Infrastructural Support for Ambient Assisted Living

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Abstract. This work describes several infrastructure contributions aimed to simplify the deployment of Ambient Assisted Living (AAL) environments so that elderly people can maximize the time they live independently, through the help of ICT, at their own homes. Three core contributions are reviewed: a) a multi-layered OSGi-based middleware architecture which enables adding new environment monitoring and actuating devices seamlessly, b) an easy-to-use elderly-accessible front-end to comfortably control from a touch screen environment services together with a custom-built alert bracelet to seek assistance anywhere at any time and c) a rule-based engine which allows the configuration of the reactive behaviour of an environment as a set of rules

1 Introduction

By 2020, 25% of the EU's population will be over 65 [1][4]. Spending on pensions, health and long-term care is expected to increase by 4-8% of GDP in coming decades, with total expenditures tripling by 2050. However, older Europeans are also important consumers with a combined wealth of over €3000 billion.

Ambient Assisted Living (AAL) [10] is an initiative from the European Union to emphasize the importance of addressing the needs of the ageing European population by reducing innovation barriers on ICT with the goal to lower future social security costs. The program intends to extend the time the elderly can live in their home environment by increasing the autonomy of people and assisting them in carrying out their daily activities. Assisted Living solutions for elderly people using ambient intelligence technology can help to cope with this trend, by providing some proactive and situation aware assistance to sustain the autonomy of the elderly, be helpful in limiting the increasing costs while concurrently providing advantages for the affected people by increasing quality of life. The goal is to enable elderly people to live longer in their preferred environment, to enhance the quality of their lives and to reduce costs for society and public health systems.

Ambient Assisted Living fosters the provision of equipment and services for the independent living of elderly people, via the seamless integration of info-communication technologies within homes and extended homes, thus increasing their quality of life and autonomy and reducing the need for being institutionalised. These include assistance to carry out their daily activities through smart objects, health and activity monitoring systems including wearables as well as context-aware services, enhancing safety and security, getting access to social, medical and emergency systems, and facilitating social contacts, in addition to context-based infotainment and entertainment.

The ZAINGUNE research project [17] is our approach to address the objectives of the AAL initiative. This paper describes our efforts devising new middleware and hardware infrastructure in order to make the AAL vision reality.

The structure of this paper is as follows. Section 2 reviews some related work on earlier research efforts on ICT innovation for AAL. Section 3 details the multi-layered OSGi-based middleware infrastructure proposed by ZAINGUNE. Section 4 explains the interaction methods offered by our platform. Section 5 reviews the intelligence behaviour though reasoning offered by ZAINGUNE. Finally, section 6 concludes the paper and details some future work plans.

2 Related work

There have been quite a few attempts [3][6][12] to create middleware which aims to simplify intelligent environment deployment, configuration and management. Among them, quite a few have considered using OSGi [13], since it is a software infrastructure which ensures platform and producer independence and easy programmability. It provides an execution environment and service interfaces to allow the discovery and dynamic cooperation of heterogeneous devices and services to guarantee evolution and external connectivity, allowing us remote control, diagnosis and management. This feature set explains why OSGi is emerging as a de facto industry standard for gateways that monitor, control and coordinate the heterogeneous devices (sensor and actuators) dynamically deployed in any kind of environment (house, factory or car). For all these reasons, we have also decided to base our middleware contributions for AAL in OSGi.

Other researchers have noticed the importance of adding reasoning capabilities to OSGi servers in order to make them more suitable for AmI environment management. A current trend of this regard is to adopt OWL-based [15] semantic ontologies [2] as knowledge repositories upon which reasoning takes place. We have taken this very same approach in a project related to ZAINGUNE named SmartLab [18], concluding that adopting semantic technologies to model and reason upon context is a very powerful mechanisms, however, it does impose high processing power demands and does not adjust, for the time being, to the real-time response requirements of AAL environments. For that, in ZAINGUNE we have adopted a traditional non-semantic more responsive and efficient-computationally rule-based engine, i.e. JBoss Rules [16], appropriate for the reactive intelligence of our system targeted to be deployed in a real house in summer 2008.

Asterisk [5] is an open source/free software implementation of a telephone private branch exchange (PBX) originally created in 1999 by Mark Spencer of Digium. Like any PBX, it allows a number of attached telephones to make calls to one another, and to connect to other telephone services including the public switched telephone network (PSTN). The basic Asterisk software includes many features available in proprietary PBX systems: voice mail, conference calling, interactive voice response (phone menus), and automatic call distribution. Users can create new functionality by writing dial plan. To attach ordinary telephones to a Linux server running Asterisk, or to connect to PSTN trunk lines, the server must be fitted with special hardware. Digium and a number of other firms sell PCI cards to attach telephones, telephone lines, T1 and E1 lines, and other analogue and digital phone services to a server. Asterisk supports a wide range of Voice over IP protocols, including SIP, MGCP and H.323. Asterisk can interoperate with most SIP telephones, acting both as registrar and as a gateway between IP phones and the PSTN. In ZAINGUNE we use the Asterisk technology to offer phone-mediated communication among home inhabitants and external users and phone-mediated interaction between home inhabitants and their instrumented intelligent environment.

Research activity in AAL has not reached its peak yet, however, it is envisaged it will do so in the forthcoming years since the European Union has just launched the 1st call for proposals under the Ambient Assisted Living Joint Programme [1]. Next we review some past AAL-related projects.

In the Gator Tech House [9], a work carried out by Florida University, a whole flat is instrumented with an assortment of coordinated, through an OSGi central server, assistive smart objects such as a smart mailbox which notifies letter arrival, a smart front door which enables to check who is outside the door and to remotely open it or a smart bathroom with a toilet paper sensor, a flush detector or a temperature regulating shower. The overall goal is to define a set of smart objects and services which populate an assistive home for elderly people.

The PAUL (Personal Assistant Unit for Living) system from University of Kaiserslautern [7] collects signals from motion detectors, wall switches or body signals, and interprets them to assist the user in his daily life but also to monitor his health condition and to safeguard him. The data is interpreted using fuzzy logic, automata, pattern recognition and neural networks. It is a good example of the application of artificial intelligence to create proactive assistive environments.

Some relevant projects funded by EU FP 6 and which cover areas related to ZAINGUNE were PERSONA (http://www.aal-persona.org/), CAALYX (http://www.caalyx.eu/), netcarity (http://www.netcarity.org/) or Soprano (http://www.soprano-ip.org/).

3 A platform for AAL

The ZAINGUNE project aims to provide the software and hardware infrastructure necessary to intelligently control the automation elements, sensors and actuators placed at a home in order to provide assistive services for the elderly or disabled inhabitants of them in their daily activities. A multi-disciplinary team has been created to carry out this work composed of: a) a building automation engineering company expert on EIB/KNX [11] bus installations, namely TECDOA, b) a company expert on undertaking Asterisk-based VoIP deployments, namely IRONTEC, c) a public housing governmental company belonging to the Basque Government, namely VISESA, and d) a research centre specialized on defining context-aware intelligent middleware for AmI environments, namely Tecnológico Fundación Deusto.

ZAINGUNE proposes an OSGi-based middleware infrastructure powered by a rule-based reasoning engine which allows the coordination and cooperation of the sensing (presence detectors, door and window opening or flooding sensors) and actuation (lighting and environment control) devices attached to a KNX-EIB bus with the sensing mechanisms offered by a set of IP surveillance cameras and the control and alert VoIP-based telephony and messaging actuation mechanisms provided through an Asterisk installation. All these heterogeneous sensing and actuation tools have been integrated into a real environment, in this case a public housing flat targeted for renting to elderly or disabled people provided by VISESA in the city of Vitoria-Gasteiz.

The following sections describe the most remarkable ICT innovations for AAL brought forward by this project, which can be summarised as:

- A multi-layered middleware infrastructure offering an easy to program web service-based API and enabling the easy integration of heterogeneous sensing and actuation mechanisms, based on the OSGi standard.
- A rule-based engine which embodies the intelligence offered by an environment instrumented by the ZAINGUNE infrastructure. It enables the configuration of the services offered by an environment as a set of IF-THEN rules, rather than having to reprogram the logic for every specific environment or every change in such environments.
- An advanced control dashboard over a tactile screen based on the web-gadget metaphor easily accessible even by computer-illiterate users, such as most of current elderly people, which facilitates triggering of services both locally (in-house) or remotely (by family members, care centers or own users when they are away). Furthermore, a subset of the functionality accessible is also available through voice commands by means of Asterisk VoIP technology.
- A custom-built alert bracelet designed to accompany the user anywhere at any time within a house which offers an alert button through which emergency help can be sought and a screen through which relevant messages can be presented.

The ZAINGUNE OSGi-based infrastructure allows for the provision of intelligent home assistive services in areas such as security, prevention or energy efficiency, which are activated whenever the rules that model such behaviours trigger. Such environment behaviour rules encapsulate the intelligent reactivity of the environment and the conditions upon which such reactivity takes place.

4 A middleware for AAL

The AAL-enabling middleware infrastructure devised in ZAINGUNE is set to meet four different goals:

- *Heterogeneous device support*. Enable the integration of heterogeneous sensing and actuating devices dynamically and in the most fault-tolerant manner.
- *Assistive Environment as a set of Cooperating Services*. Abstract away the functionality offered by different devices using different protocols and offering very diverse functionality in the form of services which are easily combined and composed to give place to higher level more complex services.
- *Programmability through a SOA-based approach*. Offer a web service-based API which is easily consumable by third parties ignorant of the inner hardware and communication details of the infrastructure deployed within a home.
- *Accessibility through an easy to user web gadget-based and secure front-end.* Enable the dynamic generation of web gadget front-ends representing the environmental services offered either by the hardware devices deployed or by the combination of the services offered by such devices. Authorization is required to access such front-end. RFID-based authentication is used locally whilst traditional user/password-based login, remotely, in order to access the ZAINGUNE-instrumented web front-end. The flows of data are communicated securely by enforcing the use of an SSL channel.

Internally, this middleware, as it is depicted by Fig. 1, is composed of the following three layers: a) hardware device layer, b) software platform layer and c) application environment layer.

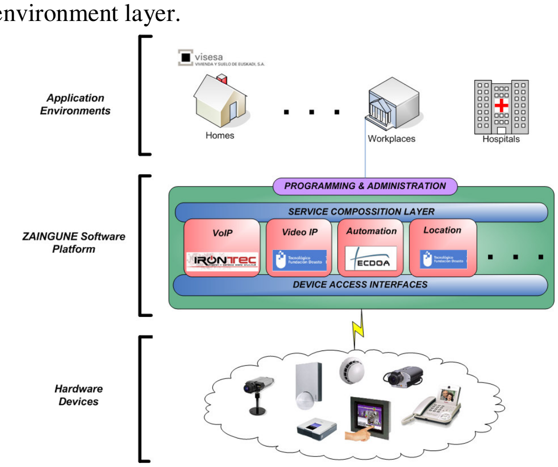

Fig. 1. Architecture of ZAINGUNE middleware infrastructure.

The *hardware device layer* is composed of the sensors and actuators which populate an environment. ZAINGUNE combines the capabilities of all the devices in Layer 1 in order to offer intelligent services to the end user. Examples of the standard and proprietary (custom-built) devices used are: a) EIB/KNX devices such as flooding sensors, door/window opening sensors, light intensity actuators and so on; b) VoIP Asterisk-compatible handsets and telephony PC cards and PTZ-enabled PTZ cameras; c) indoor location systems such as Ubisense, KNX presence sensors or RFID readers; and d) our custom-built alert bracelet device which combines an organic screen (µOLED-96-G1 of 4D Systems) with a WSN mote based on Mica2DOT capable of displaying messages broadcasted by other nearby sensing motes.

The *software platform layer* transforms the functionality provided by the devices managed by Layer 1 into software services which can be combined to give place to more advanced services. It is hosted in an OSGi server which controls the heterogeneous sensing and actuating infrastructure mentioned. Every device within an AAL environment (home, residence, hospital) is encapsulated as a bundle or execution unit within our OSGi environment. These bundles are in charge of intermediating among the applications layer and the service composition service and the hardware devices to which commands are issued through communication interfaces. Examples of the bundles created are: a) the EIB/KNX bundle which communicates through a BCU (Bus Coupling Unit) USB interface and using the KNXnet IP to KNX tunnelling server with an environment's KNX devices; b) the Video IP bundle which supports the control protocol used by D-Link DCS-5300G wireless PTZ surveillance cameras; c) the VoIP bundle which through an Ambient MD3200 card uses Asterisk software to communicate with the telephony system; d) the Ubisense bundle which connects with the Ubisense web service deployed in the machine where the Ubisense software server is located; e) the RFID bundle which enables RFID tag reading from OBID classic-pro 13.56 MHz mifare® RFID; and f) the alert bracelet bundle which controls an IP to WSN gateway in order to receive and send from/to data to our own users' alert bracelets.

Apart from the mentioned modules, several high level services have been defined which combine the functionality in the form of services associated directly to devices in the environment. Thus, high level services resulting from the combination of several basic services are produced. Examples of such are our hybrid location service merging RFID-based location details with the ubisense accurate location system or the voice synthesis and call management Asterisk-based service.

Finally, the software platform layer includes two essential components responsible of both managing the behaviour of all the deployed OSGi services and giving HTTP access to such functionality.

- **ZainguneController** – it is the core component of the internal ZAINGUNE server architecture. It manages and controls access to the components in the form of OSGi bundles which are supported by ZAINGUNE. The brain of such component is the Zaingune Rule Reasoner, based on the JBoss Rules open source system.

- **ZainguneServlet –** it behaves as an Web Service/OSGi gateway exporting the OSGi bundle functionality through Web Services. Furthermore, this component does not only allow third party applications to access ZAINGUNE internal functionality through SOAP but it also generates advanced web gadgets associated both to the basic (directly-mapped to devices) and advanced services (composition of several basic and advanced services). Fig. 2 shows the ZAINGUNE dashboard application depicting the gadgets generated by this component. It makes use of small size web gadgets in order to be accessible from different clients such as web browsers, tactile screens or mobile devices. Developed over the JavaScript library X (http://www.cross-browser.com/), it is completely modular, easing the creation and incorporation of new user interfaces for the management and control of new devices connected to the system.

The last layer, *applications environment layer*, includes all the possible application scenarios for the ZAINGUNE infrastructure. In our case, this infrastructure has been applied in offering assistive services in a public housing flat targeted to elderly or disabled people. However, the web service API offered by ZAINGUNE could be used to provide AAL services in hospitals, care centres or residences.

5 Multi-modal environment interaction

ZAINGUNE offers several mechanisms for users (and administrators) to act both locally and remotely over the environment:

- **Web gadget-based interaction**. This is the default recommended method of interacting with a ZAINGUNE-enhanced environment. An easy to use interface, namely Environment Controller, based on web gadgets with meaningful icons and big buttons enables the selection of the service category on which operations want to be carried out, namely *Help*, *Communications*, *Home* and *Surveillance*, and the services associated to such categories. Next, we explain the functionality included in each of those categories:
  - *Help*: a simple icon can be pressed by a user in order to seek help both from his family or a care centre. As a result of such interaction an automatic phone call is performed to a set of preconfigured phone numbers to which a pre-recorded risk alert message is delivered.
  - *Communication Management*. If offers the user several mechanisms to communicate with his relatives and friends. The default selected option if "call by photo" (see right hand side of Fig. 2), where an elderly person does not have to remember any phone number, it only needs to click on the photo of the person she wants to talk to in order to initiate a call to that person. On the other hand, more computer literate users may also check their email or send SMS message through this service category.
  - *Home control*. Selecting this category the user is presented with a list of the different rooms of her home. Selecting a room, all the devices and services offered within that room are offered to the user. As Fig. 2 shows,

aspects such as obtaining the current temperature, video surveillance of the room, door or window opening control or lighting luminance control can be undertaken from this section.

- *Surveillance control*. Through this category a user can have a look to the images captured by all the IP cameras deployed within a home. This can be useful for an inhabitant to check who is outside her flat and decide whether to open the door or not. Besides, it can also be useful for relatives or care centres authorized to supervise the house inhabitants.

- **Phone touchpad-based and voice-based interaction**. Both a remote and local user can interact with the environment by using preset keystroke configurations to control the environment elements. The same commands can also be issued through voice. This interaction mechanism is possible thanks to the integration of the Asterisk VoIP system with ZAINGUNE infrastructure. Besides, as a side effect of the wide deployment of VoIP phones over the house, we use their speakers to offer vocal feedback to users when alert situations take place.
- **Alert bracelet-based interaction**. Every inhabitant of a ZAINGUNE instrumented environment may carry an alert bracelet as the one shown in **Fig. 3**. This rather restricted custom-built device has been designed for only one purpose, i.e. assistance seeking or alert notification. Such bracelet could be improved by adding living signal monitoring sensors.

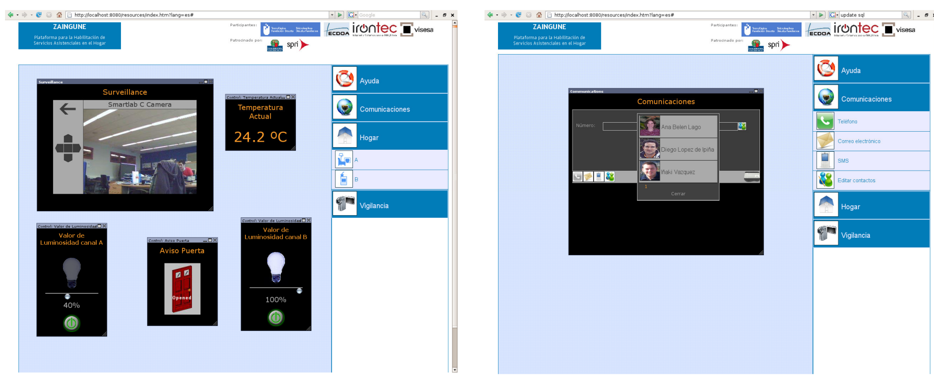

Fig. 2. ZAINGUNE Environment Controller (left) and “call by photo” (right).

Fig. 3. ZAINGUNE Alert Bracelet.

6 Intelligence through rule-based reasoning

One of the most remarkable features of ZAINGUNE's middleware infrastructure is the provision of a rule-based reasoning engine. The adoption of this engine offers two main advantages: a) it decouples environment configuration from middleware programmability. A user can simply reconfigure the behaviour of the environment by defining new rules, without having to change the source code, and b) it enables environment-initiated proactive reactions, giving answer to the user's current needs without always requiring their explicit request by any of above three mentioned interaction mechanisms.

Environment intelligence is encapsulated as a set of rules which trigger when certain sensorial situations are matched. For instance, if the flooding sensor deployed in the house bathroom is activated, the water source of the home could automatically be closed. In essence, in the rule-based paradigm used the left-hand-side part of the rules represents sensing conditions whilst the right-hand-side depicts actions to be undertaken when the left-hand-side situations are matched. These rules consist on the correlation of events coming from the sensorial infrastructure connected to the EIB/KNX bus and the set of IP cameras and VoIP telephones distributed though a home to determine the occurrence of certain situations and the activation, as a consequence, of a set of actions over the EIB or VoIP-based actuators deployed at home.

This rule-based paradigm is employed to configure the reactive behaviour of a ZAINGUNE-controlled environment. Some examples of the assistive reactions possible through ZAINGUNE, in our AAL application domain are: a) e*fficient management of energy resources*, b) s*ecurity at home* or c) *danger situation prevention*.

7 Conclusions and further work

This paper has described several ICT infrastructure contributions to enable an Ambient Assisted Living (AAL) environment. Research efforts such as ZAINGUNE should lead to the progressive adoption of ICT at elderly people's homes so that they can stay active and productive for longer; to continue to engage in society with more accessible online services; and to enjoy a healthier and higher quality of life for longer.

The main outcome of this work is an OSGi application server powered by a rule-based reasoning engine which integrates a KNX/EIB automation bus together with VoIP (through Asterisk) and VideoIP infrastructure in order to configure home environments which are aware and reactive to the special needs of people inhabiting them. Furthermore, different interaction mechanisms to request services from such application server are proposed such as a touch screen-based web gadget-based dashboard, an alert bracelet or VoIP phone-mediated interaction.

Future areas of work in ZAINGUNE will be: a) the development of a new low-cost easily deployable indoor location system based on WSN technology; b) the creation of a wizard through which the ZAINGUNE server can be parameterised for a new environment, c) the integration of workflow mechanisms to assemble complex advanced services from basic ones without requiring code modification and d) the evaluation of our infrastructure in a real home deployment.

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