Towards Medication Management in Smart Homes

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Keywords: Medication Management, Smart Home.

Abstract: Due to current demographic trends and ageing more and more people are living alone and need proper support in their daily activities. We propose a model for smart home environment upon which we base our solution described in this paper. Example solution aims to increase reassurance for people living alone by providing them with the reminding and smart home functionalities encapsulated in terms of OSGi bundles. Medication management and timely notifications combined with lighting and audio system control allow elderly users to individually increase their autonomies while living alone.

1 INTRODUCTION

According to Eurostat there is a trend of demographic ageing within the EU. The share of older people is drastically increasing from 2010 onwards because of a low fertility rate and rising life expectancy. It is estimated that the ratio of working-age people to those aged over 65 will drop from 4:1 in 2008 to less than 2:1 by 2060.

With the advancement of the technology and higher penetration of broadband networking a vast number of new possibilities in the area of intelligent environments have emerged. On the one hand there are new ways for collecting and storing data and on the other hand there are new means for interpreting and reasoning upon that data which, in addition to the improvements in human-computer interaction, greatly facilitates the advancement and development of different inventive systems. Those systems further enable development of context-aware applications with new ways of adaptation, personalization and customization that has never before been possible. Users can now choose among ever increasing number of different solutions which can ease their everyday tasks and provide them with support they need. However, current solutions still have many limitations and thus are not well established.

Usage of proprietary, legacy and isolated technologies hinders the advancement directed towards reusability and interoperability and hence also towards cost effectiveness and widespread acceptance. Nevertheless, in the last years a lot has been done in that sense, which can be seen also on the example of initiatives such as Continua Health Alliance, an open non-profit organization of more than 230 technology and healthcare companies, or Digital Living Network Alliance (DLNA), organization focused on delivering an interoperability framework of design guidelines based on open industry.

Today there are many ongoing research efforts directed towards building intelligent home environments such as Gator Tech smart house (Gator Tech, 2012) or Aware Home (Aware Home, 2012). Projects like MPOWER (Mpower, 2006) and PERSONA (Persona, 2007) aimed at developing technological platforms to enhance independent lives of elderly. Mentioned projects are also input projects into the project universAAL (*UNIVERsal open platform and reference Specification for Ambient Assisted Living)* (universAAL, 2010) which has an objective to integrate the current state-of-the-art projects and solutions into new Ambient Assisted Living (AAL) reference platform.

The above mentioned projects and initiatives, together with many similar ones, aim at utilizing different devices and systems in a way that they reduce the need of manual work of the elderly and provide them with assistance in their daily lives. Solutions provided by those projects are all about employing technology in order to offer elderly people new means of help and support.

Numerous reports show that patient noncompliance, also known as non-adherence, is a

Grguric A., Dešić S., Mošmondor M. and Kušek M..
Towards Medication Management in Smart Homes.
DOI: 10.5220/0004238002280232
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2013), pages 228-232
ISBN: 978-989-8565-37-2

major medical problem. Noncompliance is typically cited as occurring in from 50% to 75% of patients (Wertheimer, 2003). This rate is even higher in patients with chronic illnesses since their drug regimes are often long term. The economic and healthcare costs are thus even higher not to mention that a number of people die every year because of not taking the proper drug dosages at the right times.

Automation is certainly one of the key aspects that drive research in Smart Homes and, thus, also in AAL domain. Smart environments can be examined from the perspectives of work, leisure, safety, comfort and privacy. By developing medication reminder system coupled with smart home control we wanted to a) demonstrate new ways of reminding in smart homes, b) utilise different OSGi implementations for developing applications and c) transfer existing non-OSGi MPOWER FSA framework to OSGi.

The rest of this paper is organised as follows: first an example scenario and proposed smart home model are described in Section II. Section III continues with the elaboration of concrete system architecture and Section IV concludes the paper.

2 SMART HOME APPROACH

2.1 Requirements

We will use a following example to illustrate how even a pretty simple system can provide the assisted person with a good reminding and smart home functionality. Consider a 72 year old woman Agnes who lives alone, suffers from dementia and has a difficulty to move around. She has to take several medications at appropriate, often different, times. A few times she unintentionally forgot to take her medications because of which she had had medical problem and decided try to prevent this from happening again.

She knew that a plethora of different services is available and can be ordered online. In consultation with her son she decided on the most suitable solution for her problem which offers timely reminders and some smart home functionality. She bought it and after technician installed everything in her house she asked her son Steve to help her by using the part of the solution meant to be used by a caregiver. Steve took over the task of entering scheduled medication intake times to the system so Agnes could continue with her daily activities more carefree then before. By knowing that she will be reminded to take medication on time she felt reassured and relieved. Moreover, she knew that she doesn't have to be concerned whether she will see or hear the notification on her mobile since the alarm is integrated into her house and she could hear the sound and/or see the lights blinking no matter which room she is in at that specific moment.

As an addition to the reminding functionality she also acquired a service for turning the audio system and light on and off. This device helped her avoid getting up all the time which made her very happy because of the problems with her painful knees.

From this example scenario we can see that feeling of reassurance is invaluable for the end user. We are witnesses that nowadays, people are generally more willing to invest into home automation devices. Quite a few manufacturers are already addressing this area so numerous solutions for controlling and programming of heating, lighting, doors, windows and other electrical appliances already exist on the market. The next step is to see how they can be properly utilised in terms of providing appropriate support for elderly. Rapid miniaturization and development of sensors, actuators and computing devices greatly facilitate the advance of such solutions.

2.2 Proposed Model

When transferring technology explored in laboratory conditions into domestic spaces a lot of practical problems emerge. A relatively simple thing as sensor colours can greatly affect the acceptance of pervasive technology in the home. Many examples show that a trade-off between the amount of technology that can be installed and the level of support and usefulness of the system has to be made. Designers of the novel services have to take under careful consideration social and privacy issues as well as technical ones.

Sensing and responding technologies should harmoniously be incorporated in physical environments. With continuous progress in sensing, novel activity recognition methods are also being investigated. Sensors placed in houses or worn by the users are constantly becoming smaller and more advanced which definitely leads to Weiser's prophetic vision of the future of disappearing technologies (Weiser, 1991). Apart from collecting the data from the environment the opposite direction also has to be covered and this is where actuators come in by causing changes in environments.

We present a model for smart home on

Figure 1 that takes under consideration physical, logical and interaction aspects by addressing sensing

and responding, smart home service functionalities and interaction with the user.

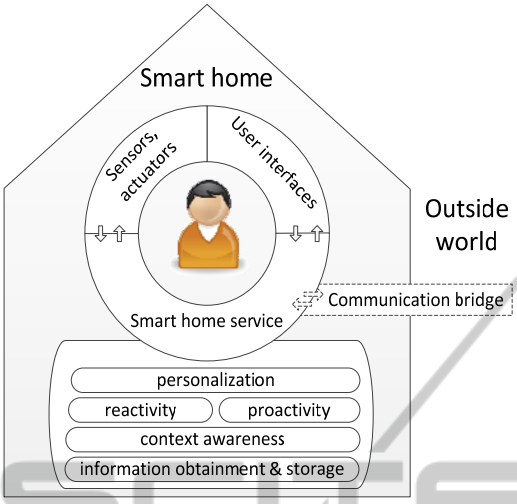

Figure 1: Proposed smart home model.

Smart home services that offer support to the inhabitants should maximise the utilization of obtained data and infer as much as possible in order to be able to provide both passive and active support to intended user. However, not all services need to be context-aware and collect data from the environment nor they need to utilise actuators. The amount of hardware or software used for particular service depends solely on service developers and their intentions, the extent of end user needs, preferences, etc. Furthermore, the amount of usefulness of the service cannot be easily measured so it is up to end users themselves to decide if some service is useful for them or not. Assistive technologies can therefore come in many flavours and can range from the simplest to the most technically sophisticated. They can be designed in countless ways considering (or not) things such as social, technical, ethical, physical and physiological factors. The most important thing is, however, that they provide some means of assisting their end users. Having in mind that people who benefit from smart home services often have really specific set of requirements services, and especially more advanced ones, have to be personalisable in some way.

Collaboration with external service and information sources (such as weather forecast) must not be neglected and can, in some cases, prove to be invaluable for the completeness of the service offering. Reusability and different orchestration of services however are not possible without the common ground for interoperability so the standardisation compliance aspects are especially important in this segment.

Interaction with the end user has a pivotal role for every system since it greatly affects the overall impression and thus also acceptance of the system. Often the interaction aspect is greatly underestimated although there are many research efforts and advances in the field of human-computer interaction. With the advancement of the technology more natural means of interaction (such as voice- or gesture- based) become possible. Multimodal interfaces offer many possibilities and much easier interaction which is especially important when dealing with the needs of elderly people who are, more often than not, really not technically savvy.

2.3 Concrete Architecture

Proposed system architecture follows above model which gives the basic understanding of the entities of smart home environment and their relationships. Developed system is built using the OSGi technology which is an industry's initiative for a standardised open specification to deliver services in different environments and to bring support for modularity for software developed in Java.

OSGi platform consists of OSGi framework and running components called *bundles* which are basically JAR (Java archive) files with additional manifest headers. OSGi facilitates componentization and assures interoperability, two very important aspects in the AAL domain.

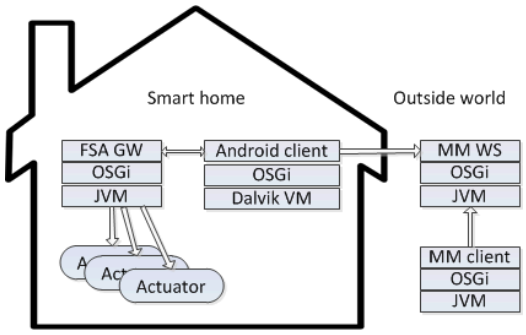

Figure 2: System architecture.

Figure 2 shows basic system architecture. Interaction of the components is illustrated in a way that it is comparable to the proposed smart home model.

Medication management client (MM client) is OSGi based Java Swing application used for setting a reminder about certain medication for specific assisted person. For this client a popular open source OSGi platform developed by the Eclipse organization called Equinox (Equinox, 2012) was used.

Apache CXF Distributed OSGi subproject (Apache CXF, 2012), or cxf-dosgi in short, was used for *Medication management web service (MM WS)* component implementation. Cxf-dosgi implements the Remote Services functionality using Web Services. It enables service invocation in distributed environment meaning that services running in other JVMs can also be invoked. Feature we used for our development was leveraging SOAP over HTTP and exposing the Service over a WSDL contract. Using this framework, one can develop and deploy web services as OSGi bundles. Apache Tomcat was used as a servlet container.

While MM client is mainly intended for formal (meaning medical personnel) or informal (meaning family members, friends, etc.) caregivers, mobile based application is primarily meant to be used by assisted person (AP). *Mobile client application* is used for presenting medication notifications and interpreting smart home controls. It is based on Prosyst's mBS Mobile OSGi platform for Android (ProSyst, 2012) which is complemented by mBS Mobile SDK which offers a number of Eclipse based tools.

For interaction with actuators a Frame Sensor Adapter (FSA) middleware from the project MPOWER was used. FSA is used as a gateway providing unified access to sensors and actuators that use different data formats and different communication channels. There are three levels of abstraction in FSA:

- *Adapters* are mediators between real devices and Virtual Sensors. They possess knowledge how to send a message via specific communication protocol. For each protocol there is a special FSA Adapter.
- *Virtual Sensors* possess knowledge of how to interpret specific messages coming from different devices.
- *Frame* offers interfaces to associate Virtual Sensors and appropriate Adapters.

For the purpose of this work needed FSA components were transferred to OSGi and necessary adjustments, such as implementation of specific Virtual Sensor, were made in order to be able to use it within our system.

Caregiver or a family member enters medication name and time when specific assisted person needs to take prescribed medication. This data then becomes available for the assisted person via web service.

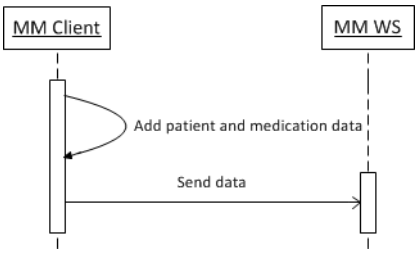

Figure 3: MM client sends data to MM WS.

Figure 3 shows transfer of a list of patient and medication related data between MM client and MM WS. When the list is downloaded on the assisted person's mobile phone it is immediately shown on the screen while appropriate timers are set in the background.

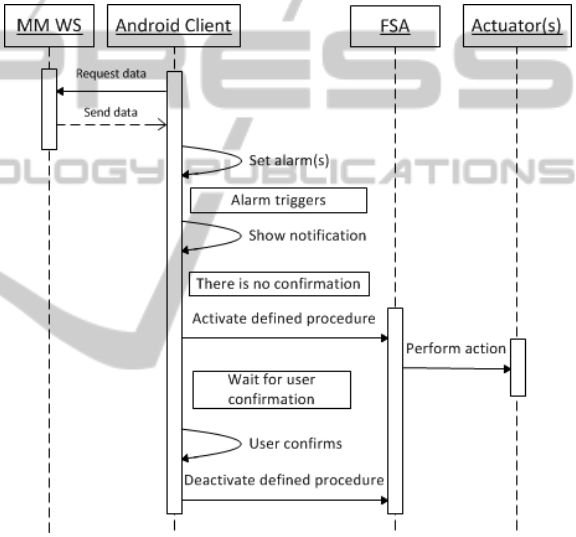

Figure 4: Sequence diagram with focus on Mobile client.

Figure 4 shows communication flow when mobile client requests medication data from MM WS, sets alarm(s) and shows notification to the user.

When the alarm is triggered user receives a notification on a mobile phone screen. If the confirmation is not received for some time a stored action is triggered and performed until user confirms the notification. In our case user (AP) gets a visual and an audio stimulus announcing that the time for medication intake has come. By acting on more than one sense probability that assisted person indeed obtains the timely reminder drastically increases. User interfaces for assisted person were made as simple and easy to use as possible, without displaying too much unnecessary information, having in mind requirements of this specific target group.

2.4 Need for a Reference Platform

Different platforms, systems and solutions try to address many problems in providing support to elderly people living alone. The question we are now facing is how to reconcile these solutions to get the maximum result. Current research contributions prove that scalable and manageable OSGi technology is very valuable for smart home environments.

universAAL platform addresses many of the issues important also for smart homes. It terms of runtime support it adds goal based interoperability between different devices and services (it uses three buses, namely Service Bus, Context Bus and a User Interaction Bus where each is responsible for handling specific calls and events between distributed nodes). In terms of support for developers it offers Developer Depot, a place where different tutorials, explanations and examples can be found. And lastly it offers uStore which, in short, can be compared with Apple's App Store but here used for requesting, offering and obtainment of AAL Services. By building on top of OSGi universAAL runtime platform also benefits from all OSGi underlying functionality. Additionally it adds automatic discovery and seamless communication of the nodes running universAAL middleware.

By using one common platform within smart homes a lot of issues in terms of interoperability, reusability, standardisation, cost reduction, simplification, reduction of time-to-market cycle, etc. can be resolved much quicker.

3 CONCLUSIONS

There is no doubt that a major shift has occurred in the way technology is used today. Many advances in science and technology allow developing services that were formerly not possible.

Since elderly people often tend to forget their medication intake schedules, reminders that incorporate the smart home environment were developed to help to alleviate these problems. Implemented solution follows proposed smart home model and shows that the usage of open standards and frameworks, such as OSGi, can greatly facilitate development of cheaper, simpler and more open AAL applications and services. By using the environment, instead just fixed screens, to attract user's attention a better outcome and medication compliance can be achieved.

It is obvious that there is a lot of room for fully integrated and pervasive solutions in smart homes. However further research is needed to fully understand the needs of the elderly and, moreover, how different technologies and solutions can help them to live independently in their homes.

ACKNOWLEDGEMENTS

Used FSA framework was initially developed under the FP6 project MPOWER (#034707) funded by the European Union and was made open source under the MIT license. This work was partly supported by the FP7 project universAAL (#247950).

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