Overview of MPOWER: Middleware Platform for the Cognitively Impaired and Elderly

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Abstract: The number of cognitively impaired and chronically ill elderly is increasing. The main objective is to support older people living independently in their homes as long as possible, with good quality of life – no place is like home. Technology is utilized to support the elderly and help provide enhanced health-care services. This paper presents the MPOWER project and the features this innovative middleware platform will provide. It will support rapid development and deployment of integrated innovative services for elderly and cognitively disabled. For this system that provides a collaborative environment for distributed and shared care, usability, security and interoperability between systems is central; biosensors and SMART house technologies are integrated; and structured mechanisms are provided for adapting to changes in user context in a distributed, mobile environment supporting various user contexts.

Keywords: Middleware platform, Dementia, Homecare, SMART house, Home Automation, Biosensors, standardization, interoperability, security.

1. Introduction

It is well known that the world's population is ageing. In 1995 it was estimated that 371 million people (6% of the world's population) were over the age of 65. This is much higher in Europe (14%) and North America (13%) than in Latin America, Asia (5%) and Africa (3%). Dementia primarily affects older people. Up to the age of 65, dementia develops in only about 1 person in 1000. This rises sharply with age to 1 person in 20 over the age of 65, and 1 person in 5 over the age of 80. Since a person's chances of developing dementia increase with advancing age, number of cases of dementia will grow quickly as world's population ages over the coming decades. According to Alzheimer's Disease International [1] there are over 24 million worldwide with dementia. Two thirds of these live in developing countries. This figure is set to increase to more than 80 million people by 2040. Much of this increase will be in rapidly developing and heavily populated regions.

Africa is a large continent and most of its countries are characterized by low incomes, low life expectancy and high prevalence of communicable diseases and malnutrition [2]. Health in general is a poorly funded area of social services in most African countries [2,3], and especially mental health services are poorly developed mainly due to insufficient human and financial resources. The absence of mental health policies or programs leaves most people with mental health problems with no care. Evidence shows that a large proportion of the global health burden is due to mental disorders and this proportion is

projected to rise in many African countries [4]. Even though the population of elderly people in Africa is still low and therefore the prevalence of dementia is not very high, other brain syndromes, which usually follow an infection, are common in Africa.

Dementia is a brain dysfunction characterised by a decline in memory and intellectual function [5]. It is a syndrome due to disease of the brain, usually of a chronic or progressive nature, in which there is disturbance of multiple higher cortical functions, including memory, thinking, orientation, comprehension, language, and judgement [6]. This is a difficult condition to manage, even in hospital or old age homes. Dementia affects every-day activities, usually deteriorate over time, and no cure is foreseen. It has a wide-ranging impact on families and close friends, who experience stress, frustration and exhaustion in caring for a loved one, as well as feelings of loss for the person they once knew. The economic costs of dementia are considerable, and a significant portion must often be borne by the individual families. If care is provided at home by a family member, the carer may have to give up employment. This increase in the ageing population and consequently in the incidence of dementia, is accompanied by social and cultural changes that will result in greatly increased cost of dementia care. Home care provided by a family member is becoming more difficult as family sizes shrink, divorce rates rise, and extended family relationships are weakened. Although most African societies have the support of families for the care of the mentally ill, urbanization and workforce mobility breaks down system of extended families, leaving mental patients without the traditional source of support.

It is obvious that such a problem cannot be solved merely by increasing the number of care-givers. In Europe, the increasing burden on the healthcare system is a consequence of population growth coupled with problem of declining birth rates. According to EC IST FP5 funded HINE project, the cost of chronic care in Europe is set to more than double from 1.7% of GDP in 2000 to 4% of GDP by around 2010. There are three ways to solve this issue: 1) Keep old model of care, increase funding – but funding scarcity difficult to overcome; 2) reduce quality of care or access to care, so that we save by not giving adequate care to all in need – socially unacceptable; or 3) develop new knowledge (models of care), technology and services that will provide high-quality care more cost-effectively in the patients' homes. MPOWER aims to address this last solution and provide technology and knowledge for changing the system in a direction where a new chronic care model is supported. Our view is that the quality of life for the people mentioned can be significantly improved by means of various modern technologies, adapted to the user's specific needs. Note that even relatively simple solutions like some medical measurements and a response to short questionnaires has shown good results and kept patients from admission to hospitals for other chronic diseases [7]. The technologies found in smart houses [8] and sensor networks [9] can cover in part the user needs. Smart houses will have a strong, positive, and emotional impact on persons with physical disabilities and older persons, improving their quality of life, giving them privacy, and making them feel that they live in an ordinary house, not in a hospital or in a special nursing home [8]. The same notion will reduce, to some extent, medical care costs per person. Also sensor networks have the potential to greatly impact many aspects of medical care [9]. For example, by outfitting patients with wireless, wearable vital sign sensors, collecting detailed real-time data on physiological status can be greatly simplified. Thus through smart house and sensor technologies one can expect enhanced provision of care in home environment.

Services for disabled and elderly have until today been very specialized and with few actors due to high access level for service provision and small markets. Existing approaches to service creation involve a great deal of re-invention for each new service, and there are no standard approaches to key issues such as the need for interoperability between different user applications. When these technical issues are combined with the fact that the services require considerable customisation and are often developed for a small group of users, the

conclusion is quickly reached that provision of such services is today technically and economically unfeasible. However, innovation in providing new services has been recognised as an important priority for the advanced homecare industry.

2. Project Objectives and Illustrative Scenarios

A key objective of our research is to ensure that elderly and people suffering from dementia remain and live independently in their homes as long as possible, with an acceptable quality of life. MPOWER focuses on their special needs and aims to develop middleware that will facilitate service development for their evolving needs. These days advanced SMART house and biosensor technologies have become available and affordable. However, since proprietary interfaces and fragmented services remain obstacles toward their wide deployment, and healthcare and ambient intelligence involves the convergence of several computing areas, our aim is for the proposed MPOWER sensor and SMART house integration middleware to make it easier for manufacturers of such technology to integrate with new services for the cognitively disabled. Thus a main objective of MPOWER is to provide standards-based technology which makes it easier and commercially feasible for the service oriented ICT industry to provide services to smaller groups of users, and develop distributed integrated applications offering innovative services. As a result the inclusion of the cognitively disabled and elderly into the society will be made easier through the provision of interoperable, and cost effective targeted services.

To achieve the above stated objectives MPOWER will define and implement an open platform based on international standards to simplify and speed up the task of developing and deploying services for persons with cognitively disabilities and elderly. The platform will support: 1) Integration of SMART house and sensor technology; 2) Interoperability between profession and institution specific systems (today different stakeholders have systems with limited support for interchange of information); 3) Secure and safe information management, including both social and medical information; and 4) Mobile users which often change context and tools. The project will develop the platform as a suite of independent and reusable building blocks, and will demonstrate its feasibility and power as well as validate the approach and services through the deployment of two end-user applications. The end-user applications include the development of individual plan management, to demonstrate the feasibility of the platform for dynamic sharing of plans and information providing a collaborative environment for distributed and shared care, and smart home and sensor environment, to demonstrate the feasibility of the platform for interconnectivity and integration of smart home and sensor technologies. The project will also promote standardisation through aligning its work with ongoing development of HL 7 [10], building on and contributing to existing and emerging security and interoperability standards; and promote the MPOWER platform internationally through the European Association of Homes and Services for the Ageing (EAHSA).

There is potentially a large market for services for the cognitively disabled and elderly, and considerable scope of innovation. But technical difficulties and the resulting high development costs today make it commercially unattractive to develop them. To overcome these difficulties, the project will identify commonly occurring technical issues that need to be solved each time a new integrated service for elderly and cognitively disabled is designed and hence specify and implement components which address these issues.

In order to illustrate our ideas for the provision of MPOWER like services we provide two different scenarios below to cover the four areas of technical innovation in the project. The first scenario uses the middleware dealing with information models, interoperability and security. The second scenario uses the middleware dealing with sensor interfacing, interoperability and security, but will to some extent use the information middleware in relation to context information.

Scenario 1 - Information sharing scenario. Joe (71) and Annie (68) have always been an active couple. Lately Annie has experienced problems with managing her everyday living due to early dementia and she is included in a program designed for persons with dementia and their family. They decide to start using a secure, role-based and shared information space service that makes all stakeholders able to share relevant information with Annie. This includes an individual plan for the patient, that receives relevant information from all stakeholders and presents them. This merged plan reminds Annie about her obligations via her mobile phone. Relevant medical information is shared between the different treatment and care providers involved, including shared medication lists. Education material for both Annie and her family is also provided. Her grandchild Peter can now send a text message about his next football match, and this is automatically included in her activity plan. At home Joe and Annie have a touch screen computer to manage their information space. Dependent of the situation of the user and available interaction solution, information is presented in the most user-friendly way.

Scenario 2 - Smart house scenario. Helene is 78 years and has started to forget small, but sometimes important things. She and her husband want to live at home as long as they can, but due to their reduced ability to walk and the growing dementia problem for Helene, they need to upgrade their apartment. A well proven calculation model is used to analyse the cost benefit for the situation and it shows that by introducing the SMART house technology, they will probably be able to stay at home for 5-8 years extra. The total cost of upgrading their apartment is € 28.400, but high cost of institutionalisation (calculated to € 100 pr. day ~ € 182.500 for 5 years) and studies showing the improved quality of life for people living at home, force the social office to decide to finance the apartment upgrade.

Based on earlier experiences a system should provide easy support for communication with the medical support team and family, medical surveillance, evaluation and storage of all measure data, alarm triggering, patient education program and management of home appliances and front door. This drives the work for the design of the system and the supporting technologies that will be introduced.

3. Proposed Approach / Methodology

The MPOWER technical approach (see Figure 1) combines Agile Software Development (ASD) and Model Driven Architectures (MDA) [11,12,13]. ASD focuses on optimising quality of software and documentation by facilitating high level of interaction between members of the development teams and the end-users. The MDA approach is beneficial to MPOWER as it facilitates integration by separating business and application logic from underlying technology. The platform independent models of applications can be realized through the MDA on several platforms, including Web Services, .NET, CORBA and J2EE. The MPOWER Service Platform will be build on standards based secure communication services as well as internationally accepted Healthcare standards.

The MPOWER framework for service development will provide knowledge and guidelines in the form of service lifecycle models, and produce a handbook that identifies and characterises the different phases in provision of secure services for cognitively disabled and elderly. The MPOWER service platform for service and system integration will facilitate integration and standardisation by providing distributed middleware APIs for service description, service lookup and communication. It will be build on standard technologies, reuse and tailor dedicated safety and security components based on state-of-the-art security mechanisms for secure communication, storage, and access control. Middleware components will be provided so as to offer interoperability between legacy systems and SMART house and sensor technology. To better tailor the system for the elderly and cognitively disabled a multimodal user interface will be implemented with duplicate means of interaction, e.g. voice and images, as well as context middleware [14] to

support the development of applications adaptive to changing execution environments and user groups.

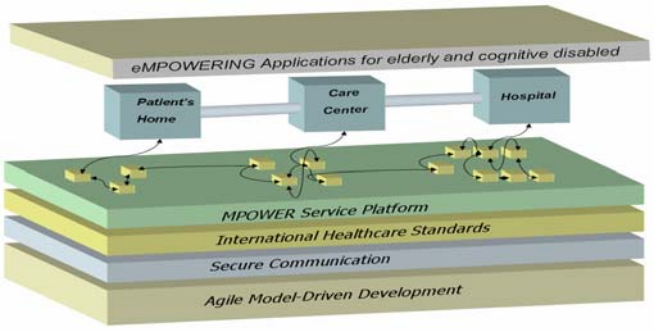

Figure 1: MPOWER Technical Approach

The evaluation of the developed technology will be on two levels: framework and platform evaluation; and proof-of-concept evaluation. The framework and platform evaluation will be based on Post Mortem analyses after each phase in the project to improve the next version of technology, as well as structured interviews of involved software developers. The Proof-of-Concept evaluation will include a set of methods including Site Acceptance Tests with a focus on fulfilling the requirements, usability tests for identifying usability shortcomings and possible biases in relation to end user evaluation, and end user evaluation based on questionnaires and structured interviews of the different stakeholders.

The project started with identification of the user needs and requirements, and identification of state of the art in the fields of security, interoperability, healthcare and sensor/SMART house technologies. It is now in the design phase, where the reference, overall and middleware component architectures are established, mapping the requirements into platform components. In addition, work is in progress for the selection of the standards that the solution will utilize (interoperability, security and sensor/SMART house standards).

4. Proposed Architecture and Technologies

The MPOWER middleware service platform will offer a set of reusable components and services to enable rapid development of smart house applications to support the everyday living of elderly and cognitively disabled. Connecting sensors and computing devices together can be a complex and time-consuming task, but by reusing existing components and shared services, new applications can be developed and deployed more rapidly.

The MPOWER platform is based on the Service-Oriented Architecture concept. In practice, this means that a running service, e.g. a Web Service for looking up details of a medicine based on its ATC-code, can be used by any application on the same network. The MPOWER platform will describe how to integrate with such services and how to deploy them. Typical services for HomeCare applications will be developed and made available as a part of the MPOWER Framework.

The architecture of an application based on the MPOWER Service Framework will include one or more running instances of the MPOWER Service Platform. Figure 2 shows an application where a Smart Home is monitored from a Control Center, both running the MPOWER Service Platform and communicating through a MPOWER Common Services platform offering security and communication services. In the Smart Home, several devices communicate wirelessly with the MPOWER Service Platform instance. For example, the Indoor Positioning Device will periodically report where the user is, and the Movement Sensor will trigger an alarm if the user is not moving for a defined time period. Each morning, the daily calendar is printed. In addition, the user gets reminders about daily tasks, including medication, on his SmartPhone as well as from the Electronic Pill Dispenser for the medication. The SmartPhone has a built-in GPS device that tracks the user when he is

outdoor. Through the HomeCare Station the user can communicate (using text, voice and video) with other users and caregivers [15], ask questions, and use the Edutainment-system. All these devices are controlled through the MPOWER Service Platform. In the Control Center a mainframe server is running the Individual Plan System, a multi-speciality system used for teamwork treatment and management (e.g. a collaborative healthcare management system [16]). The Control Center Care Station is a mobile unit that enables the caregivers to securely access information about homecare users from anywhere through the MPOWER Service Platform. An Alarm Central connected to the platform feeds updated data to the Surveillance monitor from all the Smart Homes which belong to the Control Center's user group. The MPOWER Common Services platform runs services for information lookup, message routing, Public Key Infrastructure (PKI) and other.

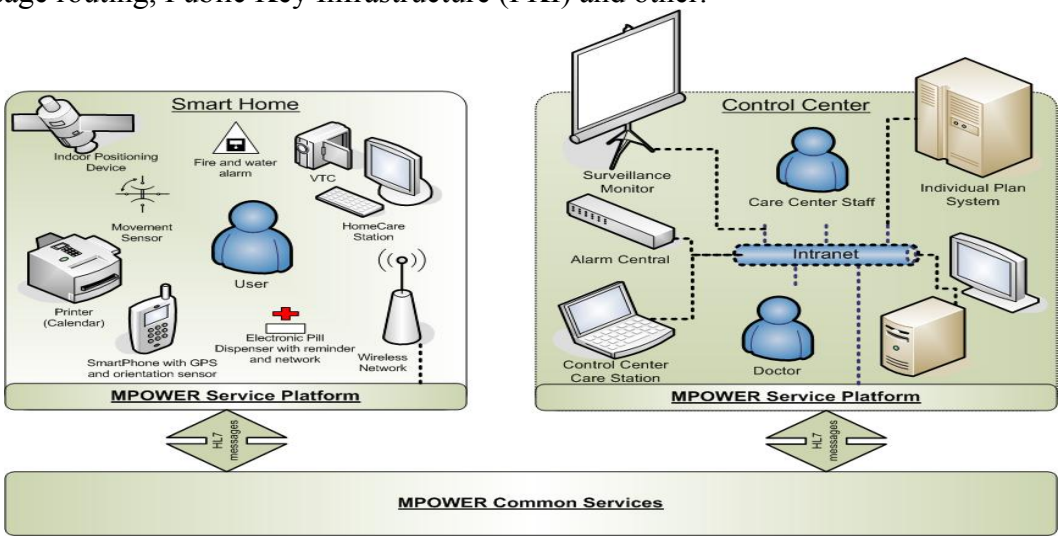

Figure 2: An example of a MPOWER-based application

A Smart House can incorporate any or a combination of categories of sensor devices and appliances. Environmental sensors to register temperature, humidity, smoke, position and sound; domestic appliances' management for management of cooker, fridge, air-condition and water temperature; power management system controlling light and power supply; internet connection to communicate with stakeholders; alarms and motion detectors for security; and sensors to measure vital signs (e.g. ECG) and provide telehomecare.

5. MPOWER Reference Architecture

The reference architecture is based on IBM's reference architecture for Service-Oriented Architecture [17] and consists of five layers – each layer comprising a set of "components":

- Resource Layer. This consists of existing custom built applications, such as databases storing e.g., patient-administrative, medication, and management information such as calendar events. Other relevant resources are information from (smart) sensors such as physiological monitoring devices, temperature sensors and burglar alarms systems.
- Service components Layer. To expose the functionality of the components and services in Resource layer, service components provide high-level access to their information and control functions. A typical service component is a SMART house-sensor driver that encapsulates and implements sensor communication logic for higher-layer services.
- Services Layer. The services the business chooses to expose reside in this layer. They can be discoverable or be statically bound and then invoked, or choreographed into a composite (business) service. The underlying service components provide service realization using the functionality provided by their interfaces. The interfaces get exported out as service descriptions in this layer, where they are exposed for use.

- Business Process Layer. Compositions and choreographies of services exposed in the Services Layer are defined in this layer. Services are bundled into a flow through orchestration or choreography, and act together as a single application. These applications support specific use cases and business processes. An example of homecare business process is management of shared calendar where calendar, user information, and medical plans are accessed through a set of services and service components.
- Application Layer. This is usually out of scope for discussions around SOA, but is useful to demonstrate which layers will be included in a complete SOA. This layer provides a user interface that uses underlying services. Note that SOA decouples user interface from components. Two types of applications, that represent the two proof-of-concept applications, are defined in the application layer: HomeCare and SmartHouse.

The five categories of services are given below:

- Management Services for managing services, users, access rights and system contexts.
- Information Services for individual plan, calendar, medication list, and knowledge sources, in addition to services for accessibility, e.g. text-to-speech.
- Sensor Services for configuring devices and retrieving sensor information.
- Security Services for authentication and authorization of users and system components as well as other services such as logging.
- Communication Services for sending messages and notifications to users and systems. Separate alarm services that allow configuration of how the alarms should be handled, depending on context, as well as synchronization services for individual plan, calendar and medication lists are also provided.

The services in the Services Layer can be distributed and reused in a network, and accessed through standard interfaces over standard protocols. To demonstrate the distribution and reuse, a "BookCalendarEvent" example is given. The example is an Individual Plan application that provides a function for booking a calendar event in a calendar system. This function is exposed to the user through the BookCalendarEvent Application-layer component. This component uses a Business Service called CalendarManagement that is orchestrated from the Query and BookEvent MPOWER-middleware services exposing the Calendar system, and the Authenticate and Authorize services that expose the User Management system functionality. The two latter services are generic access control services that run in the MPOWER Service Center. The Calendar and User Management systems implement the service components and resource services layers.

6. Expected Project Results

MPOWER will through proof-of-concept applications, demonstrate how it is possible to support daily living of the elderly and cognitively disabled people and provide a platform that makes it possible to speed up the development of new services for the target group. For all stakeholders involved with a patient, MPOWER will provide services that improve their ability to communicate and to manage the situation of receiving or giving care.

The patients will receive technology and procedures that will support them performing well and adequately meeting the expectations of the rest of the society. The family will feel more relaxed and safe. They will have tools that help them communicate and organise day-to-day information and situations. The care providers will have tools that help them cooperate to provide adequate care and treatment for the patients in a cost-efficient way. Friends can take more part in the patient's day-to-day activities and will be able to share information with the patient. The society will experience patient relatives that are less stressed and better able to cope with their situation. Further, the inclusion of the patients will become better through increased social activities from the patients. Technology supporting individual adapted services will improve the quality of life for all stakeholders.

7. Expected Business Benefits

Provision of services for elderly and cognitively disabled patients will in the next decade increase rapidly due to the increase in elderly population. This makes the service provision a growing market with improved business opportunities. MPOWER will impact in two areas: standardisation of information and components; and integrated services provision.

In the area of standardisation, the project's impact is rooted in the fact that it provides a platform with standardised components using (and contributing to) up-to-date information model standards, e.g. HL7. The platform is a ready-to-use starting point that frees application developers from the need to deal with low-level technical issues in each new development cycle, and allows them to concentrate on innovative value-added functions. The development of the middleware allows easier development of applications that are customized for different environments, and makes it easier to customize services to the specific needs of selected and new user groups. This will have far-reaching consequences:

- It will now take less time to develop new services, leading to shorter time-to-market, reduced risks and lower investment costs. Reductions in the cost and complexity of service development will open the service provision market to new players.
- Lower development costs will lead to an increase in the number of services developed and enhanced functionality of provided services. These factors will increase revenues for service providers, network operators, and advanced terminal manufacturers..
- Applications that are designed for cognitively disabled and elderly are usable by everyone, and as such open up business opportunities for millions of users.
- The economic costs for the care of cognitively disabled and elderly are long lasting and considerable [4], involving health and social services. The MPOWER platform in collaboration with the SMART house technologies can offer quality healthcare services and ease the burden of expensive hospitalization.
- Africa has limited healthcare resources and MPOWER can help by creating a network for collecting and disseminating relevant healthcare information allowing professionals from around the world to interact, facilitating the exchange of experiences between countries and transfer of knowledge. This way, Africa and the developing world can benefit not only from costs savings, but also from increased productivity of health care professionals. It will also promote training and national planning, overcoming the jurisdictional barriers to cooperation and facilitating medical communication, improved information infrastructure and international technical cooperation.
- In Africa and developing countries, technology distribution and access deficiencies, and low level of capital investments in health care sector are obstacles to the dissemination of e-health applications. MPOWER promotes telecommunication infrastructure based on wireless infrastructure-less technologies and is therefore easy to deploy and run.

In the area of provision of integrated services, opportunities will arise from the fact that the SMART house and sensor technology providers will be able to develop more comprehensive and integrated solutions. They will be able to emerge to become total service providers and in this way fulfil the user needs in a total different way. This will again lead to more valuable services that will create opportunities for more profit.

8. Conclusions

In this paper we present an overview of MPOWER which aims to design a middleware platform for providing services to cognitively impaired and elderly. Its primary result will be the platform for the design, development and deployment of interoperable applications offering innovative end-user services. A distributed architecture describing the platform, and the interfaces/interactions between middleware components will be produced. In addition, a set of middleware building blocks, providing the key application-level services

needed to create integrated services, and which can be re-used in designing different services, will be provided. Open APIs will be defined for each MPOWER middleware building block. Proof-of-concept applications for two user sites will be developed. Development of these applications will drive the project, and provide a mechanism to validate the platform.

As a consequence of the MPOWER results, it will be easier and will take less time to develop, deploy and customize services to the specific needs of selected user groups. New services can be composed by reusing existing components and shared services. Therefore, the development of new services will involve lower investment costs and reduced risks. This will allow the provision of enhanced, specialized and innovative services and applications that cover the specific needs of disabled and elderly. In addition, this solution supports a new model of chronic care which is expected to greatly help the elderly and cognitively disabled, it will reduce, to some extent, their medical care costs, while providing them with high-quality of care in their home environment. As a final point, this solution will make easier the provision of integrated, interoperable and cost effective targeted services that will allow the inclusion of the cognitively disabled and elderly into the society and help them cope with their daily activities. This will allow family and friends of the patients to feel that their loved one is secure and feel comfortable with the situation.

Given the MPOWER middleware platform, further research is needed to determine the non-technological constraints for a specific region concerned, considering social, cultural and legal conditions, possible constraints and options to build, employ and support an appropriate model of care.

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