Chapter 14
IoT in Ambient Assistant Living Environments: A View from Europe

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14.1 Introduction to AAL IoT Approach

The Internet of Things (IoT) paradigm, as already manifested, is leading to smart objects being capable of identifying, locating, sensing and connecting, and thus opening possibilities for new forms of communication between people and things, as well as amongst things. This evolution benefits new application scenarios that promote the ambient assisted living (AAL) environments. AAL systems encompass ICT in order to support elderly people in their daily routine thus prolonging an independent and safe lifestyle.

It is commonly accepted that intelligent, customizable, and multifaceted home monitoring and control comprise one of the most rapidly evolving ICT domains. To address respective challenges, novel technical approaches are required to cover all aspects of home environment monitoring. On one hand, the significance of such endeavors is highlighted by the high interest that home monitoring receives both from academia and from industry [1–4] mainly under the term AAL environment systems. On the other hand, relative views are further emphasized by several studies concerning the population's everyday life characteristics.

Focusing on the European view on the issue, according to the 2012 EU Ageing Report, the part of European population aged over 65 will almost double by 2060—rising from 87.5 million in 2010 to 152.6 million—while the number of older people (aged 80 years and above) is projected to increase even more, almost tripling from

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23.7 million in 2010 to 62.4 million in 2060 [1]. At the same time, critical advances in the medical domain offer valuable tools to the senior population allowing them to stay active for as long as possible. However, extending the life time expectation of the general population is unavoidably accompanied by increased frequency of chronic disorders manifestation. Such occurrences greatly degrade life quality and at the same time emphasize the need for advanced AAL technologies and deployments. It is important to note that respective needs apply both to the user and their equally old spouses or relatives that undertake the responsibility of care provision, effectively extending the range of people requiring AAL services.

Additionally, moving beyond specific chronic disorders, AAL includes other equally important aspects under the umbrella of new solutions towards improving the quality of life, supporting health needs, facilitating concepts such as "aging well" or "healthy aging," and maintaining the social participation of the elders. All the above clearly indicate a new rapidly growing market for health devices and services that support seniors in their home environments. Provision of such services must cover a wide range of requirements including medication schedule reminders, monitoring of vital signs, and dispatching of medical alerts in the case of emergency situations such as falls and accidents, affective monitoring, urging people to stay active and creative and many more.

Based on the aforementioned EU report, the number of elderly people in need of constant care and attention will increase significantly in the near future. Another observation advocating the extensions and enhancement of AAL technologies relates to the fact that contemporary approaches and services are and will be rendered totally inadequate. Specifically, hospitalization, nursing homes, or employing personal care givers at home for a continuously increasing population percentage are not a viable solution due to practical [2], economical [5], and psychological [4] reasons. Another perspective of paramount importance, yet most of times ignored by existing approaches is that AAL services (and not only for elderly people but also in general) are a highly personalized, multiparametric and multifaceted challenge not able to be addressed solely by existing approaches.

AAL IoT solutions, on the other hand, acknowledge and even capitalize on the fact that what a person may need or expect from home monitoring can be quite diverse. On one hand, a typical category is the users suffering from specific medical conditions. In that respect, the actual condition (e.g., kinetic difficulties, heart conditions, brain conditions, etc.) and the needs for each specific user are diverse (or diversified) and thus a "one size fits all" solution is not adequate. On the other hand, AAL need to also cover cases where home monitoring is needed because he/she spends a lot of time on its own and a general monitoring on the user's well-being is desired. Furthermore, home monitoring requirements gaining active interest focus on safety issues (e.g., the user forgot to turn off the oven or close a window/door before going to sleep). Such cases although not directly related to medical conditions also comprise services of high added value for the general population [6].

14.2 AAL Involved Technologies

For all the above reasons, AAL represents a fundamental research domain that has drawn massive attention. Moving to the more technical aspects, AAL rather than being a technology itself, AAL encompasses IoT approach, embedded networked devices and sensors, algorithms, and diverse ICT technologies to support people in their preferred environment. Such interdependencies and collaborations amongst different ICT domains further enhance the added value of respective research efforts and deployments. Another aspect differentiating AAL development from other ICT advancements concerns the requirement to pose minimum intrusion thus yielding significant added value of allowing the person to be self-reliant and independent. Furthermore, as AAL approaches are applied into more and more scenarios they also move beyond the human factor and focus on a wide range of characteristics of the environment itself characterizing typical IoT platforms.

Specific areas towards which AAL technologies extend include security, surveillance, energy consumption, and remote access attracting increasing interest. Additionally, in many cases people (especially elderly) tend to spend significant part of each day away from home. Consequently, a home monitoring system able to detect events related to safety and security (i.e., a window/door left open, the oven is left on, etc.) could be an invaluable tool [7, 8]. Power consumption monitoring pertaining to security, well-being, economy as well as carbon footprint control services comprise another critical aspect of nowadays AAL enabled by IoT capabilities with energy demand-response programs support [9, 10] representing also research objectives of high added value. In order for the aforementioned services to be implemented significant advancements in ICT fields such as wireless sensor networks (WSN) regarding ultra-low power consumption embedded systems and miniaturization [11, 12] are required. Based on the respective observations over the last years both the number of available WSN platforms offering different capabilities and the range of different sensors' support continuously increase moving towards a holistic home environment platform. However, high degree of heterogeneity in all prominent technological areas still remains a critical challenge prohibiting widespread utilization [13, 14]. Finally, one of the latest trends in AAL technologies receiving active interest from the European research community (e.g., Horizon 2020 research projects calls) is help provision with daily activities, based on monitoring activities of daily living (ADL) and issuing reminders [15], as well as helping with mobility and automation [16]. Exploiting novel sensor modality such as video processing, audio processing as well as processing approaches such as fuzzy logic and affective modeling offer enhanced monitoring and control capabilities. Finally, such technologies promote sociability amongst users sharing common interest, activities, and hobbies or with their family, friends, doctors, and caregivers [17, 18] highlighting further the interconnection with IoT approaches.

14.3 Research Efforts: Paving the Way of AAL IoT

This section describes mainly active projects funded by the EU regarding the AAL domain under the IoT paradigm. The projects are presented under the view of the objectives and the expected impact addressed by common or similar calls which will be used as a common ground. The majority of the described projects (five out of six) have been accepted in "PHC-19-2014—Advancing active and healthy ageing with ICT: service robotics within assisted living environments" call [19] while the last one has been funded under the "FP7-ICT-Challenge 5: ICT for Health, Ageing Well, Inclusion and Governance" call.

In the PHC-19 call, the EU identifies and highlights the needs that the increasing ageing European population has to deal with. Namely, issues regarding risk of cognitive impairment, frailty, and social exclusion with considerable negative consequences for their independence, quality of life, including that of those who care for them, and for the sustainability of health and care systems. The call focuses on the development of robotic services applied in the context of AAL and particularly for supporting ageing population. The key concepts that need to be addressed regard modularity, cost effectiveness, reliability, flexibility, applicability to realistic settings, and acceptability by the end users.

The outcomes of the projects funded under the PHC-19 call are expected to contribute with respect to validation of the benefits offered by the developed robotic services, the reduction of the time spent in institutional medical care, and the improvement of quality of life.

RAMCIP Project The RAMCIP (Robotic Assistant for MCI Patients at home, Grant Agreement no: 643433) [20] scope is to research and develop real robotic solutions for assistive robotics for the elderly and those suffering from mild cognitive impairments (MCI) and dementia. The desired functionalities are given through the development of a service robot with high-level cognitive functions. These functions are driven through modeling and monitoring of the home environment, the user and other co-located persons, allowing the robot to take optimal decision regarding when and how to provide assistance, in a proactive and discreet way [21].

The proposed system's core is an autonomously moving service robot with an on-board touch screen and a dexterous robotic hand and arm. The objectives of the project can be summarized in developing a service robot that will be capable of understanding actions, complex activities, and behavior of multiple persons in the user's home and provide proactive, discreet, and optimal assistance to the user. Furthermore, the project deals with establishing advanced communication channels between the user and the robot. Another key objective of the project is the development of advanced physical interaction between the robot and the home environment in order to support assistance activities that involve physical interaction between the robot and the user. These key functionalities that the RAMCIP robot will deliver are briefly presented in Fig. 14.1.

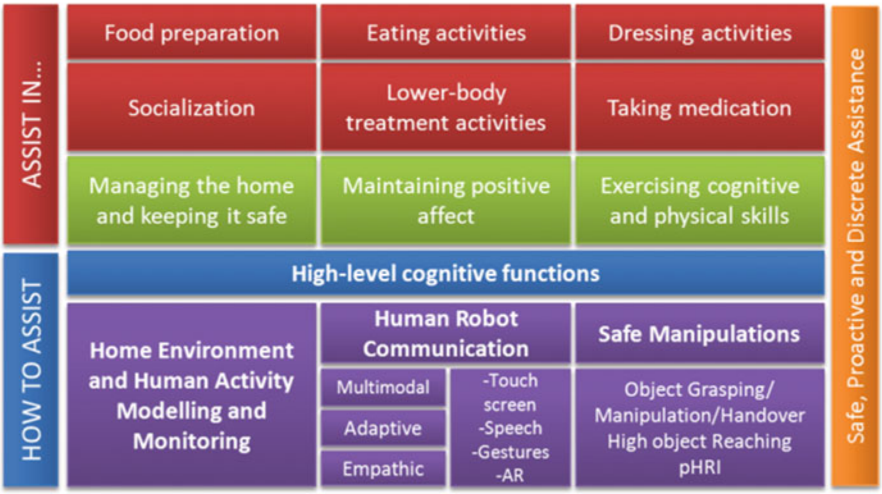

Fig. 14.1 The RAMCIP vision

The innovation points of the RAMCIP project can be summarized as:

- Advanced cognitive functions of the service robot driving proactive and discreet assistance provision through user and environment monitoring and modeling.
- Advanced human–robot communication channels based on multimodal interfaces (speech, gestures, touch screen, and augmenting reality (AR) displays).
- Dexterous robotic manipulation introduced in the context of service robots for AAL environments focused on human–robot interaction (HRI).

The promising functionalities that the project envisages to impose to current robotic technologies will deliver new case studies for the IoT field. The solutions that the project presents regarding the HRI aim to improve the system's acceptability and provide a more user-centric approach. The evaluation of the project's advances will be performed in two pilot sites in Poland and Spain.

Growmeup Project The Growmeup project (Specification of User Needs Analysis and Design of Behaviour Patterns Model, Grant Agreement no: 643647) [22], as the rest of the PHC-19 call projects, presents its approach on providing affordable robotic services in favor of the elders and their well-being. The project focuses on five innovation key points and particularly [23]:

1. To enhance HRI dialogue.
2. Provide a robot with learning capabilities, i.e., learn user habits, preferences, routines, etc.
3. Interaction of robots through cloud infrastructure.
4. Detection of external devices that extend robot's functionalities through a scalable and adaptable architecture.
5. Deliver robot capable to manipulate uncertainty of user's behavior and adapt to its environment.

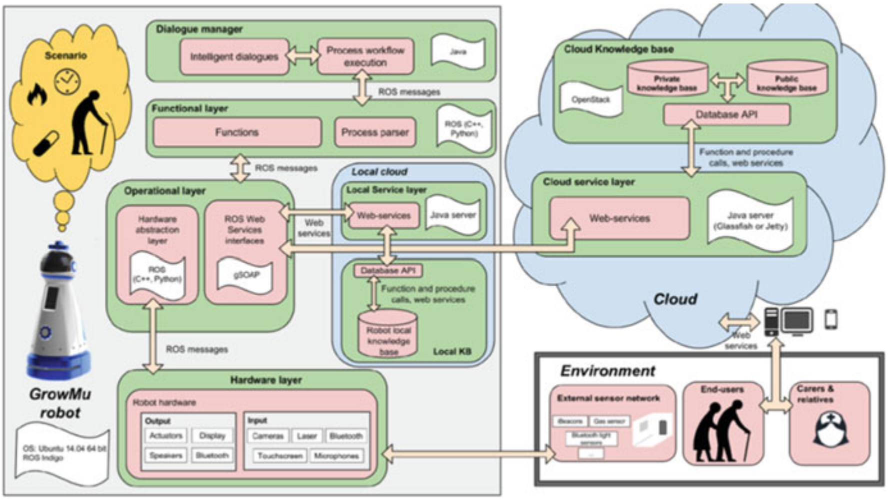

Fig. 14.2 Growmeup architecture

The Growmeup system consists of four main components. These components along with their sub-systems are presented in Fig. 14.2. The core component of the system is the cloud infrastructure that supports information exchange between service robots. This structure equips the robot with capabilities to adapt its services and abilities and therefore enhance its functionalities autonomously. The cloud infrastructure is composed of the knowledge base, the computational expensive algorithm, and the application services. The interconnection with the rest components is accomplished through web services as it is also shown in Fig. 14.2.

The smart environment is the second main component of the system. It refers to external network of sensors and actuators that are deployed in the user's environment. These external devices provide functionalities such as temperature measurements, door status, fire detection, object localization based to iBeacons, etc.

Finally, the last two components of the system are the human and robot actors. The human actors apart from the elder it includes care givers and relatives. Humans are interacting with the robot directly or indirectly through the cloud infrastructure. Figure 14.2 gives some insights in the robot's structure, technologies, and interfaces.

The Growmeup project realizes the IoT paradigm through the cloud infrastructure that constitutes the link among the objects, the user, and the services. The service is an application that runs on the cloud and is accessible through web services. The main contribution of the services to the overall system functionality is to:

- provide support for daily home activities
- provide interfaces for exchanging and storing data
- execute the algorithms and deliver their outcomes.

The service approach of the system through the cloud structure is expected to deliver the required flexibility as addressed by the call objectives. Moreover, the interfaces that deliver the interaction with external devices will provide modularity that is required to make the system flexible and adaptable to user needs and characteristics. Safe results about the cost effectiveness of the system cannot be made since the system is yet under development. Finally, the last objectives of the call that refer to the reliability, the applicability to realistic setting, and the acceptance by the end users will be investigated during the trials of the project.

MARIO Project The MARIO project (Managing Active and healthy aging with use of caRing servIce robots, Grant Agreement no: 643808) [24] addresses the difficult challenges of loneliness, isolation, and dementia in older persons through service robots. The main objectives of MARIO pertain to an improved interaction with end users and assisted living environments in order to enable iterative development and preparation for post-project uptake. The project aims to support and receive "robot applications" similar to the paradigm offered by community for smartphones so as to empower development and creativity, enable the robot to perform new functionalities over time, and support discovery and improve usefulness for end users through cost effective solutions.

From the ICT point of view, the project incorporates advances in machine learning techniques and semantic analysis methods to make the robot more personable, useful, and accepted by end users [25].

The challenges that the project tries to address as highlighted in [26] concern:

1. Effectively assessing persons with dementia in the community provided they are suitable users for the robot (especially in countries with less developed community care structures).
2. Finding optimum trade-off between the needs and preferences of caregivers and end users while most efforts so far are focused solely on the caregivers.
3. Identifying meaningful activities and potential forms of achieving social connectedness that will add genuine value to the daily life of a person with dementia.
4. Designing a dementia-friendly interface that allows for a sufficiently comprehensive range of functionalities without being overwhelming or disorienting for a person with dementia will be essential for the successfully implementation of a genuinely empowering use of the technology.
5. Realistic assessment of the benefits of robot assisted care over traditional approaches to care, without implicit endorsement of a technological imperative.

MARIO claims to offer opportunities to progress beyond the current state of the art in the five following innovation areas:

1. Integration of robot semantics with existing structured and unstructured data, leveraging on current data integration practices such as the linked data principles, W3C semantic web standards Resource Description Format (RDF), SPARQL, and rule interchange format (RIF), semantic web-oriented machine reading, and ontologies.

2. "Entity-centric" knowledge management: each entity and its relations have a public identity that provides a first access to the knowledge consumed by robots. Such identity is given by resolvable URLs that use simple Web and Internet protocols to provide useful knowledge as a representative of real world entities.
3. Introduction to reading/listening semantic-web-oriented machine in robots.
4. Development of an ontology network using the Ontologies for Robotics and Automation. The network will evolve and expand by integrating ontologies emerging from interaction with assisted human, sensors, or with other robots.
5. Ability to advance robot knowledge by learning new ontology patterns from its experience with users and the robot network eventually in place.

MARIO tries to address the needs for modularity and flexibility through smartphone's application community. Developed applications can be tailored to user's needs and characteristics. In that sense, MARIO is expected to deliver flexibility, modularity, and increased system's acceptance by the users. From the IoT perspective, MARIO invests on the semantic interoperability through the usage of ontologies that deliver data and their semantics at the same time leaving the communication technologies aside. As expected, concrete conclusions about the system's overall performance will come up after the respective evaluation process.

ENRICHme The ENRICHme project (ENabling Robot and assisted living environment for Independent Care and Health Monitoring of the Elderly, Grant Agreement no: 643691) [27] aims to improve the quality of life of elderly people suffering of MCI in the context of AAL for the ageing European population at greater risk of cognitive impairment, frailty, and social exclusion, using a service robot within an assisted living environment.

The project utilizes robotic approaches in order to develop engaging solutions for HRI that automatically learn from long-term experience and adapt to the elderly person in terms of perceptual and cognitive capacity. In that context, it introduces three levels of intelligence: robot, ambient, and social intelligence. These three key concepts are realized in the project through a robot that encompasses safe navigation, monitoring, and interaction with the person along with home automation and ambient sensing for long-term monitoring of human motion and daily/weekly/monthly life activities (in relation to the use of RFID tagged objects around the environment). Figure 14.3 demonstrates an abstract view of the system's architecture. The figure highlights the components of the intelligent environment of the elder (ambient, robot, and social intelligence) along with their interconnections.

Two in-depth validation trials will be carried for the overall scientific assessment of the ENRICHME system aiming at identifying the potential impact of the system in supporting the active and healthy ageing of European citizens. Data on system sensibility and sensitivity will be compared with those already available in the literature and current elderly housing facilities. Physiological indexes will be analyzed versus other parameters (e.g., motion, behavioral, clinical, video analysis,

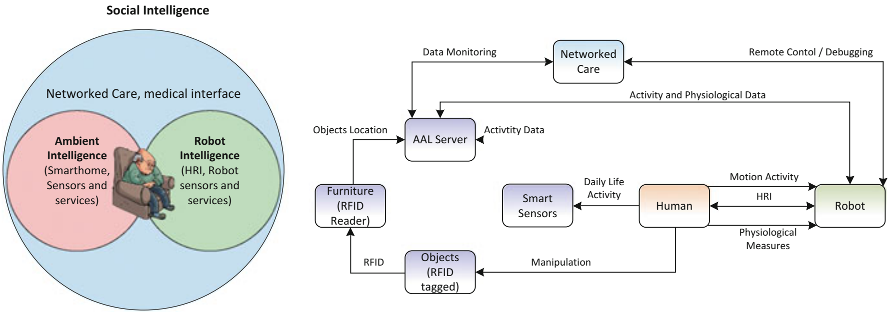

Fig. 14.3 The ENRICHme system

and ethnographic observation) to check if the collected information coincides with and brings new insights into clinical and HRI situations.

RADIO The RADIO project (Robots in Assisted Living Environments: Unobtrusive, efficient, reliable and modular solutions for independent ageing, Grant Agreement no: 643892) [28] develops an integrated smart home/assistant robot system, attempting to increase the levels of acceptance and unobtrusiveness. RADIO objectives are focused on using the integrated smart home/assistant robot system as the sensing equipment for health monitoring with sensors that do not need to be discrete and distant or masked and cumbersome to install. Instead, sensors will be realized as a natural component of the smart home/assistant robot functionalities. The key ICT advancements of the RADIO project can be summarized in:

1. Integration of unobtrusive medical sensors
2. Heterogeneous networking and architectural solutions in the robotic and smart home domain
3. Design for usability by users not familiar to technologies
4. Scalable architecture for wide area application and heterogeneous components

The conceptual architecture schema as depicted in Fig. 14.4 highlights the three major interconnected planes of the system. Namely, the RADIO system consists of the end user's environment, the care giver's environment, and the care institution environment. Each plane contains several sub-modules that deliver their functionalities to the respective plane [29].

In the context of RADIO, the smart home service and the IoT platform are viewed as a single solution, however, the IoT platform has ICT resources that can be exploited aside from the smart home service, and hence by other ICT resources of the RADIO solution. Those resources are exposed as a RESTful API. The core services currently provided by the IoT platform are Sensor Service that is mainly responsible for managing the data and the status of the sensors and actuators of the respective deployment; Event Service that provides real time communication between the IoT platform and the smart home. RADIO Ecosystem services of

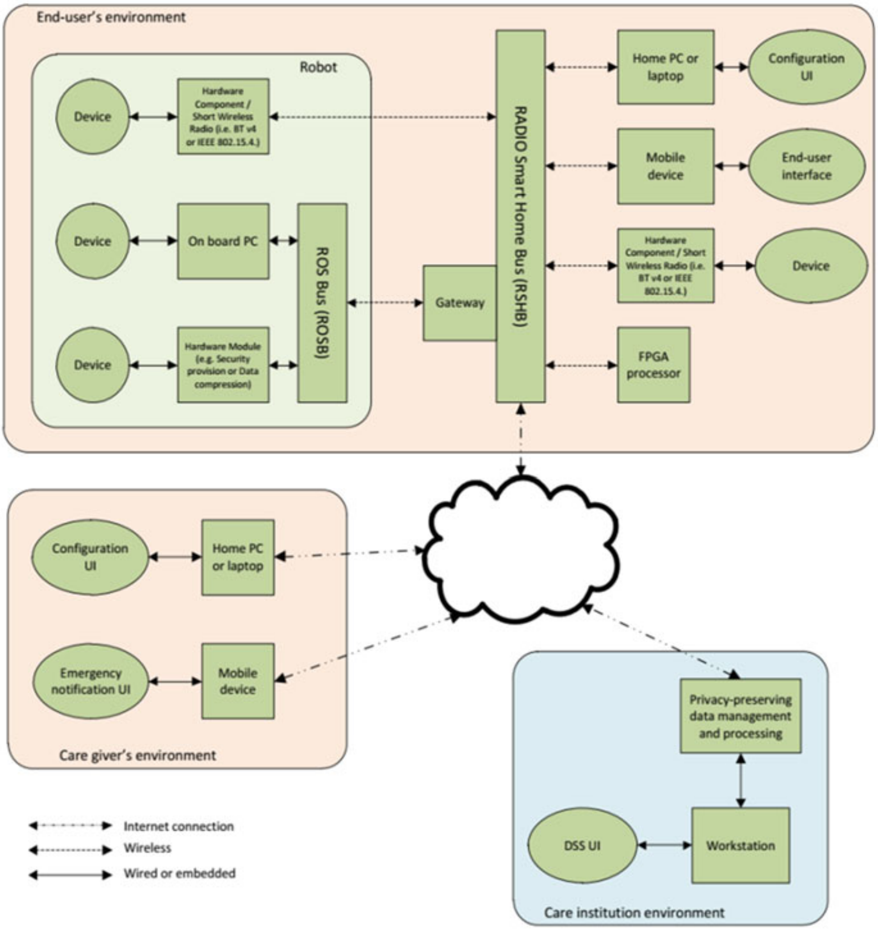

Fig. 14.4 Conceptual architecture of the RADIO system

automation and notifications will build upon those services, thus, in the following, we provide some context of how those services currently operate.

ROBOT-ERA The objective of the Robot-Era project (Implementation and integration of advance Robotic systems and intelligent Environments in real scenarios for the ageing population, Grant Agreement no: 288899) [30] is to develop, implement, and demonstrate the general feasibility, scientific/technical effectiveness, and social/legal plausibility and acceptability by end users of a plurality of complete advanced robotic services. These services will be integrated in intelligent environments, which will actively work in real conditions and cooperate with real people and between them to favor independent living, improve the quality of life, and the efficiency of care for elderly people.

ROBOT-ERA aims to enhance the quality and the acceptability of current robotic services and deliver new functionalities and services with increased performance. Its scope is pursued by exploiting previous knowledge on robotics and ambient intelligence technologies, cognitive-inspired robot learning architectures, elderly user-needs, and methodology of design for acceptability. These keystones are fundamental for the real deployment in order to find the most appropriate and successful solutions and overcome actual barriers to the exploitation of robotic services [31, 32].

The system intends to provide a personalized medical support to the users in a continuous manner, by leveraging the use of companion robots, distributed sensors in the environment, and a cloud platform. Exploiting the cloud robotics paradigm, computation-intensive tasks are assigned to the cloud. Therefore, access is achieved to a vast amount of data and the storage capabilities are increased. The indoor user localization and environmental monitoring algorithms are developed and offloaded onto the cloud considering the Software as a Service (SaaS) paradigm. This architecture improves the robot's functionalities without increasing the on-board computational load. Furthermore, different users and robotic agents are able to use the proposed services not being preoccupied about software maintenance. The list of the implemented SaaS that the project offers is reported below:

1. User indoor localization based services
2. Care reminding services
3. Environmental monitoring services

Modern cloud approaches are also applied in the ROBOT-ERA project through the SaaS model. SaaS, as leveraged by ROBOT-ERA, has become a key requirement for the evolving IoT solutions. The applicability of the system along with acceptability rate from the users will be tested during the pilots that will be performed in Peccioli (Italy) and Örebro (Sweden).

14.4 Maturity Analysis of AAL IoT Developments and Platforms

Having analyzed the technical and the societal objectives for each EU funded project, in this section we illustrate the in-field trials and planned use-cases of each project. For a fair and meaningful comparison, we narrow down the set of projects to those that are based on mobile robotic platforms for AAL environments. This leaves at our disposal five projects: RADIO [28], RAMCIP [20], growmeup [22], Mario [24], and ENRICHME [27]. Note that in this selection we include only active projects.

The purpose of this section is to reveal how the use-cases are selected, what is the common ground and the differences between the selected use-cases among the projects and eventually if there are use-case scenarios that are overlooked by the projects' workplan. The reason that we concentrate in the selection of the use-cases and the in-field trials is that these aspects of the projects represent a first-class metric for validating the technology readiness level (TRL) produced in each case. Below is our characterization for each project.

Finally, we have to mention at this point that our assessment is restricted to the information that is available in the corresponding projects' websites (including related information such as press releases, public deliverables, and project presentations). Any aspects of the projects that are not covered in their websites and probably described in the detailed technical annexes of the projects are out of scope for this chapter.

RADIO The RADIO project sets forward a novel approach to acceptance and unobtrusiveness in AAL environments. The underlying idea is that the sensing mechanism is not discrete but it acts as an obvious and accepted part of the user's daily life. More specifically, the sensing mechanism consists of an integrated smart home and the assistant robot system. According to RADIO, the robotic system must be considered as an unobtrusive "pet" and in this way, sensors do not need to be discrete and distant or masked and cumbersome to install. In other words, the sensing mechanism must be perceived as a natural component of the smart home/assistant robot functionalities.

The target population of RADIO technology is elderly people without any significant physical or mental impairment. By collecting and analyzing behavioral data, doctors can diagnose cognitive impairment symptoms early and take timely remedial actions. As such, the end users are able to maintain their independent life, prolong the time spent at home, and improve their quality of life. In RADIO, the robot also acts as the contact point for home automation conveniences, such as lights that can be switched on and off. Additional activities of daily life (ADL) and mood recognition methods ranges from the time spent out of the house or carrying out a given activity in it, to sleeping patterns, to recognizing whether the end user has changed clothes, washed, or other crucial indications required by the doctors. Finally, the RADIO robot is designed to recognize the mood of the users by means of both speech and facial characteristics analysis.

The RADIO approach will be evaluated at actual elderly care facilities and under realistic conditions at clinical partners' premises. Moreover, technical testing is also planned in two full-scale smart home apartments with multiple rooms. In particular, the RADIO consortium includes three clinical piloting partners that will run four sets of experiments in three phases. The first phase, called formative phase, will be carried out in an early stage of the project with elderly end users in a hospital dedicated to neuro-motor rehabilitation of patients. The second phase, called intermediate phase, will run in the same hospital, while the third phase, called summative phase, includes two sets of experiments: one at a healthcare provider and geriatric center and one at the private homes (outside of any medical care institutions) of end users who have volunteered to participate in the RADIO piloting plan.

Overall, it can be considered that the RADIO project includes a rich piloting plan that is sufficient enough to ensure a mature end solution. This is because the clinical objectives of the projects will be tested in three different environments with different parameters and requirements, while technical objectives will be further validated in two smart home environments. What is also interesting is that the piloting plans are spread across the whole duration of the project allowing a complete and iterative evaluation of the RADIO system. Apart from the above objectives, installing the RADIO in different environments and premises will also validate the flexibility and ease of installation of the prototype.

RAMCIP The RAMCIP project follows a different mentality. It is based on robotic assistant at home; in contrast to the RADIO approach in which the robot acts more as an "observer." As noted, the target population in RAMCIP is patients with MCI and dementia. The approach relies on a robotic platform consisting of an autonomous moving robot with an on-board touch screen and dexterous robotic hand and arm. The robot is considered as a service-centric machine with cognitive functionality. This functionally is driven through modeling and monitoring of the home environment, the user and other co-located persons, allowing the robot to take optimal decision regarding when and how to provide assistance.

In essence, the RAMCIP project aims to develop a service robot (i.e., a home assistance to the user) capable to understanding the behavior and activities of the monitored persons. The project also deals with providing entertainment functions to the users, e.g., access to social media, teleconferences with relatives or caregivers as well as other, more practical assistive functionalities such as bringing objects to the user or picking up objects from the floor.

The RAMCIP project includes a detailed demonstration/validation plan with multiple pilot trials. In the foreseen trials, elderly people will be assessed by medical doctors and psychologists in order to be categorized into two groups: the control group and the clinical group. The patients suffering from MCI and Alzheimer's disease (AD) will be assigned to the clinical group. The control group will consist of normal elderly persons and this group will be used to assess the normal person–robot interaction. With this approach, potential problems related with normal aging process will be defined and separated from MCI/AD dedicated problems. This is of paramount importance and within the RAMCIP project, a detailed analysis is performed to study the inclusion/exclusion criteria of each group.

The evaluation of the project's advances will be performed in two pilot sites. More specifically, in two neurological instructions specializing in several neurodegenerative diseases such as Alzheimer's disease, dementia, multiple sclerosis, and epilepsy. It can be considered that the field areas covered by the piloting partners are capable to specify/validate/demonstrate the user-centric technology of RAMCIP project. Moreover, the project set forward a unique approach to improve the social life of the patients. This has a real social impact since this is the main and most important problem in the target patients group of the project.

GrowMeUp Similar to the RAMCIP project, the GrowMeUp target is to build a service-centric robotic platform aiming to increase the years of independent and active/autonomous living, thus the quality of life of older persons. In contrast to the RAMCIP project, the target population group is people with light physical or mental health problems (at the age of 65+) who live alone at home and can find pleasure and relief in getting support or stimulation to carry out their daily activities over the ageing process.

In more details, in the GrowMeUp approach the robotic system will be able to learn the older persons needs and habits over time and enhance (‘grow up’/scale up) its functionality to compensate for the elder’s degradation of abilities, to support, encourage, and engage the older persons to stay longer active, independent, and socially involved while carrying out their daily life at home.

The envisioned technology heavily relies on machine learning mechanisms that will enable the GrowMeUp service robot to extend and increase its knowledge continuously over time. In addition, cloud based technologies are utilized to share and distribute the gained knowledge with multiple other robots, so that other robots making use of the cloud, can learn from the experience of each other and thus increase their own functionality/competencies and at the same time reduce learning effort. The daily activities support will be provided in a human like way characterized by behavior and emotional understanding, intelligent dialoguing, and personalized services provision.

The GrowMeUp prototypes will be tested in one big healthcare site that includes fully operational apartments and in the private homes of elderly people managed by a home care service provider. The two trials have been carefully selected so as elderly persons can live with the greatest possible independence and activity. The trial workplan is organized in two main phases: the pre-trials and the final-trials phases. Both phases will last for a remarkably long duration (3 and 9 months, respectively) revealing that the project follows an iterative and thorough evaluation plan. In other words, the project workplan includes ample room to identify new user needs and requirements, to suggest corrective measures to any encountered problem, and finally to propose refinements or use-case scenarios’ adaptations.

It is important to note that the GrowMeUp trials involve a multidisciplinary team including technical directors, social workers, social animators, psychologists, nurses, and direct action helpers. Also during the final trials, for each one of the elderly, a virtual care team will be assigned consisting of minimum three carers and one younger person (family relative or volunteer at the end user institution in the age of 15–18). As such, it can be considered that the project has a sustainable exploitation strategy since the generated technology will be validated by a large and multidisciplinary team in real environments and for a long duration.

MARIO The MARIO project will also build a service oriented robotic platform. The aim of the project is to provide a solution to loneliness, isolation, and dementia in older persons. The underlying idea of the project is to increase the self-perception and brain stimulation of monitoring elders through the robot. Similar to the previous projects, MARIO includes an extensive and long running piloting plans that are overlapped with the validation and R&D activities of the project.

There are three piloting partners in the project namely, a nursing unit, a social care and community support unit, and a hospital unit specializing in comprehensive geriatric assessment.

Overall, the project has a clear commercialization strategy and specific effort is devoted to bring the MARIO solution to the end users through market deployment, e.g., by addressing licensing and integration aspects. As also noted, this direction is also supported by the fact that MARIO will set forward a framework for receiving "robot applications" similar to the app community for smartphones. As such, this will enable the robot to perform new functionalities over time, improve usefulness for the end users while lowering costs.

ENRICHME As in the previous three projects, the ENRICHME project relies on an interactive, service-oriented, and mobile robot. The target population group is elderly people suffering from MCI. As noted, the project relies on three main pillars: robot, ambient, and social intelligence. These three concepts are realized through a robot with safe navigation, monitoring, and interaction with the person along with home automation and ambient sensing for long-term monitoring of human motion and daily/weekly/monthly life activities. In essence, a prime target of ENRICHME is to act as an enabling tool to enrich the social activities of the patients and as a result their quality of life.

The project includes two piloting phases: testing in AAL laboratories and validation at the elderly facilities. The first one will be performed in two different sites and its aim is to provide user feedback to the development activities of the project in order to improve the final prototype. The second one will be performed in three different sites and its aim is to offer the final assessment of the ENRICHME prototype. It is important to note that all trial sites will be provided by the project partners. Another important aspect is that the final validation phase will run for 12 months in three different sites simultaneously.

A Critical View Although the analyzed projects have different technical and societal objectives and in the most of the cases different target population groups, the common ground in all of them is that they include a rich and long running piloting plan. More specifically, in all cases the piloting/trials approach includes multiple phases that are spread across the whole duration of the project. This common to all projects approach ensures, to the extent that it is possible, that the projects will deliver a mature and close to market technology.

Another common parameter that must be highlighted is that the consortia include the correct balance between ICT and medical/clinical experts. The largest number of the medical/clinical partners is in the ENRICHME projects (five partners in total). Among all projects, almost 35 % (on average) of the partners belong to the medical/clinical field. This is of added value, since the end solutions delivered by each project will be assessed by real-life end users, namely not only by elderly persons, doctors, and nurses but also by social workers, psychologists, and any kind of direct action helpers and caregivers.

While at the time of writing the mentioned projects are running for almost 1 year, it would be interesting to repeat the current analysis at the end of the lifetime of the projects. This will allow us to put the results and achievements of each project side-by-side and draw more concrete results and conclusions about this relatively new field of research, i.e., robotic assistance in AAL environments. Such evaluation will be interesting to be performed in all aspects of the projects (apart from the achievement of the technical objectives) including commercial achievements, achievements in medical assessment technology, etc.

14.5 Conclusions

This chapter presented how the IoT paradigm is realized on the AAL domain through a thorough study of EU funded projects. Initially, it has been highlighted the societal impact of the AAL advancements and how they are benefitted by the IoT evolution. Current trends are captured by restricting the survey on recent projects that five of them are still active and one of them has been recently completed. The projects have been described based on the objectives they address as defined by the respective calls. The main scope of the chapter was to identify and highlight the technological pillars that IoT paradigm shares with the AAL domain along with the respective ICT and societal advancements. A big part of the chapter was dedicated on the presentation of the use-cases and the planned in-fields trials of each project. Thereby, a primary evaluation of each project's TRL level has been attempted.

References

1. European Commission, *The 2012 Ageing Report. Economic and Budgetary Projections for the 27 EU Member States (2010–2060)* (European Economy, Feb 2012)
2. T. Panagiotakopoulos, A. Theodosiou, A. Kameas, Exploring ambient assisted living job profiles. Proceedings of the 6th International Conference on Pervasive Technologies Related to Assistive Environments, 2013
3. Centers for Disease Control and Prevention, *Chronic Disease Overview: Costs of Chronic Disease*, http://www.cdc.gov/chronicdisease/
4. A.M. Holmes, P. Deb, The effect of chronic illness on the psychological health of family members. J. Ment. Health Policy Econ. **6**, 13–22 (2003)
5. Centers for Disease Control and Prevention, *Chronic Disease Overview: Costs of Chronic Disease*, http://www.cdc.gov/nccdphp/overview.htm
6. G. Van Den Broek, F. Cavallo, C. Wehrmann, *AALIANCE Ambient Assisted Living Roadmap. Ambient Intelligence and Smart Environments* (IOS Press, Amsterdam, 2010)

7. N. Xian, X. Chen, C. Liu, Development of safety monitoring system based on WSN. Proceedings of the International Conference on Electrical and Control Engineering, 2011
8. O. Garcia-Morchon, P. Res, H. Baldus, The ANGEL WSN security architecture. Proceedings of the Third International Conference on Sensor Technologies and Applications, 2009
9. L.D. Ha, S. Ploix et al., Tabu search for the optimization of household energy consumption. Proceedings of the International Conference on Information Reuse and Integration, 2006
10. H. Albadi, E.F. El-Saadany, Demand response in electricity markets: An overview. Proceedings of the Power Engineering Society General Meeting, 2007
11. Y. Zhang, L. Sun et al., Ubiquitous WSN for healthcare: Recent advances and future prospects. J. Internet Things (2014)
12. D. Ruffieux, M. Contaldo et al., Ultra low power and miniaturized MEMS-based radio for BAN and WSN applications. Proceedings of the ESSCIRC, 2010
13. V. Potdar, A. Sharif, E. Chang, Wireless sensor networks: A survey. Proceedings of the International Conference on Advanced Information Networking and Applications Workshops, 2009
14. D. Culler, D. Estrin, M. Srivastava, Overview of sensor networks. IEEE Comput. **37**(8), 41–49 (2004)
15. M.E. Pollack, L. Brown et al., Autominder: An intelligent cognitive orthotic system for people with memory impairment. Proceedings of the Robotic Autonomous Systems, 2003
16. M. Spenko, H. Yu et al., Pamm—A robotic aid to the elderly for mobility assistance and monitoring for the elderly. IEEE Trans. Neural Syst. Rehabil. Eng. **15**(3), 327–335 (2006)
17. E.D. Mynatt, J. Rowan et al., Digital family portraits: Supporting peace of mind for extended family members. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2001
18. F. Vetere, H. Davis et al., The magic box and collage: Responding to the challenge of distributed intergenerational play. Int. J. Hum. Comput. Stud. **67**, 165–178 (2009)
19. PHC-19-2014, Advancing active and healthy ageing with ICT: Service robotics within assisted living environments, http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/668-phc-19-2014.html
20. RAMCIP Project, Robotic assistant for MCI patients at home, http://www.ramcip-project.eu/ramcip/
21. RAMCIP Project, Report on end-user requirements and use cases break down (Public Deliverable, 2016)
22. Growmeup Project, Specification of user needs analysis and design of behaviour patterns model, http://www.growmeup.eu/
23. Growmeup Project, Specification of overall system architecture and security and privacy infrastructure (Public Deliverable, 2016)
24. MARIO Project, Managing active and healthy aging with use of caring service robots, http://www.mario-project.eu/
25. M. Mongiovì, D.R. Recupero et al., Semantic reconciliation of knowledge extracted from text through a novel machine reader. Proceedings of the International Conference on Knowledge Capture, 2015
26. H. Felzmann, K. Murphy et al., Robot-assisted care for elderly with dementia: Is there a potential for genuine end-user empowerment? Proceedings of the International Conference on Human-Robot Interaction Workshops, 2015
27. ENRICHme Project, Enabling robot and assisted living environment for independent care and health monitoring of the elderly, http://www.enrichme.eu/
28. RADIO Project, Robots in assisted living environments: Unobtrusive, efficient, reliable and modular solutions for independent ageing, http://www.radio-project.eu/
29. C. Antonopoulos, G. Keramidas et al., Robots in assisted living environments as an unobtrusive, efficient, reliable and modular solution for independent ageing: The RADIO perspective. Proceedings of the International Symposium in Applied Reconfigurable Computing, 2015

30. ROBOT-ERA Project, Implementation and integration of advanced robotic systems and intelligent environments in real scenarios for the ageing population, http://www.robot-era.eu/
31. M. Bonaccorsi, F. Lauraa et al., Design of cloud robotic services for senior citizens to improve independent living in multiple environments. J. Artif. Intell. Soc. Econ. (2015)
32. P. Dario, A synoptic glance and main objectives. Robot-Era presentation, 2013