponding data model.

The interactions between the global and local nodes are illustrated in Figure 3-19. These nodes exchange information regarding the mentioned events that are generated inside the local nodes, according to the subscribed AAL services. The mechanism for sending the events is based on REST services, which is supported by the Windows Communication Foundation (WCF) framework [41].

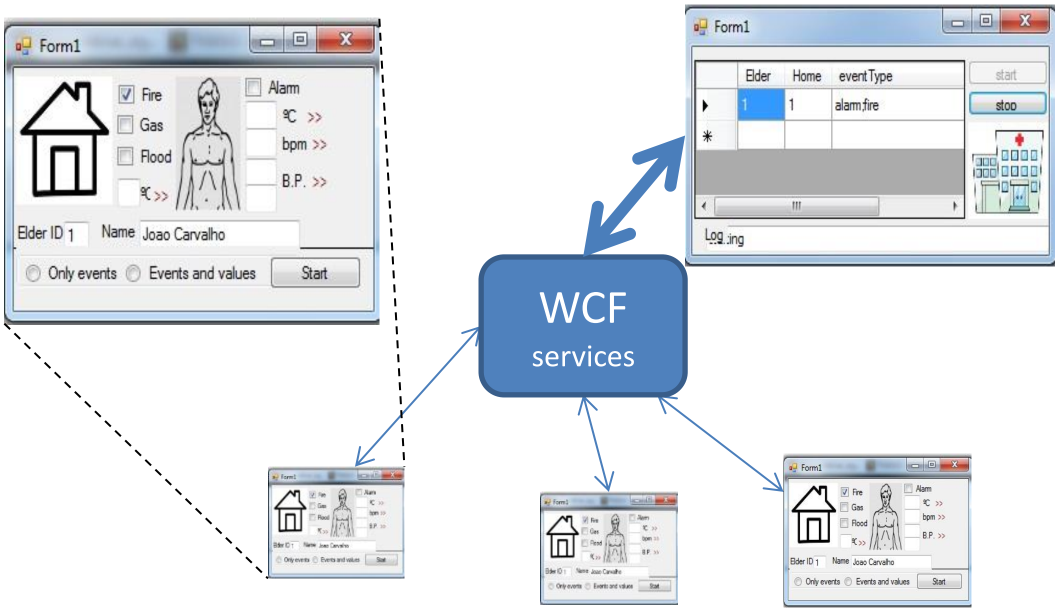


Figure 3-19 – Global and local infrastructures interacting through WCF.

3.4.7 The AAL system as a whole

The AAL ecosystem platform was assembled together as a complete simulation system, in which information regarding AAL events flow from users and user's homes (local infrastructures) into global infrastructure nodes (Figure 3-20). Member's management, services subscription, billing and other previously established requirements are fulfilled in the cloud portal, illustrated at the top of the mentioned figure. Partnership creation is also registered through this portal.

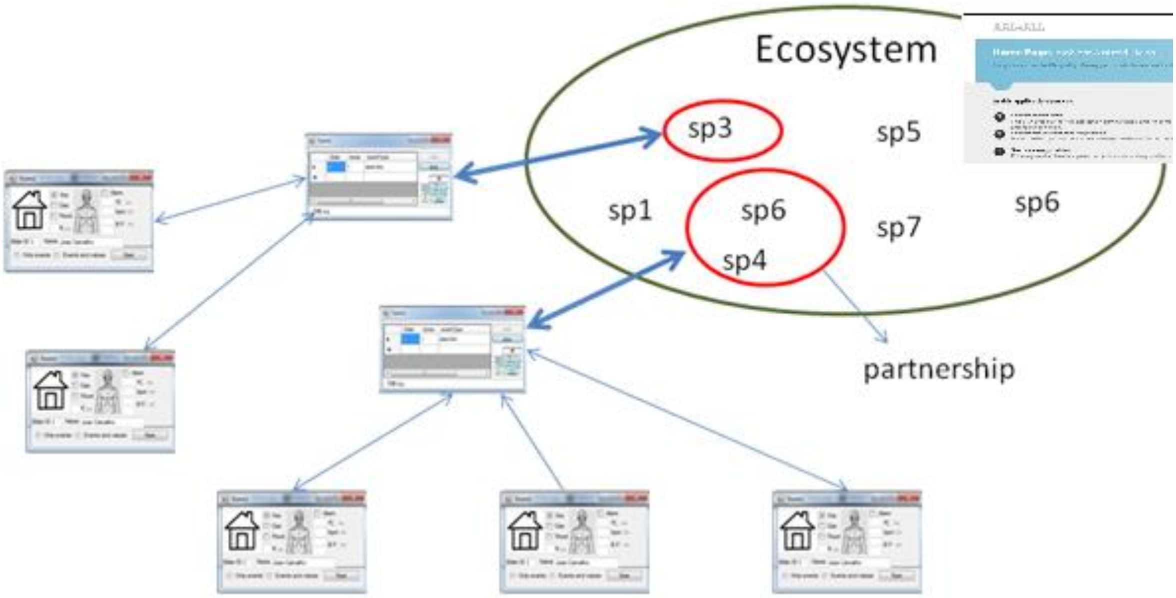


Figure 3-20 –The AAL ecosystem implemented as a global simulation system

During the simulation of the whole system, we could verify and certify that implementation of the ecosystem components follow the specifications established in previous sections, and that it also fulfills the functional requirements that were also established for each component of the ecosystem management. Each time a new user is registered, the corresponding UI of the local node is created. A pre-specification number of AAL services are also launched.

While the complete system is operated, we can perceive its dynamics, in which each local node sends observations to the global nodes. Information regarding these observations and events is stored in the corresponding tables of the ecosystem database.

3.4.8 Analysis of the system

Before ending this chapter, it is important to mention some remarks on the outcomes of the simulated ecosystem.

Although our approach for testing the ecosystem was based on simulation, the specification and the data models were used as if the system was a real one. Simulation of events we generated and flowed in real clock, in which we could simulate specific situations in the user's homes, which would allow service providers to trigger assistance services and home interventions. Furthermore, we are planning to integrate real nodes (e.g., real homes and users) in the simulation system, as future work.

The strategy of simulating the AAL ecosystem can be seen as a prior stage to design a real ecosystem. That is because through the several performed simulations we had the opportunity to find mistakes and improve specifications much earlier. Without using simulation, we would have to fix mistakes and wrong specification during system development or operation, which would increase costs and potentially cause harmful effects on the users living alone at their homes. In this regard, we take simulation as a system design paradigm [42].

4 Conclusion

4.1 Synthesis of the work

As mentioned before, the world is suffering big demographic changes, with the constant increase of aged population. In 2050, it is expected that the number of people with more than 65 years old will reach the 1500 million. With this context, it is absolutely necessary to work on solutions that are able to improve the life quality and the independence of this age group of population and helping avoid bankruptcy of social security systems.

With this context in mind, it was proposed the implementation of an Ambient AAL Ecosystem, which uses technology as a way to improve the independence and welfare of aged people.

In order to define the best approach for our implementation, the first step was to revise the state of the art, considering the relevant technological aspects of existing AAL systems. With this literature review, we concluded that current approaches have been too techno-centric and realized that a collaboration-based approach would be more promising in terms of impacts in the AAL area.

Our contribution to this effort was to specify and instantiate the ecosystem layer proposed in the AAL4ALL project.

We started by identifying the functional requirements of the ecosystem management layer, followed by corresponding specifications and data models. These were formulated as canonical models, which allow the characterization of complex systems using simple, yet useful structures.

Afterwards, we developed the ecosystem management application in a Microsoft Azure Cloud Computing infrastructure. Local and Global nodes were implemented in C#. The interaction between these nodes was based on WCF.

The system was tested using a simulation approach, which allowed understanding the dynamics inside the ecosystem, certify the correctness of the specified models, fix design and implementation mistakes, and perceive whether we could profitably use our approach for the development of a real ecosystem.

4.2 Achieved Results

During our work, we focused on the specification and implementation of concepts and structures for developing an AAL ecosystem. As mentioned before, we used these canonical-based specifications to simulate the dynamics of the ecosystem life-cycle. With this purpose in mind, several aspects needed to be studied, in order to take the best possible decisions and to achieve satisfactory specifications and models. The results that were achieved include the following:

- Study and characterization of the AAL structure that was used in this project.
- Specification of functional requirements and specification of corresponding AAL architecture, according to our goals.
- Development of the ecosystem management system using a Cloud Computing framework.
- Development of local and global infrastructure nodes, which interact through WCF.
- Test and verification of the system through simulation.

As mentioned before, using canonical specifications, which allows system simulation, helped to spot design and implementation mistakes, which are now avoided in the real system implementation, which conforms the concept of simulation as a design paradigm.

4.3 Future Work

Before starting to suggest future lines of action, it is worth to mention the context of this work. As mentioned before, the study and creation of an AAL ecosystem is a task which currently involves tens of researchers inside the AAL4ALL project. In this project, each one is working on concrete parts of the ecosystem development. This is important for our lines of future work, because it is recommended our future effort complements those at the project. As such, our strategy for future work is more focused on aspects, which will increase the functionality and quality of our AAL ecosystem, and at the same time, will profitable complement the tasks and results for the AAL4ALL project.

Therefore, our set of future work action comprises the integration of real users and nodes in the simulated ecosystem. An illustration of a real node which allows integrate real sensors and actuators is in Figure 4-1. The integration of these nodes in the simulated ecosystem, would allow the progressive transformation of our system from simulation to a real one.

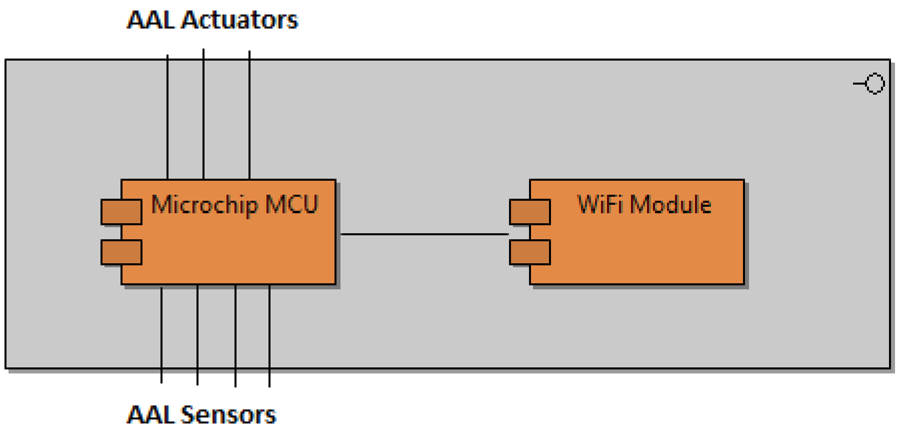


Figure 4-1 – Possible future configuration for the implementation of a local infrastructure.

Additionally, these nodes would then be installed in a number of homes, as a way to certify that the proposed ecosystem was specified in a way that allows further development towards real products, which could already be "marketed".

Other interesting future work is to study scenarios to evaluate certain failure situations.

Other necessary and very useful component is the development of a knowledge-base, which by making inferences with the observations from the sensors, would trigger the corresponding events, from which service provider would provide assistance if required. This component would select the adequate intervention regarding the event, sometimes sending an SMS to relatives, other times sending a rescuing team to the user's home.

Another functionality for future work is the integration of business processes and service composition inside the simulations of the ecosystem. This would allow provision of AAL assistance services, which would require several steps performed by several actors, in order to provide complete assistance services.

Finally, we would like to incorporate in our system the capacity of modeling users with newly assistance necessities. This would allow determining how to automatically formulate tailored packages of services and formation of corresponding partnerships.

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6 Appendix

Appendix A
Complete Data Models

A.1 Global Infrastructure Complete Data Model

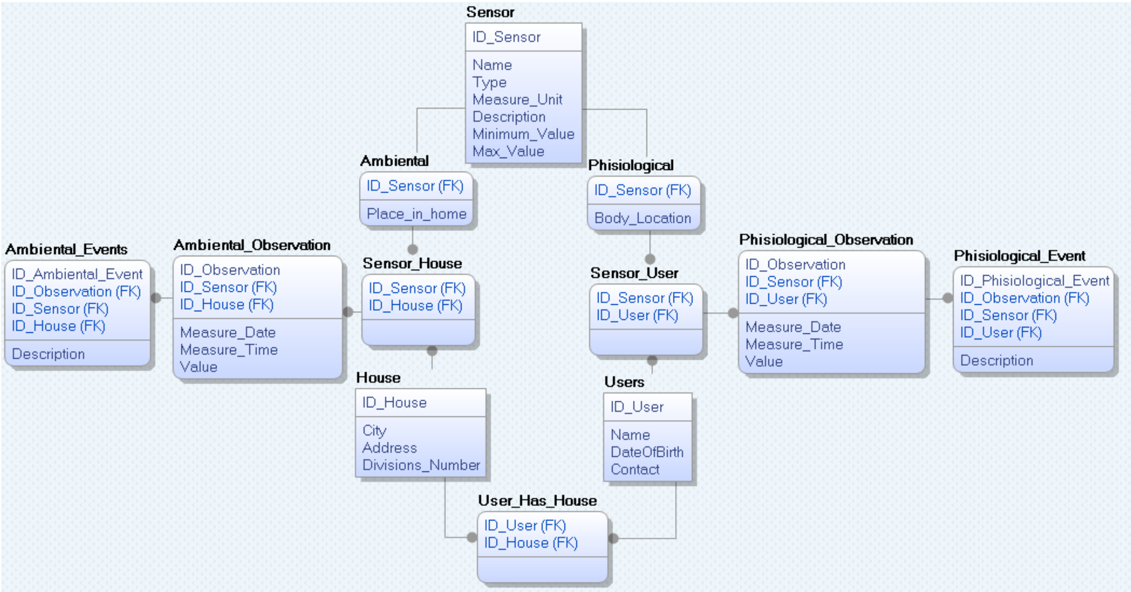

Image 1- Global Infrastructure Complete Data Model

6.1 A.2 Ecosystem Management Complete Data Model

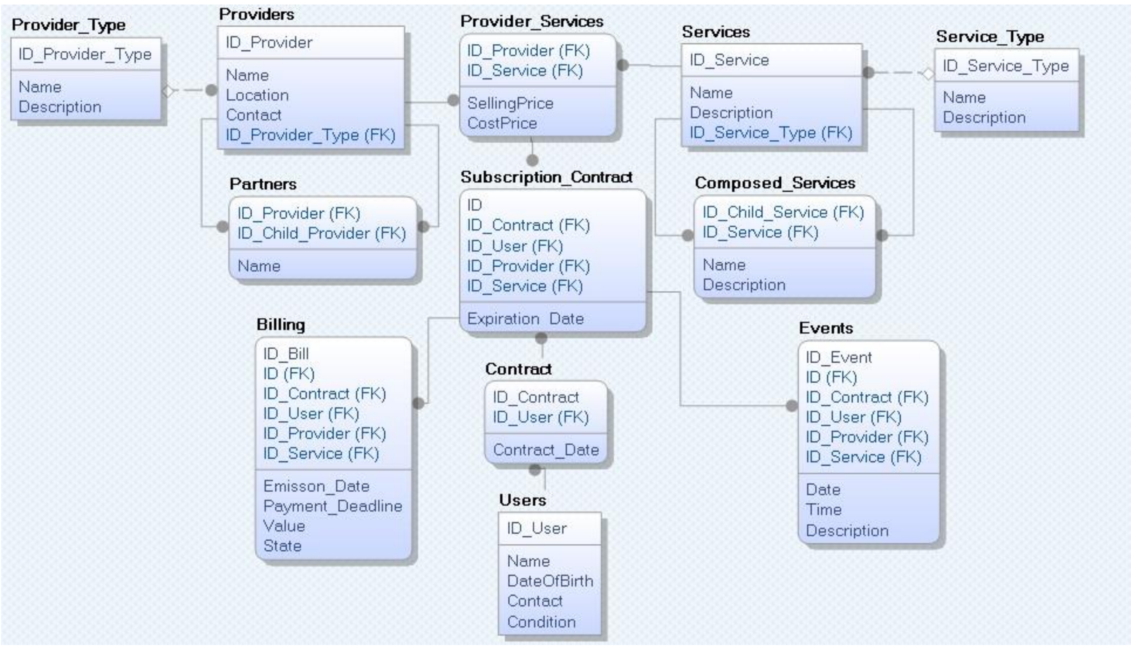

Image 2- Ecosystem Management Complete Data Model