Enabling an Internet of Things Framework for Ambient Assisted Living

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Abstract. Ambient Assisted Living (AAL) technologies hold great potential to meet the challenges of health, support, comfort and social services in European countries. After years of research, innovation and development in the field of health care and life support, there is still a lack of good practices on how to improve the market uptake of AAL solutions, how to commercialize laboratory results and prototypes and achieve widely accepted mature solutions with a significant footprint in the European market. The Internet of Things (IoT) consists of Internet connected objects such as sensors and actuators, as well as Smart appliances. Due to its characteristics, requirement and impact on real life system, the IoT has gained significant attention over the last few years. The major goal of this paper is to strategically specify and demonstrate the impact of the usage of IoT technology and the respect of IoT specification on the quality and future collaborative usage and extendability of deployed AAL solutions in real life.

Keywords: Internet of Things - Enabling Ambient Assisted Living - AAL for real life - new generation for AAL solutions

1 Introduction

Ambient Assisted Living (AAL) technologies hold great potential to meet the challenges of health, support, luxury and social services in European countries. In fact, supporting people in independent living using Information Communication Technology (ICT) is a great opportunity to solve the upcoming challenges. Different ICT as well as technical components, such as sensors or actuators are integrated in one system in order to make this possible used autonomously. The users can use it to participate in social and professional life more easily, secure, and independently. Even after years of research, innovation, and development in the field of health care and life support, there is still a lack of good practices on how to improve the market uptake of AAL solutions, how to commercialize laboratory results and prototypes and achieve widely accepted, mature solutions with a significant footprint in the European market. There is a chance to make Europe the largest region to adopt and align AAL and innovations from related fields.

From another side, the Internet of Things (IoT) is covering various aspects of the extension of the Internet and the web in the physical world, through widely spatially distributed devices with embedded identification, sensing capabilities and intelligent acting. In this perspective, the IoT will be more things-oriented, thus managing, deploying and coordinating in an intelligent way with sets of smart objects. This innovation will be enabled through the inclusion of electronics in everyday physical objects, making them smart and allowing them to seamlessly integrate into the global infrastructure of the physical Internet. This will lead to new opportunities for the ICT sector, paving the way for new services and applications are able to take advantage of the link between the physical and virtual worlds [29].

The major goal of this paper is to strategically specify and demonstrate the impact of the usage of IoT technology, the respect of IoT philosophy and system flexibility on the quality and future collaborative usage and extendability of deployed AAL system in real life. With respect to the previous vision, we must attire the reader attention that this paper will not address the impact of IoT on AAL from a theoretical laboratory perspective, but from real deployed AAL systems in real life one and therefore fitting the real life requirement, especially related to system extension, interoperability, personalisation and adaptation. Although the diversity and the high quality of the available AAL solutions, they have a main common factor which is their closed aspect [5]. Closed platforms are a software system, where only the service developers and/or provider have access and control over the applications. Closed systems are only accessible for specific, homogeneous and compatible applications or devices. Actually, most AAL products and technologies are coming as closed black box, where the end user can simply profit from the presented service as its original form [23]. Similarly, only the original developer is able to update and change the source code. From the point of view of connected devices, only pre-installed sensors and actuators can be taken into consideration. No new functionalities, sensors, or actuators can be straightforwardly added to the original setup [18].

The following paper is structured into section 2 which gives an overview about the IoT domain, architecture, advantages and related requirement. Section 3 discuss and argue the feasibility and foresee the added value behind the usage of IoT architecture for AAL solutions. Section 4 present the created AAL solution based on IoT system requirement. Section 5 perceives the impact from a real life perspective of the created solution. Finally, section 6 concludes the paper with the learned lessons and the future directions.

2 Advantages of an IoT architecture and derived requirements

Over the past decade, the field of IoT has gained much attention especially in the industry area due the technical operational capacity such a field might offer [11]. It aims to create a world where everything as intelligent objects are linked to the Internet and communicate with each other with a minimum of human intervention. The ultimate goal is to create "a better world for humans" where things around us know what we like, what we want, what we need and act accordingly without explicit instructions, which is well aligned with the ubiquitous computing philosophy.

The term IoT is used to cover the various aspects related to the extension of the network and the Internet into the physical world, through the deployment of a wide range of devices that are distributed spatially and typically integrate sensing, processing, and acting. As IoT is still in early development phase [21], the research there is still in its infancy [7]. Therefore, there are no standard definitions for technology operations. The following definitions are provided by different researchers.

- Definition by Tan et al. [25]: Things have identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environment, and user contexts.
- Definition by the European Commission [8]: The semantic origin of the expression is composed by two words and concepts: Internet and Thing, where Internet can be defined as the world-wide network of computer networks, based on a standard communication protocol, the Internet suite (TCP/IP), while Thing is an object not precisely identifiable Therefore, semantically, Internet of Things means a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols.
- Definition by Saint-Exupery [20]: The Internet of Things allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any path/network and Any service.

From an AAL perspective, the first definition seems to be the most suitable to enable the IoT for AAL. This definition encapsulates the AAL vision, especially related to devices, environment, context, and Ubiquitous Computing [6].

2.1 The essential characteristics of an IoT system

In this section, we will briefly highlight the characteristics of an IoT system. This is necessary, in order to specify the main criterion that an AAL system must fulfill in real-life to be an IoT compatible system .

- Intelligence: Where a context awareness framework must be part of the installed and deployed IOT-AAL system. It aims to Collect and transform the Row data to knowledge and reason about it in an intelligent way.
- Architecture: Internet of things architecture, with reference to [3] and [19], should make uses of a mixed architecture. Primarily there would be two architectures: event driven and time driven. Some sensors produce data when an event occurs (e.g. door sensor, motion sensors); the rest produce data continuously, based on specified time frames (e.g. environment sensor). Mostly, IoT are event driven where common rules are used in such systems.

- Complex system: The IoT architecture is composed of a big number of objects (sensors and actuators) that must autonomously interact with the corresponding environment and the related users. Newly added devices must be automatically recognized, added, and start providing their functionalities. The processing and interaction with the different things will depends on the added value provided by the different devices. In some cases, passive things will simply provide measurements. In other cases, objects may have larger memory, better processing, and advanced reasoning capabilities, which make them more intelligent.
- Size considerations: It is predicted that there will be 50-100 billion devices connected to the Internet by 2020 [24]. The IoT framework and the related system architecture need to take such a complexity in consideration and especially to en-sure the interaction among these objects.
- Time considerations: The real-time processing of the device data, the real-time recognition of several contextual situations, and the related decision must be ensured by IoT systems.
- Service-oriented architecture: Due to the requirement of an IoT system to be a distributed, flexible system, consuming resources as a service has become the most common approach [4]. Everything-as-a-service, especially based on platform is highly efficient, scalable, and easy to use [27].

2.2 Essential requirements of an IoT system

From a system level point of view, it can be seen that the Internet of things as a distributed system of things consisting of a very large number of smart appliances as producers and consumers of information. The ability to interface with the physical word is achieved through the presence of devices able to sense physical phenomena and translate them into a stream of information, or through other devices able to receive conceptual information and translate it onto actions.

From a service level perspective, creating, composing and integrating services or resources provided by smart objects, are the main challenges that must be addressed [16]. This requires the definition of an architectures and methods for virtualizing objects. This will requires the usage of a standardized representation of smart objects, thus hindering the heterogeneity of devices/resources. Similarly, it will require making use of methods for flawlessly integrating and composing the resources and services of smart objects into value-added services for users.

Finally, from a conceptual level, the IoT architecture and especially applications builds on three main pillars, related to the ability of smart objects to be identifiable, interactive and communicative.

2.3 The paradigm of IoT and system architecture

The Internet of Things was originally thought as extending the principles of the Internet as a network organisation concept to physical things. That is, things would get a unique ID, which is machine readable and an associated digital representation on the web [28]. Whereas ubiquitous computing was designed to make objects intelligent and create richer interaction, the Internet of Things was much more focused on virtual representations of automatically identifiable objects. Obviously, both concepts are important pieces of a future Internet and the IoT scope. In this regard, the IoT applications will requires interaction with heterogeneous sensors, aggregators, actuators, and a diverse domain of context-aware applications, while preserving the security and privacy. In order to meet the above requirements, the IoT will require the usage of a software platform, in this context called middleware, ensuring the abstraction to applications from the things, and offering multiple services. There have been a lot of researches towards building up this middleware addressing interoperability across heterogeneous devices serving diverse domains of applications, adaptation, context awareness, device discovery and management, scalability, managing a large data volumes and, privacy, security aspects of the IoT environment [22]. In fact, the middleware for IoT is required as it is very difficult to define and enforce a common standard among the diverse devices belonging to the different domains in IoT. Therefore, a middleware acts as a bond, joining the heterogeneous components together, providing application programming interfacing (API) for the physical layers and required services to the applications, thus hiding all the details of diversity. A middleware will also ensure the unification of the sensing framework, a formal modeling and representation of the real world, pluggable reasoning engines for high-level contexts recognition and delivery of runtime service composition mechanisms thus simplifying and empowering the development of context aware applications.

3 IoT and AAL

We must recall that the paper scope is not a specification or a contribution to the IoT domain, but mainly the extraction and synthesise of the major characteristics, requirements and best practice that IoT systems are using, thus enabling it for a successful deployment of AAL systems that link to the IoT ones.

AAL builds upon Ambient Intelligent, whereas the latter one aims at building digital environments that are aware of the humans presence, their behaviors and needs through a very rich in sensing, computing and actuation capabilities that are designed to respond in an intelligent way to changes in the environment and the user needs, in order to support them carrying out specific tasks. It builds upon the Ubiquitous Computing concept [**?**]. Aarts et al. [9] summarise the five key features that characterise an AmI system:

- Embedded: Networked devices are integrated into the environment.
- Context aware: System recognises the environment, related embedded devises, people and their situational context.
- Personalized: System can tailor itself to meet peoples needs and profile.
- Adaptive: System can change in response to people and environment changes.
- Anticipatory: System anticipates peoples desires without conscious mediation

Compared with the highlighted requirement of an IoT system in subsection 2.1, we can conclude that the Context aware, the Personalized, the Adaptative and the Anticipatory feature meets the intelligence requirement of IoT while the Embedded one corresponds the IoT complex system architecture.

Aligned with the privious analysis, Wichert et al. [1] stated that AAL applications area shares several factor with the IoT ones. Most AmI systems are based on the inclusion of sensing and computing capabilities embedded in the environment, where context-awareness is the key element for reasoning, both in AmI and IoT. Accordingly, one of the main focuses of research in AmI has been the development of reasoning techniques for inferring activities of users and devising appropriate response strategies from the embedded devices [2]. Due to the highlighted intersections, the IoT system architecture and specification with its awareness about real life system constraint and major facilities will enable the following concepts for AAL:

- Concept of integration of open scenarios, whereby new functions, capabilities and services need to be accommodated at run-time, without them having been necessarily considered at design time.
- Concept of self-configuration and self-organization, possibly cognitive, capabilities needed to provide this additional degree of flexibility.
- Concept of loosening coupling: a loosing link between devices, system, reasoners and interfaces will enable Plug-and-Play of devices, system flexibility and interoperability between the different component.
- Concept of system distribution: The assisted person environment is not restricted to specific location (eg. home), but might be extended to his car, hospital, green places... where linking the different distributed appliances will be with a major added value for a full awareness of the end user context and situation. Same requirement will fit the relation between different systems like the a local (e.g apartment) and a more global one (eg. building).
- Concept of adaptability to diverse contexts, with different resources available and possibly deployment environments changing over time.
- Concept of interoperability between the different system components.

With reference to the specified concepts and driven by the main advantages the IoT might bring real life AAL system in term of intelligence, flexibility, adaptability and distributions... the next section will highlight our contribution in terms of an IoT-enabled AAL system that has already been deployed in real life, showcasing the advantages and providing lessons learned.

4 uSmAAL: a real-life use case for an IoT-enabled AAL system

Supporting people in independent living using ICT is a great opportunity to solve upcoming societal challenges. Primarily these are related to the ageing of the European population where AAL solutions aims to increase the quality-of-life that causes increased demands on on comfort and luxury [10] [13] [14]. AAL technologies, Smart Homes, Smart Buildings and eHealth applications that are based on advanced IoT technologies may help in increasing peoples security, support, comfort and therefore reduce the consumption of resources associated to buildings (electricity, water). It can also improve the satisfaction level of inhabitants. Within the created system, a key role is played by sensors and actuators which are used to both monitor tenant security, increase comfort, optimize resource consumption as well as to proactively detecting the current needs of the users. Such a scenario integrates a number of different subsystems and hence requires a high level interoperability add to the ability to reason in a distributed and cooperative way to control the environment in order to ensure that decisions taken on the resources under control (e.g., switch on/off lighting, heating, cooling, etc.) are in line with the users needs and expectations. They are strictly intertwined to current or future activities of the tenants. Based on the prerequisites and collected requirements from one side, and the main gathered advantages of the IoT field in real life, the universAAL Smart AAL System (uSmAAL) has been created. It forms an open, flexible, reusable and easily expandable system for providing smart AAL services based on the open source platform universAAL [12]. The created AAL system follows the IoT architecture and incorporates the desired robustness, flexibility and extendability into its system architecture. The created system is running on top of the semantic open platform universAAL and is mainly composed of a middleware, a context awareness module, layers for flexible access, abstraction, and integration, and a set of sensors and actuators. The architecture is shown in Figure 1.

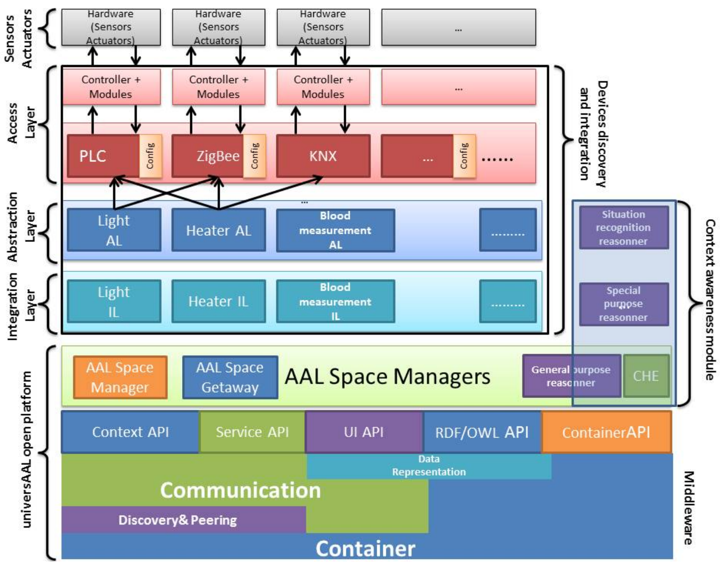

Fig. 1. uSmAAL System architecture

4.1 Sensing/Acting layer

From the IoT devices perspectives, all devises are characterized by a unique identifier and unique address mainly composed by the IP address of the related Gateway/controller add to the local device address. The different devices have different locations, characterized by different addresses and connection protocols (light, heater, presence sensors, phones, blood pressure...). Currently, the implemented system cover more than 1000 devices distributed in the different locations the system is covering. Its mainly composed by two components: actuators and sensors. The actuators represent hardware devices which can be controlled, e.g. lights, heaters, outlets, blinds, etc. This means it is possible to change the status of the device, by performing some interaction. This interaction can be performed by direct change of the actuator values, or automatically by the system itself (e.g. reasoning). In both cases the controller will perform an action which will result in the desired outcome. It may also be possible that an actuator is controlled manually like switching a lamp by pressing a button. If so, the controller will be automatically notified about such an action. The second component is represented through the sensors. A sensor measures values and registers modifications in the environment and notifies the controller about it. A sensor can before example a motion sensor, a light sensor, a temperature sensor or a CO2 sensor... Since sensors are measuring specific variables of the environment (temperature, CO2 value, etc.), they can keep track of the actual status of it. Thus they build the basis for specified rules and reasoning. For example reasoning like turning on the light in a room if there is movement at night, is based on the sensors for movement and daylight.

4.2 Device Discovery and Integration Layer

The universAAL Device Discovery and Integration is an abstraction layer able to represent and to facilitate the integration of sensors and actuators in the platform. From the analysis of the solutions adopted for the different network technologies, a common pattern is emerged as far as the architecture layering is concerned for the sensor and actuator networks integration. The created architecture is typically organized upon three sub-layers namely the Access, Abstraction and Integration, Figure 2.

Access Layer: The Access Layer is usually composed of a number of technology drivers, sometime already integrated in the operating system with well-defined API. There are two approaches generally followed to use the drivers API. In case of vertical solutions, a controller interacts directly with the specific remote devices through the drivers and sometime provides a user interface to configure the device. The creation of proxies can be automatized whether the technology supports a discovery mechanism, and notification of new devices joining/leaving the sub-network is provided. A controller or a gateway specifies a standard for the communication where different hardware devices, mainly in a smart environment, are connected to. Within the created AAL system, the access layer aims

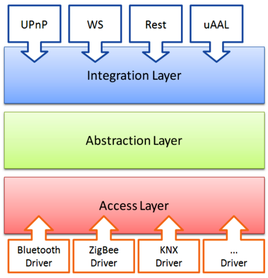

Fig. 2. universAAL Device discovery and integration structure

to establish the communication between the created IoT AAL Device abstraction layer and the concrete IoT appliances. Examples of implemented protocols are PLCs (Programmable Logic Controller) [15] KNX controller [17] or ZigBee controller. [30].

Abstraction Layer: The Abstraction layer aims to transforms the proxies, which are a flat and raw representation of the physical networked nodes installed in the Internet to more significant device objects, with an easier and intuitive interface for the developers. As the created system is profit from the semantic capability as a main interoperable enabler, the related abstract device ontologies are also defined, where the different objects will be characterized by different Uniform Resources Identifiers (URI). This layer is also occupied by a component integrator and discovery.

Integration layer: Finally, the Integration Layer publishes the proxys instantiated in the abstract layer by creating new endpoints according to a specific technology. Multiple end-points can be created for each sensor, thus providing multiple way of integrating sensor networks.

The three layers whether implemented on the same host machine or in a distributed system architecture describe a gateway solution adopted to map an IP-based devices (sensors and actuator) to virtual one. Through the installed uSmAAL AAL system, the Device Discovery and Integration layer has been implemented and aims to builds the interface between the real world and the Abstraction level of uSmAAL. This layer receives commands from the created AAL services and applications and translates them into low level ones depending on the addressed devices. This means if a specific device is turned on by some an AAL service, the layer will receives this command and redirect it to the correspondent device which, based on the hardware protocol, transfer the command to the addressed device. The other way around, if a device is manually turned on, the AAL service will be automatically notified, same in case of new devices. As this layer builds the bridge between the virtual word and the real one, it represents a core component of the system since it allow a complete separation between the Real word and the virtual one.

4.3 Context awareness module

The uSmAAL system is classified as a modular architecture, where its composed by several modules dynamically communicating to each others. The modular approach, as a key for future programming technology, aims to divide the set of complete application to basic modules. It intends to facilitate the re-combination of modules differently, thus offering several new sets of services. The recombination process is reinforced through several components developed within the universAAL system, mainly the context awareness framework. As previously discussed, context awareness plays a crucial role in any ubiquitous computing, AmI and AAL systems. The main goal of the context awareness is to improve the usability of applications through adapting their comportment dependent on the context. Ambient assisted living aims to anticipate user needs, according to the situation they are in, by means of semantically understanding the environment status and on-the-fly composition of different service components. This requires applications to be able to understand the context and situation the user is in. Such a theme has been addressed within the ambient intelligence, ambient assisted living and pervasive computing fields, leading to a number of solutions able to leverage contextual information coming from a number of sources. As observed till now, The created system is also enriched by a context awareness module able to semantically perceive the virtual device status.

The created module aims implement and extend the universAAL context awareness framework [26] to create new intelligent rules recognizing high level semantic context (situation) or a combination of AAL services to be executed under certain recognized circumstances. Figure 3 present the main component collaborating togethers thus ensuring a very flexible and complete context aware module for IoT.

IoT related Domains modelling: The created module aims to provides the capabilities for powerful high level reasoning based on semantic web technology. To do, a main first step consist on the semantic modelling of contextual data related to the addressed environment hardware. Also, as the IoT related application require a kind of virtualization of the different connected hardware to maximize its usage in real life situation, the created system has made an attempt to abstract and semantically model the whole environment with all its details, especially through the implementation of the following ontologies: Physical World, Profile, Furniture, Device, Service, Context and situation ontology...

Context Perception and Acquisition: The context perception and acquisition sub-module aims to instantiate the different created ontologies though the Devise discovery and integration layer, more specifically, the integration layer. This will held to the creation of a Knowledge base composed by the ontologies schema and the related instances.

Situation Management: Situation awareness can be seen as the capability of the different created entities to be aware of the situation changes and au-

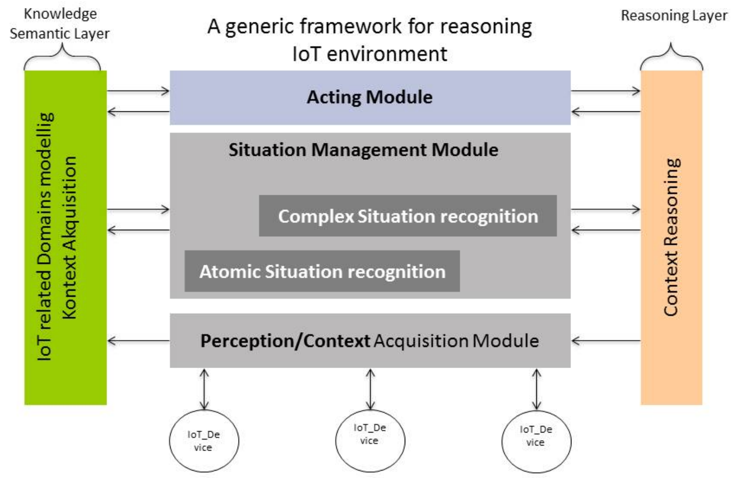

Fig. 3. A generic framework for reasoning IoT environment

tomatically adapt themselves to such changes to satisfy user requirements. In this concern, the Situation Management aims at recognizing different situations based on the available context. The different situation are divided onto simple ones if they are directly inferred based on specific context, for example an alarm situation might be recognized once a smoke context is created. In more advanced cases, complex situation like cooking activity might be inferred next to the combination of different context and/or simple situations. The continuing evolutions of the system in term of changes of the environment status makes the Situation Management one of the most desired IoT features to support the real life new circumstances thus ensuring the system adaptation and flexibility.

Semantic reasoning: The created AAL system aims to reason on available knowledge, thus coming with more mature information about the air quality, the persons activities, the environment status, the energy consumption the medical situation of the users... The new inferred information will be therefore used for further decision (eg. services execution, service combinations...).For example, one key technology installed behind the uSmAAL is the localization of residents in their homes and neighbourhoods. Once installed,the main recognized context will be related to the person position and posture. based on the basic context, more complex situation related the the user activities will be inferred. At a third level, many services can be placed together such as modular fall detection, intrusion detection, alerts when leaving the house or if the window is still open;

Warning if young children or people with dementia leave the bed, turning on the light when standing up from the bed, energy saving by turning of devices if the room is left and much more. Modular technologies will be the main key toward offering better services with minimum cost.

Acting module The uSmAAL created system is full based on semantic modelling of the different entities. Among them, the different available services are also abstracted and semantically modelled. After succeeding modelling the different devices and situations, the provisioning of contextual information as a key functionality for the IoT system will enables through the acting module a context/situation based actions as the output of the Reasoner. The acting module will grant that the right service will be executed.

4.4 universAAL open platform

The above highlighted uSmAAL AAL function and services are running on the top of the semantic open platform universAAL. The latter one has been built in a community effort since 2010 and finally established in January 2014 [26]. It provides the result as an open source software platform for AAL domain.The universAAL platform is an open-source software platform for the development, operation and marketing of AAL applications. It is offered with the Apache Software-License 2.0 and is especially designed for the development of open and distributed AAL systems. As a semantic open platform, and thanks to its unique features [12], universAAL will allow the creation of a sustainable ecosystem of AAL applications and services providers. From developer point of view, open platform-universAAL offer an assisted development environment to create AAL application based on the universAAL open platform, a distribution of AAL services over different processing components in a network and sharing information and composing services between all developed application and services. It allows also the coss-exploitation of the offered functionalities, facilitating the extension of an application in terms of functionalities and devices and simplifying the adaptation of a certain application to new circumstances

5 Perceived impact of IoT on the deployed AAL system architecture

The IoT, via its characteristics and requirement, has positively affected the created AAL system through changing the system architecture and increasing its flexibility and accessibility. More concretely, the system intelligence has been empowered through the inclusion of a context awareness module. In fact, transforming the Row data to knowledge and reason about it has increased the system flexibility, where the direct link between sensors and actuators has been avoided and alternated via an intermediate situations layer. Respecting the IoT characteristics has also empowered the system adaptability as all kinds of reasoning and acting are taking the end user and its current situation and profile in consideration and freely inferring the new actions or knowledge without any direct dependency with the hardware level.

As the IoT architecture support complex systems, the addressed Device Discovery and Integration layer has completely disconnected the high level AAL system, where all virtual devices and their related characteristics are created, from the low level one where the devices, their ip addresses and access protocol are defined. In case of AAL system for real life usage, the provision of the complex architecture has supported avoiding the system vendor lock through the ability of installing different devises from a verity of protocols seen from a high level as devices from the same type. It has also increased the system ability to extend its infrastructure, where new devices are automatically detected, included and updated in the high level part of the system. This is achieved while keeping a real time communication and reflection any the device event and time driven status.

The IoT concept of service oriented architecture has increased the system modularity where complex applications have been splitted to elementary modules with simply role. This has increases the system extendability, adaptability and flexibility of creating a verity of scenarios as a service composition.

Finally, having all projects, services and applications sharing the same semantic model and running on the top of the same platform has granted a full cooperation between the different entities without being syntactically or physically linked to each others. This has allowed a cooperative development add to a flexible importing and integration of other services.

After more than 6 months of operational system in real life, the implemented IoT vision within the uSmAAL system has proved a high flexibility with system integration, extensibility, adaptability, plug and Play and personalization.

6 Conclusion

Existing AAL systems are bound to already implemented services and special types of hardware devices. This lack of dynamic makes them rather unusable for the long term usage in a real life environment. Due to its characteristics, requirement and impact on real life system, the IoT has gained significant attention over the last few years. Through the made study between AAL and IoT characteristics, covered area and related requirement, we come to the conclusion that IoT systems not only fit most of AAL requirement and characteristics, but it offer also a good coverage to empower the AAL real life system chances to sustain and succeed face the dynamic and continuously requests for changes, adaption and extension add to the hardware related issues. The AAL system inspire its robustness from the implementation of the IoT characteristics, mainly from Intelligence, architecture, support of complex system, scalability, real time processing, service oriented Architecture and Middleware based implementation. The created uSmAAL system has made a successful attempt to adapt the closed AAL system to an IoT one. This experience has enriched our expertise, thus opening the door a new generation of Ambient Assisted Living solution compared to the classic closed ones. We have made an attempt through the current paper to highlight the advantages of enabling the IoT architecture for the Ambient Assisted Living system, thus assuring the system flexibility, adaptability and extendability. Further future work will mainly articulate complex situation recognition in an IoT environment, impact of real life uncertainty of data on reasoning add to empowering the explicit interaction between the IoT enabled AAL system of the end users.

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