A Novel Architecture and Process for Ambient Assisted Living – The HERA approach

Nikolaos Spanoudakis, *Member, IEEE*, Boris Grabner, Olga Lymperopoulou, Verena Moser-Siegmeth, Stylianos Pantelopoulos, Paraskevi Sakka and Pavlos Moraitis

Abstract—**This paper aims to present a novel architecture for the indoors Ambient Assisted Living domain. This domain synthesizes features from the home-based e-health and ambient intelligence scientific areas. The HERA system addresses mainly the needs of elderly in the early stages of the Alzheimer disease aiming to improve the quality of their home life and extend its duration. Other user categories are elderly suffering from cardiovascular diseases and diabetes. The novelty of this architecture is the use of the TV and Set-Top-Box probably already existing in a user's home (and the remote control with which the user is familiar) providing services from an application server integrating agent technology-based personal assistance.**

I. Introduction

The area of Ambient Assisted Living (AAL) emerged as the amalgam of Ambient Inteligence (AmI) and home based e-Health. The latter has been described as the combination of telehomecare and smart homes, i.e. the two-way communication between a healthcare provider and a patient in his/her place of residence and monitoring of residents who are not necessarily home care patients, such as, e.g. many elderly [5].

The HERA project (http://aal-hera.eu, see deliverable D2.2) aims to build an AAL system to provide cost-effective specialized assisted living services for the elderly people suffering from MCI or mild/moderate AD or other diseases (diabetes, cardiovascular) with identified risk factors, which will significantly improve the quality of their home life, extend its duration and at the same time reinforce social networking. In order too achieve this goal, HERA will provide the following main categories of services:

- Cognitive reinforcement services: These services enhance the cognitive functions of the users and aim at delaying the progression of the disease.
- Patient specific home care services: This service category includes social reinforcement services, reality orientation support services and services capable to monitor several disease risk factors.
- General home care services for elderly: This service category includes medication reminder services, information services as well as alarm services in cases of abnormal health conditions.

HERA will apply technological solutions for aiding users managing their daily lives. Thus, by using the HERA system, the time to be at home, rather than in an institution, will be prolonged and relieve them from visiting the specialists often, while keeping them able to perform their daily activities and social interactions.

This paper aims to present a novel system architecture and systems analysis process including a brief survey of the state of the art and a discussion on requirements gathering.

Manuscript received July 15, 2010.

II. Background

Ambient Assisted Living (AAL) is about creating products and services helping for the well being of a person through providing unobtrusive support for daily life based on context and the situation of the assisted person. It is currently one of the most important and better funded research and development areas, because of the increasing average age of the total population, especially in the developed countries, that can lead to creating large costs for the public, but also for individuals, for the intensive care for the elderly people at home and to reduced quality of life of these people as their social skills diminish ([4], [6]).

HERA is concerned with addressing the non-trivial task [6] of engineering an AAL system addressing the needs of the elderly suffering from moderate and mild Alzheimer Disease (AD) as well as from Mild Cognitive Impairment (MCI) and those elderly suffering from cardiovascular diseases and diabetes (referred to as users from now on). This application domain is about offering indoor assistance aiming to enhance the autonomy and quality of life of the user. A number of challenges are related to engineering such systems [4]:

- *Adaptability.* No two human beings have the same needs or everyday life habits. An AAL system must be able to adapt to a particular user.

- *Natural and anticipatory Human-Computer Interaction (HCI).* The people that need assistance very often have limitations and handicaps.
- *Heterogeneity.* AAL systems are expected to be capable of being integrated with several subsystems developed by different manufacturers (IT equipment, sensors, electrical equipment, etc).

Regarding home based e-Health, one of the trends within the field is the migration from technical prototypes to integrated, user-centered solutions and their evaluation. Moreover, there exist a number of hinders and restrictions when it comes to practical and sustainable use of it [5]:

- the lack of standards for combining incompatible information systems;
- the lack of an evaluation framework considering legal, ethical, economical, usability and technical aspects;

In order to address these challenges we need to review and assess the relevant state of the art. Adaptability depends on intelligent techniques and the agent technology brings ideas and techniques (originally from the artificial intelligence domain) mainly from the area of personal assistance field. HCI depends on system architecture for service instantiation and delivery and at the user's home multimodal user interfaces. Heterogeneity depends on the use of standards but also on architecture such as a service oriented architecture that claims to address this non-functional requirement. Finally, a user-centered approach with a well defined evaluation process must be followed.

Previous works in this area ([1], [2]) introduced agent based systems for AmI for assisting in taking care of people with Alzheimer but they on one hand required the aid of a nurse or caregiver and on the other hand used RFID tags [2] or NFC technology [1]. Both technologies are used to identify the location of the user using radio frequency identification technologies that require the use of sensors in different places at home and the use of another sensor on the user's body for identifying his location.

III. HERA Requirements Capture

The following general steps were decided to be followed for gathering the HERA requirements:

1) Read in the literature and analyze previous works and document a) User needs, b) Ethical issues and c) Regulatory framework
2) Perform semi-structured interviews with professionals (six to eight representatives)
3) Conduct discussions with each patient and possibly family care givers user group (10 representatives)
4) Possible second round of interviews with professionals

The main user groups for the HERA system are the patients and the medical personnel. Patients can be:

- Mild Alzheimer Disease (AD), older than 65 years
- Moderate AD, older than years
- Mild Cognitive Impairment (MCI), older than 65 years
- Elderly, older than 65 years
- People with Cardiovascular disease, older than 55 years
- People with diabetes without need of insulin > 55 years

The AD users are further divided in two user groups, as they have different characteristics, symptoms, needs and, possibly, requirements (see e.g. [3]). In brief:

- Mild AD: Frequent recent memory loss, particularly of recent conversations and events. Repeated questions, some problems expressing language. Depression and apathy can occur. Personality changes may accompany functional decline. Need reminders for daily activities, and difficulties with sequencing impact driving early in this stage.
- Moderate AD: Can no longer cover up problems. Pervasive and persistent memory loss impacts life across settings. Rambling speech, unusual reasoning, confusion about current events, time and place. Potential to become lost in familiar settings, sleep disturbances and mood or behavioral symptoms accelerate. Nearly 80% of the patients exhibit emotional and behavioral problems which are aggravated by stress and change. Need structure, reminders, and assistance with activities of daily living.

IV. HERA Architecture

For defining the system architecture the first step was to identify the stakeholders that participate in the HERA value chain along with their goals:

- *Elderly person or user.* Needs help to manage his daily life.
- *Health service provider* (Hospitals, Specialized centers). Needs to be assisted in its task to take care of a large number of patients.
- *Internet Service Provider (ISP), Portal, or Telecom Operator (telco).* Needs to expand its client base.

In order to satisfy the needs of the stakeholders, the requirements presented in the previous section and the challenges related to the development of such systems we identified the architecture shown in Figure 1.

- The TVset/Set-Top-Box (including a remote control) is the main user interface for the elderly.
- The Bluetooth medical devices (blood pressure measuring device, weight scales) allowing for medical data retrieval for further processing.
- The Health center medical personnel can access the patients' medical data but also upload new content.
- The HERA Services platform that hosts all the applications.

Thus, the HERA system software components will reside on the services platform. Its architecture is depicted in Figure 2. The Apache web server, an open source http server executed both on Linux and Windows is utilized along with MySQL Community Server RDBMS, which is generally available (no license required) and has all the necessary features needed by our application, plus the Java Database Driver Connector (JDBC Driver - Connector/J) that enables developers to build database applications in Java.

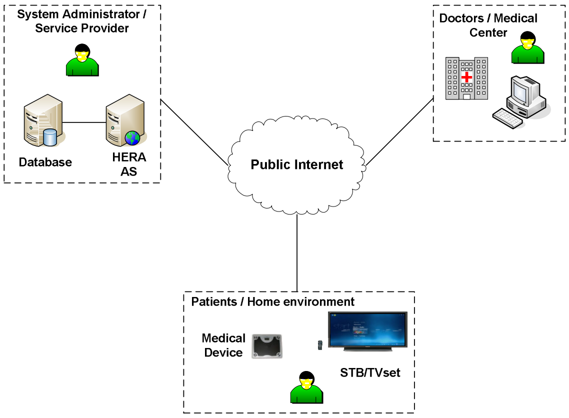

Fig. 1. HERA architecture depicting the stakeholders, i.e., the elderly/patients at home, the doctors and the medical personnel of a medical center and the service provider that can be a telecom operator or any portal.

The HERA system is built as a classical three tier Enterprise Java Beans (EJB) technology architecture (http://java.sun.com/products/ejb). In the middle tier (application logic) there are two groups of components, the first is the different services components and the second is the main HERA system modules. The idea is that the HERA system is a concrete system that allows service providers to hook in providing services. Thus the services logic can be on the HERA server side or at an external application server. Towards this end, the interfaces between the different HERA components are built using the common, standardized web services technology (http://www.w3.org). All communication interfaces are based on Internet technologies supporting standard security mechanisms including SSL, HTTPS and Secure Web Services.

The HERA platform will provide the following services:

- The cognitive reinforcement service aims to stimulate mental activity through playing specific games
- An asynchronous doctor-patient communication service allows the doctors to share information with their patients about the management of their disease, their age, or changes in everyday life.
- The blood pressure service allows the patient to monitor his blood pressure and share the data with his doctor
- A body weight monitoring service allows patients suffering from diabetes type 2, high blood pressure and/or other cardiac diseases or who are just overweight to monitor their body weight and share the data with their doctor
- The reminder service reminds patients about certain activities that they have to perform (such as take their pills or measure their blood pressure)
- A service that provides nutrition counseling to patients suffering from diabetes type 2 and/or have overweight or in general people that would like to have a nutrition tracking service. The service is used without the involvement of doctors

The main HERA components are the following:

- The "Notifications Module" is responsible for sending text based notifications to a specific HERA user.
- The "Measurements Module" is responsible for receiving measurements from the medical devices.
- The "AonTV Module" is responsible for interfacing with the IPTV commercial platform provided by Telekom Austria (AonTV).
- The "System Administration Module" is responsible for handling of creation/removal of user/doctor entries in the database and setting of the respective policies. It also maintains the nutrition counseling database.
- The "Authentication Module" is responsible for authenticating a HERA user.
- The "Policy Management Module" is responsible for accessing the database managing what information is available for every HERA component and user group.
- The "Multi-Agent System Module" is responsible for learning the user's habits, personalizing several services such as the pill reminder and the passive communication and for reminding him to do his daily tasks using Personal Assistant agents (see e.g. [7], [8]). The JADE framework will be used for developing this module (http://jade.tilab.com).

Finally the Human Machine Interfaces (HMIs) provide all the necessary graphical elements so that HERA platform users can access, view, modify their stored profiles and data.

V. HERA Evaluation Process

In order to better assist the evaluation process the HERA system deployment will take place in two phases. In the first one it will be deployed in the medical center's premises for evaluation by the medical personnel and for controlled interaction with the patients and in the second phase it will be deployed inside the users' homes for final evaluation. After the first phase deployment there will be an initial system evaluation, the bug reports and feature requests will be forwarded to the developers and a final HERA system version will be deployed before the start of phase 2.

For the trials at the site of the Red Cross (Rotez Krauz) in Austria, the goal is to select a number of 10-15 test-users. The health situation of the selected users will match into the elaborated use cases. A balanced sample will be intended.

At the Greek site, a total of 25 individuals (15 healthy elderly and 10 MCI patients, mild and moderate AD patients) will be selected to participate in the project trials phase. The user selection process will be performed on-site by the medical experts comprising the clinical staff of HYGEIA hospital.

Both pilot sites (Greek and Austrian) will deploy a helpdesk. Telekom Austria will offer 7x24 support for

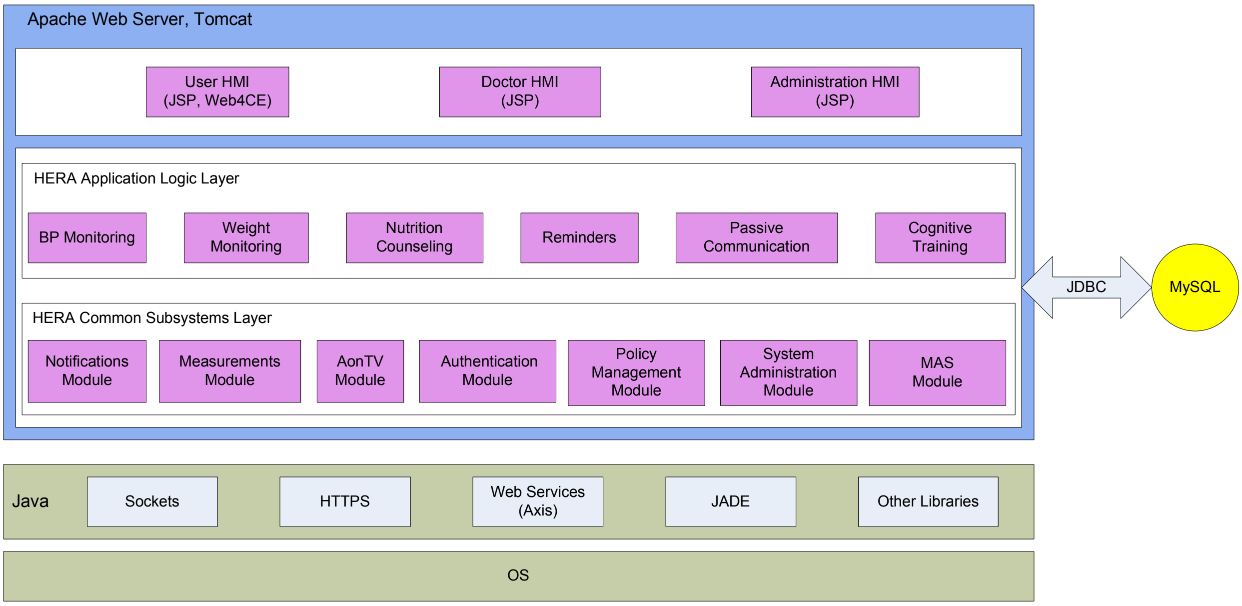

Fig. 2. HERA system three-tiered server architecture.

technical issues related to AonTV and equipment malfunctions through its standard customer care service. As far as support regarding the HERA applications operation and functionality is concerned, Telekom Austria will provide a helpdesk for the 2nd trials phase that will be operational for specific hours per day (e.g. 2 hours/day).

There will be two helpdesks for the Greek site. The main one will be the helpdesk at Hygeia hospital that is already operational. The Hygeia help center will be equipped with trouble shooting steps to be followed at each kind of problem. If the problem is not resolved then it will be forwarded to the Singular Logic helpdesk either through email or voice mail. If the call is made during the specific hours then it can be forwarded to the Singular help center.

The Singular Logic (http://www.singularlogic.eu) help center will be able to resolve questions regarding the web applications. It will also be able to identify the malfunctioning component and send bug reports to the developing partners responsible for the failure. The Singular Logic helpdesk will be operational for specific hours per day (e.g. 2 hours/day).

Finally, training material will be prepared in both Greek and Austrian languages regarding the deployed HERA services at each site.

VI. CONCLUSION

In this paper we presented the HERA system requirements capturing methodology and architecture along with the evaluation process. In order to address the challenges of adaptability, HCI, heterogeneity and user evaluation that are inherent in AAL systems, the following architectural choices are the novelty of this approach:

- Adaptability: Personal Assistant agents will be used for service personalization and adaptation.
- Natural and anticipatory Human-Computer Interaction (HCI): The use of the TV set is ensuring a quick learning curve for users.
- Heterogeneity: The use of a service oriented architecture allows the different sub-systems to be connected in a plug and play manner in a standardized way.
- A clear user-centered project implementation process

REFERENCES

[1] J. Bravo, D. López-de-Ipiña, C. Fuentes, R. Hervás, R. Peña, M. Vergara, and G. Casero, "Enabling NFC Technology for Supporting Chronic Diseases: A Proposal for Alzheimer Caregivers," Ambient Intelligence, LNCS 5355, Berlin, Heidelberg: Springer Berlin Heidelberg, 2008, pp. 109-125.

[2] J. M. Corchado, J. Bajo, Y. de Paz and D. I. Tapia, "Intelligent environment for monitoring Alzheimer patients, agent technology for health care," Decision Support Systems, vol. 44, 2008, pp. 382-396.

[3] K. N. Fountoulakis, M. Tsolaki, H. Chantzi, A. Kazis, "Mini Mental State Examination (MMSE): A validation study in Greece," American Journal of Alzheimer's Disease and Other Dementias, vol. 15 (6), 2000, pp. 342-345.

[4] T. Kleinberger, M. Becker, E. Ras, A. Holzinger, and P. Müller, "Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces," Universal Access in Human-Computer Interaction. Ambient Interaction, LNCS 4555, Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 103-112.

[5] S. Koch, "Home telehealth--current state and future trends," Int. journal of medical informatics, vol. 75, 2006, pp. 565-76.

[6] J. Nehmer, M. Becker, A. Karshmer, and R. Lamm, "Living assistance systems: an ambient intelligence approach," Proceedings of the 28th International Conference on Software Engineering, Shanghai, China, May 20 – 28, 2006, pp. 43-50.

[7] N. Spanoudakis, P. Moraitis and Y. Dimopoulos, "Engineering an Agent-based Approach to Ambient Assisted Living," Adjunct Proceedings of the 3rd European Conference on Ambient Intelligence (AmI09), Workshop on Interactions Techniques and Metaphors in Assistive Smart Environments (IntTech'09), Salzburg, Austria, November 18, 2009, pp. 268-271.

[8] K. Sycara, M. Paolucci, M. Van Velsen, and J. A. Giampapa "The RETSINA MAS Infrastructure," Autonomous Agents and Multi-Agent Systems, vol. 7, July, 2003, pp. 29-48.