The role of business processes in creation of adaptive health-care applications by utilization of MPOWER platform

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Abstract – The number of cognitively impaired and elderly is rapidly increasing. The objective of health-care applications for elderly and cognitively impaired is supporting their independent living for a prolonged period with a good quality of life. The MPOWER project aims to achieve this goal through an innovative platform that provides a set of basic functionalities required in creation of advanced health-care applications for the stated target group. The MPOWER platform is based on service-oriented architecture that presents a model where platform's basic functionalities are decomposed into distinct independent units – services. The creation of advanced health-care applications is done through development of business processes that tie and synchronize the execution of platform's services. The expression of the application-specific logic in business processes enables rapid adaptation of the application by modification of the business processes rules. In this paper we describe the overall MPOWER platform architecture and demonstrate how a proof-of-concept application, showing the use of MPOWER services, can be easily adapted by modifying underlying business rules.

I. INTRODUCTION

In their 60-ties many people start experiencing age related changes and diseases. Thus, their biological and psychological age starts influencing their quality of everyday living. The trend in the European countries is to support independent living of elderly at home for as long as possible [12]. Part of an effort to provide prolonged independent living of the elderly is the creation of extended health-care services that cater for the elderly at their homes.

MPOWER [3, 11] is a research and development project that builds a middleware platform supporting fast development and distribution of health-care services for elderly and cognitively disabled people. Through the use of MPOWER platform IT industry can deliver cost-effective innovative services for advanced medical care. The MPOWER platform consists of a set of basic functionalities necessary for creating extended health-care services. The platform is defined through an iterative process that includes capturing general end-users' requirements, design and development of platform, and development, testing and evaluation of proof-of-concept applications.

The paper starts with a description of principles and technologies of contemporary software development that are used in the process of the creation of MPOWER platform. After briefly covering all relevant parts of MPOWER platform architecture we focus on a particular set of platform's basic services related to the management of medical and social information. We describe the process of gathering services' requirements from users based on real-life scenarios. Furthermore, we show the definition of services' information model that conforms to the HL7 standard [8] for exchanging medical and social data. Finally, we demonstrate how services are created based on the defined information model.

To evaluate defined services we develop and demonstrate a proof-of-concept application. The proof-of-concept application composes existing platform services using a flexible business process. The business process can be adapted in accordance to the modifications of proof-of-concept application users' needs.

In the following section, the architectural principles and technologies of MPOWER platform are described. Section III describes MPOWER platform, while the section IV describes the process of defining medical and social services of the platform. Section V gives and example application developed using MPOWER platform and demonstrates the adaptiveness of the application achieved through business processes. Finally, the Section VI gives the concluding remarks.

II. ARCHITECTURAL PRINCIPLES AND TECHNOLOGIES

The main goals of the MPOWER platform are the cost-effectiveness, simplicity and adaptiveness of the platform itself, as well as of the health-care services developed using the platform. To achieve these goals the MPOWER platform utilizes service-oriented architecture [1] and model-driven development [4].

The service-oriented architectures enable development of loosely-coupled sets of functionalities – services, which can be easily integrated into meaningful applications. While developing service-oriented platform, the crucial problem is the mapping of the domain concepts into meaningful mutually independent services that can be easily managed and integrated when required. The model-driven development allows for model based capturing of requirements, design of domain concepts, and creation of services. Use of model-driven development speeds up the detection of the appropriate mapping of domain concepts to the platform services. Furthermore, model-driven development allows for quick modification of the developed set of services through code generation and integration techniques.

A. Service-Oriented architectures

Information systems need to support business changes quickly and efficiently. However, they also need to adapt to the fast development of new technologies. The most of the existing enterprise systems are heterogeneous, containing a range of different systems, technologies and architectures. Integration of these technologies is crucial because only integrated systems can deliver business values like decreased cost of software development and maintenance. Service-oriented architecture (SOA) [6] is the latest architectural approach related to integration, development and maintenance of complex enterprise information systems. SOA is not completely new architecture, but rather the evolution of previously known distributed architectures that improves and extends flexibility of earlier integration methods. An important objective of SOA is the ability to apply potential future changes to the developed applications in a relatively easy and straightforward way. SOA defines concepts to enable cost-efficient development and integration of information systems. Those concepts support loosely coupled, business-aligned services to enable flexible and dynamically re-configurable business process realization using interface-based service descriptions. Although, SOA is not directly related to any technology, it is often implemented using web services technologies [1].

Probably the most important SOA concept is the composition of services into business processes. Business processes compose several services into a process that follows a set of business rules. The business processes are developed using a dedicated BPEL language [2] and an engine on which business process definitions can be executed. The simplicity of the BPEL language and the availability of the graphical development tools that further simplify business process development create an environment where business processes can be defined and modified quickly.

B. Model-Driven Architecture

Model Driven Architecture (MDA) [4] is a framework based on the Unified Modeling Language (UML) [10] and other industry standards for visualizing, storing, and exchanging software designs and models. However, unlike UML, MDA promotes the creation of machine-readable, highly abstract models that are developed independently of the implementation technology and stored in standardized repositories. There, they can be accessed repeatedly and automatically transformed by tools into schemas, code skeletons, test harnesses, integration code, and deployment scripts for various platforms.

III. MPOWER MIDDLEWARE ARCHITECTURE

A. MPOWER Architecture

The MPOWER SOA architecture is based on IBMôs reference architecture for Service-Oriented Architectures [5]. The MPOWER SOA architecture is presented in Figure 1 and consists of five layers: physical layer, service components layer, services layer, business processes layer, and interface layer.

Physical layer consists of existing custom built applications, such as databases storing e.g., patient-administrative information, medication information, and management information such as calendar events. Other relevant resources in MPOWER are information from (smart) sensors such as physiological monitoring devices and temperature sensors.

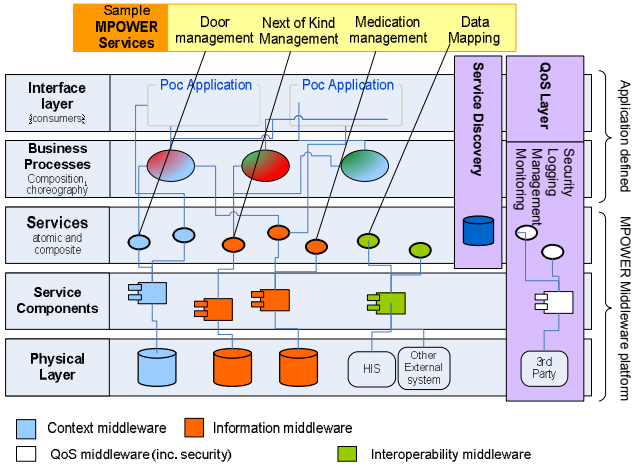

Figure 1. MPOWER reference architecture

Service components layer exposes the functionality of the physical components and databases in the physical layer. The service components provide a high-level access to information and control functions of physical resources. A typical service component in MPOWER is a smart-house sensor driver that encapsulates and implements the sensor communication logic for the higher-layer services.

Services layer contains the implementations of the services that are created within the MPOWER platform. Each service is described by its interface and made available to potential application developers. The descriptions of the services are stored in the registry where they can be discovered using service discovery mechanisms. Furthermore, services can be invoked, or possibly, composed into composite services (business processes).

Business process layer defines the business rules of the applications that are created using the MPOWER middleware. The business rules are defined as business processes that compose and choreograph the services exposed in the service layer. Each business process defines a set of services that are orchestrated and choreographed so that they act as a single business operation. An example of a homecare business process is the management of a shared calendar where calendar, user (patient and caregiver) information, and medical plans are accessed through a set of services and service components.

Interface layer provides graphical user interfaces to the services and business processes. These interfaces serve as the access point through which the users of health-care applications access the health-care services.

B. MPOWER Middleware

The MPOWER middleware provides the three lower layers of the overall MPOWER architecture as presented in Figure 1. The MPOWER middleware consists of a set of services and components that can be used by the application developers to rapidly design and implement an application. The services provided as a part of the MPOWER Middleware are grouped into five categories as described below and illustrated in Figure 1.

Context services are services related to the monitoring and management of the context of a patient. For instance, these services provide information about location of the patient in his house. The context services are realized through a set of sensors and actuators located in the patientôs premises. Furthermore, these services also provide functionalities that enable adding, removing and adjusting the devices and sensors. Example of context service is door management service that tracks the state of the doors in patientôs house.

Information (Medical and Social services) enable management of social information and events of the patient. For instance, these services handle information regarding patientsô schedules, personal information, and social contacts. Furthermore, these services enable management of medications and treatments that a patient is receiving. Through these services health-care professionals can enter medication and treatment plans that are going to be applied for a particular user. On the other side, the patients can examine the medications and treatments they are receiving.

Interoperability services enable interoperability of MPOWER platform with the other platforms that are relevant for health-care application. Primarily these services enable integration of medical services with existing medical systems of hospitals or particular state medication systems. On the other hand, these services also enable integration with communication systems such as telecom operators or Internet messaging systems.

QoS Services provide functionalities for managing existing services, users, access rights and system contexts. The QoS services include a set of security services that cater for platform authentication, authorization and logging functionalities.

IV. INFORMATION MODELS

In this section we concentrate on the definition of the Medication management and Calendar management services that are developed as the part of the medical and social services of the MPOWER platform. We choose to describe these services as an example of the overall service process definition in MPOWER platform. Additionally, we choose these service as example since they involve HL7 health standard, thus we can demonstrate the inclusion of health-standards into service design process.

A. Health Level 7 (HL7)

Health Level Seven is an American National Standards Institute accredited Standards Developing Organizations operating in health-care area. Health Level Sevenôs domain is clinical and administrative data, which by definition maps well to the MPOWER domain scope. HL7 Version 3 standard [9] uses well-defined methodology based on a Reference information model. The reference information model provides an explicit representation of the semantic and lexical connections that exist between the information contained in HL7 messages that are used to exchange medical data. The HL7 methodology is fully technology independent, thus the process of going from business analyses until completely defined message contents uses UML modeling paradigm and related diagrams, and is completely independent of any technology that will be used in implementation stage. However, most of the systems, including MPOWER, use XML enabled technology as the final message container. The requirement of respecting the methodology implies that messages need to be specified using the reference information model as the starting point. Further, messages are refined through domain information model that select and defines messages that are relevant to some medical domain to a refined message information model. The refined message information model contains messages descriptions for specific operations and services. From this point HL7 tooling is used to derive serialized messages and XML schemas that define the form and the content of the message in a computer processable format.

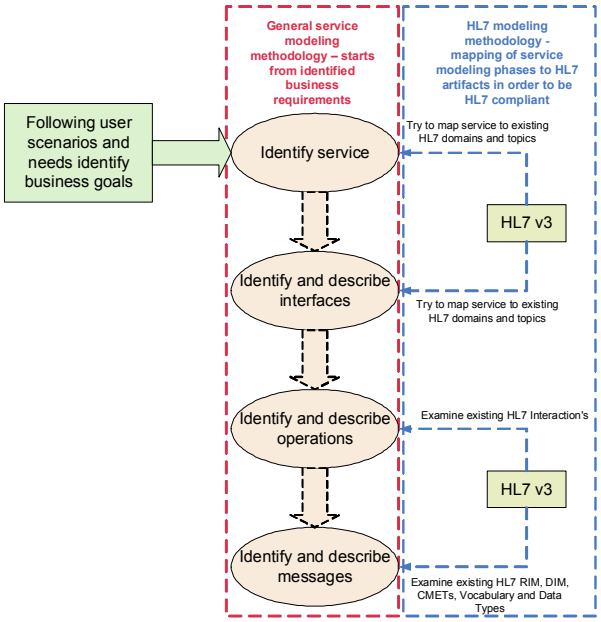

Figure 2. Medical and social information modeling process

B. Service definition process

The overall process of defining information models in the MPOWER platform is presented in Figure 2. The process uses ñtop-downò approach, thus it starts from detailed business requirements and refines them in a stepwise fashion down to a software implementation. In the process, we identify the required services, define interfaces that form the services, define the operations that make interfaces, and finally define the messages that are

used in operations. In the figure we can see parallel modeling sequences of HL7 and MPOWER methodologies. The parallel modeling sequences are required because each step of MPOWER modeling needs to be synchronized and correlated to HL7 specification in order to finally arrive to a complete service definition that is conformant to HL7 standards.

We demonstrate the process of defining MPOWER services on Medication management and Calendar services.

C. Medication management service

The requirement for medication management functionalities came from the interviews with patients suffering of cognitively disabilities and nurses that treat them. The interfaces and operations for the service are detected and selected from the HL7 services ballot [8]. Finally, the message contents are generated using HL7 tooling.

The Medication management service deals with the description of messages medicines for the purposes of messaging information about patient medication list. Operations of Medication management service range from basic functionalities for managing medication list to operations for fetching medical information from the database. Typical operations of the Medication management service are: addDrugForPatient ï adds new drug to a patientôs medicine list, deleteDrugForPatient ï deletes drug from a patientôs medicine list, retrieveDrugList ï retrieves drug list for requested patient, and retrieveDrugInfo ï retrieves detailed information about medication (description, package type, using guidelines etc.).

D. Calendar management service

The requirement for calendar management functionalities came through the interviews with families of elderly that needed a way to organize everyday tasks of they loved ones. The selection of appropriate HL7 services and operations, and generations of messages is done equivalently as with the Medication management service.

The Calendar management services enable communication of events related to the scheduling of appointments for healthcare services and scheduling of different social activities. The scheduling system maintains a set of schedules related to certain person or resource, managing the process of arranging and booking appointments. Typical operations of Calendar management services are: bookActivity ï writes new activity into a userôs schedule, cancelActivity ï deletes activity from a userôs schedule, retrieveExistingActivities ï retrieves the list of existing activities from a requested userôs schedule, retrieveActivityInfo ï retrieves detailed information about activity.

V. PROOF-OF-CONCEPT APPLICATION

To validate our approach of modeling services and to demonstrate that created services can be easily used for flexible health-care applications we develop a Proof-of-concept application (POCA). The POCA development starts with the capturing of specific user needs through a scenario that is specified by the end user. The implementation of the POCA is realized through the development of business processes that are specific to the application and identifiable in the described scenarios. The users are provided with a user interface that hides the complexity of the system and offers simple commands to use the system.

A. Description of scenario

Rosa lives alone in a small house in a village. She was diagnosed Alzheimerôs disease 3 years ago and she is aware about the decline of her cognitive abilities. Some neighbors support Rosa with activities and she is more or less included in the social life. Every two weeks Rosa has to see the doctor to check her health condition. Due to the fact that medications she is using (number and sort of pills, when they should be takené) are often changed, during the meeting the doctor gives Rosa a lot of additional information about what she should take care of (e.g. avoid some edibles, which side effect some of the pills have etc.).

Basic scenario

In the basic scenario, the POCA system maintains the list of medications that are prescribed to Rosa. Rosa can at any time access the system and get specific information about medications that she is currently prescribed to. These additional information are entered by doctor and can contain various data related to the medication use. Furthermore, POCA maintains a scheduling system that maintains the schedule when Rosa needs to take the medication. The POCA system can initiate a reminder for Rosa to take the medication at appropriate time.

Upgraded scenario

In the upgraded scenario, Rosaôs condition has worsened, and Rosa sometimes forgets to take her medications even though she receives reminders from POCA system. Thus, POCA needs to be accommodated to this change.

B. Realization of basic scenario through business process

The basic scenario can be implemented using business process that coordinates the Medication management and Calendar management services as presented in Figure 3.

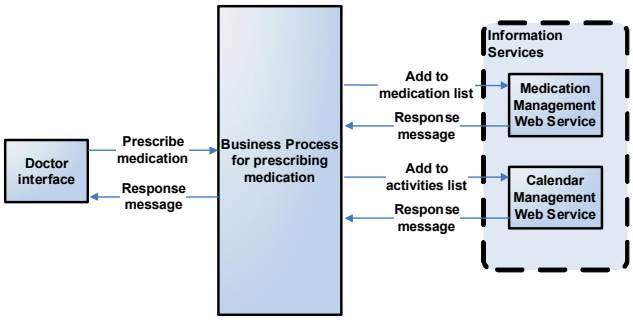

Figure 3. Business process for prescribing medication to a patient

The doctor uses Doctor interface to enter medications into Rosaôs medication list. The Doctor interface uses business process to submit a medication to Rosaôs list of medications. While submitting the medications the business process not only inserts the medication into Rosaôs medication list using the Medication management service, but also makes a call to Calendar services where it schedules activities for Rosa. The scheduled activities contain reminders that will remind the Rosa when she needs to take the medication.

Similarly, Rosa has user interfaces that she uses to access the systems services. The interfaces need not access the systemsô services through business processes. For instance, interface for Rosa can access MPOWER services directly and display the list of medications prescribed to Rosa. The implemented interface is demonstrated in Figure 4.

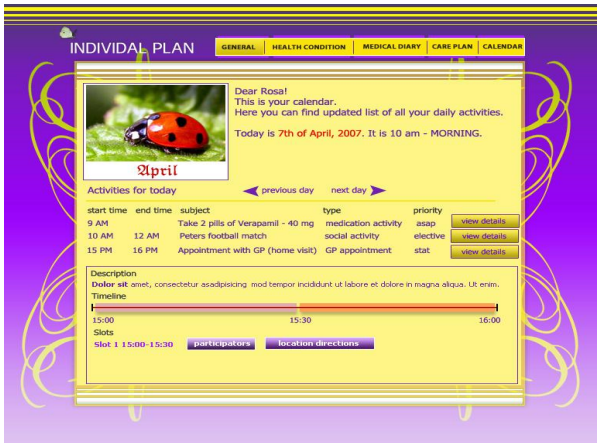

Figure 4. User interface for proof-of-concept application

C. Adaptation of scenario through business process

After Rosaôs condition has worsened the POCA logic needs to be modified to accommodate to additional functionality that is required from the system. For instance, the system may be adopted in a way that Rosa is assigned a caregiver that is willing to help her to take the medications. The caregiver need to be updated of any modifications to Rosaôs list of medications or schedules.

The POCAs functionality is modified by modifying medication prescription business process as presented in Figure 5.

The upgraded business process coordinates three services. New service that business process uses is Message sending service from Interoperability services package. The Message sending service cooperates with telecom provider and enables sending SMS messages. When a new medication is prescribed through the new business process, the process not only adds medication to the list of medications and schedules a reminder, but also sends an SMS to the caregiver notifying him of the modifications to Rosaôs medication plan.

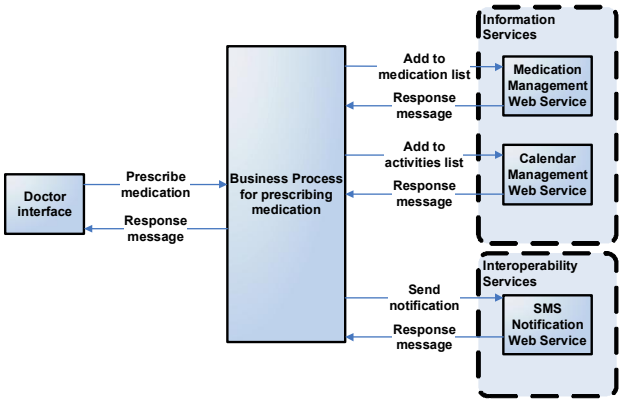

Figure 5. Adapted business process for prescribing medication to a patient

VI. CONCLUSION

MPOWER is a service-oriented platform that allows for quick and modifiable creation of health-care applications for elderly and cognitively impaired. The MPOWER middleware platform consists of a set of services that are specifically selected and designed for use in the domain of health-care for the stated group of people.

With MPOWER platform, applications are developed by creating services-based business processes that coordinate the services of the platform to achieve a specific application goal. As demonstrated in the proof-of-concept application, business processes provide a valuable asset when developing applications for elderly. The primary benefit of business process based applications is the ease of adaptiveness that is highly needed in the health-care of elderly.

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