Toward Dynamic Service Provisioning in the Homecare Domain

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***Abstract*—Dynamicity is one of the main challenges in providing sustainable solutions for the homecare domain. The dynamicity of homecare systems, caused by external entities like care-receivers and care-givers, can be addressed through combining distributed and heterogenous services both in design and runtime. In general, several research fields such as dynamic service composition, context-aware service composition and dynamic configuration contribute to provide solutions to handle the dynamicity. However, the dynamicity requirements and constrains in homecare domain demands its own solutions. In this paper, we explain our understanding of a homecare provisioning platform and its external entities which interact with the platform. Based on our application scenario and literature study, we identify different types of changes which are imposed by the external entities. Moreover, the characteristics of the external entities, which need to be taken into account to address the dynamicity, are discussed. Then, we study the existing dynamic service composition approaches to see their feasibility for the homecare domain. Finally, we explain our motivation for choosing a hybrid service composition approach as our basis for the homecare provisioning platform with respect to the identified changes and characteristics coming from the external entities.**

Keywords: Homecare, independent living, service provisioning, dynamicity, adaptation, personalization, hybrid service composition, processes and rules.

I. Introduction

The ageing population trend in industrialized countries is expected to cause several serious challenges in the near future. One of these challenges will be how to cope with the need of care for elderly. It will be difficult to support elderly in the role of care-receivers, if the existing healthcare systems and processes remain the same [1]. A promising solution to this problem is to improve healthcare systems and to support independent living for elderly in their own homes by way of homecare service provisioning [2]. Provisioning of homecare services can be made feasible by using ICT based services which can be composed and coordinated in a loosely coupled manner.

An important challenge to realize homecare service provisioning is to find effective ways to handle the dynamicity demands of the homecare domain. These demands call for adaptability of (orchestration of) services in response to a) frequently occurring contextual changes like a care-receiver's location and activity, or b) slowly developing changes in a care-receiver's requirements like his/her extent of impairment [3].

Especially the frequently occurring changes should be addressed by the homecare provisioning platform. In case the provisioning can not perform the runtime adaptation, services and service coordination/composition process should be modified at design time. A tailoring platform can be used by the care-givers such as nurses (as they are aware of the care-receiver's situation), to tailor the services and processes before deployment to the provisioning platform [4].

In general, several research fields such as dynamic workflow management [5], automatic (a.k.a. adaptive or dynamic) service composition [6] [7], context-aware service composition [8] and dynamic configuration [9] contribute to address the dynamicity challenge. Nevertheless, adaption to changing conditions and requirements is still one of the main problems for providing elderly-centric homecare services.

Our objective is to provide a provisioning platform which supports adaptability, taking account of the dynamicity requirements and constraints of the homecare domain. Using this platform, different types of homecare services can be configured, composed and presented as a seamless homecare application to the care-receivers. The homecare services can be either provided (hosted) by internal devices installed at care homes or by third-party care centers like a clinic outside care home. Prior to the design of the provisioning platform and its architecture, we should decide on the approach to provide adaptive and dynamic service provisioning.

Our main contribution is answering the question: what is the most suitable homecare service provisioning approach to address dynamicity? To answer this questions, we need to know the dynamicity requirements and constraints of the homecare domain. Based on our literature study and also an application scenario, first, we identify the external entities which interact with the homecare services provisioning platform. Then, we identify the changes imposed by these external entities on the homecare services. We further explain the characteristics of the external entities that imply several constraints on providing the solutions. Finally, we discuss several automatic service composition solutions and present their pros and cons in respect to the identified demands and constrains.

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The remaining of this paper is organized as follows: Section II presents a homecare application scenario to be used as an example for the rest of this paper. In Section III, we define our service provisioning platform and how it interacts with external entities. In Section IV, we identify the types of changes imposed by each external entity and how they should be addressed either through the tailoring or the provisioning platform. In addition, the characteristics of the external entities that might constrain the homecare service provisioning approach are discussed. In Section V, several existing service composition approaches are explained in relation to the dynamicity demands of the homecare domain. Section VI motivates an existing hybrid dynamic service composition approach to be applied for the homecare domain. In Section VII, we briefly explain our plan for future work and to implement the provisioning platform with respect to the hybrid service composition approach. Finally, in Section VIII, we conclude our discussion and explains how we plan to proceed further.

II. Application Scenario

We use the following homecare application scenario to motivate the work presented in this paper and to clarify our discussion.

John and Marie are patients with a minor form of Chronic Obstructive Pulmonary Disease (COPD). Their quality of life is improved when being active and regulating their weight. However, when being active, for example walking, it is important to monitor their oxygen saturation for safety reasons. If the saturation level drops too low, exacerbation may occur, leading to hospitalization and more expensive long-term care. Additionally, John has a hearing disorder while Marie has vision impairment. Besides that, both of them suffer from amnesia and need to be reminded for doing their tasks. Nancy as a professional care-giver is responsible to create and tailor the homecare services installed in their care homes. The care homes are equipped with a Tablet PC, a PDA, a medicine dispenser and an oxygen saturation meter. MobiHealth [1], as one of the third-party service providers, encapsulates measurement devices such as oxygen saturation meter and provides measurement services which can be used by other homecare services. Nancy creates two personalized reminder services for both John and Marie, (1) to remind them to attach the oxygen saturation meter before leaving the home and (2) to remind them to take their medicine on time. Nancy tailors the services to use Tablet as a reminder device for Marie and to use a high voice volume either on Tablet or PDA as a reminder device for John. John and Marie have individual preferences with respect to the delivery of the reminder service. For instance, John prefers to get a vibration reminder on his PDA instead of voice, when he has company. At runtime, the Tablet becomes unavailable, therefore the provisioning platform adapts the reminder service of Marie to use PDA with voice instead of Tablet. If John or Marie do not connect the oxygen saturation meter when they leave their homes or if the oxygen saturation drops below a predefined threshold, an alarm is sent to the care center. The predefined thresholds and corresponding tasks are different for John and Marie. In case of frequently ignored reminders, the provisioning platform adapt the reminder service, for instance, because of hearing impairment development for John, it increases the default volume of reminder and informs Nancy to re-tailor the service. At runtime, if John is outside of his home, the provisioning platform sends the reminder earlier than it is predefined by Nancy. Nancy visits John and Marie every day and based on their evolving health condition, she also decides to re-tailor the services, for instance, the need for a particular medicine and thus, the provisioning platform updates the medicine reminder service during its execution.

[1] http://www.mobihealth.com

III. Provisioning vs tailoring

To adapt the homecare services to the changes, the provisioning platform should be able to adapt services, while they are being executed. If the runtime adaption is not applicable, the care-givers modify the homecare services at design time through the tailoring platform and then (re)deploy them to the provisioning platform. In order to avoid any misunderstanding, we should explain our perception from the tailoring and provisioning platforms and their interaction with each other. Figure 1, shows the overall view of the tailoring and provisioning platforms.

We define service tailoring as a process which consist all activities that a care-giver performs at design time, i.e., prior to the provisioning of homecare services. The service tailoring ends with the specification of the homecare services, i.e., service plan which constrain the behaviour of the homecare services at runtime. The service plan should foresee all the possible changes and determine the corresponding desired behavior of the services. The tailoring platform is responsible to enhance the creation and tailoring of the service plans by providing Graphical User interface (GUI) for the care-givers. After confirming the service plan by the care-givers, it is deployed to the provisioning platform to be executed.

In our definition, a service plan refers to one or more service building blocks (SBBs) and describes the configuration and orchestration of instances of these SBBs as well as decision rules with respect to run-time behaviour. The SBBs, like a medicine dispenser or reminder, are the smallest manageable services which cannot be broken down further into smaller services from the care-givers point of view. Configuration parameters allow the care-givers to specify different aspects of the SBBs such as service operations and user interface modalities. Orchestration schemes determine how SBBs are composed. Decision rules determine the possible adaptation at runtime, based on evaluation of the rules with runtime data (e.g., context values). For example, decision rules can be used to choose between alternative operations of one SBB or between alternative data and control flows among the SBBs, based on specific runtime circumstances.

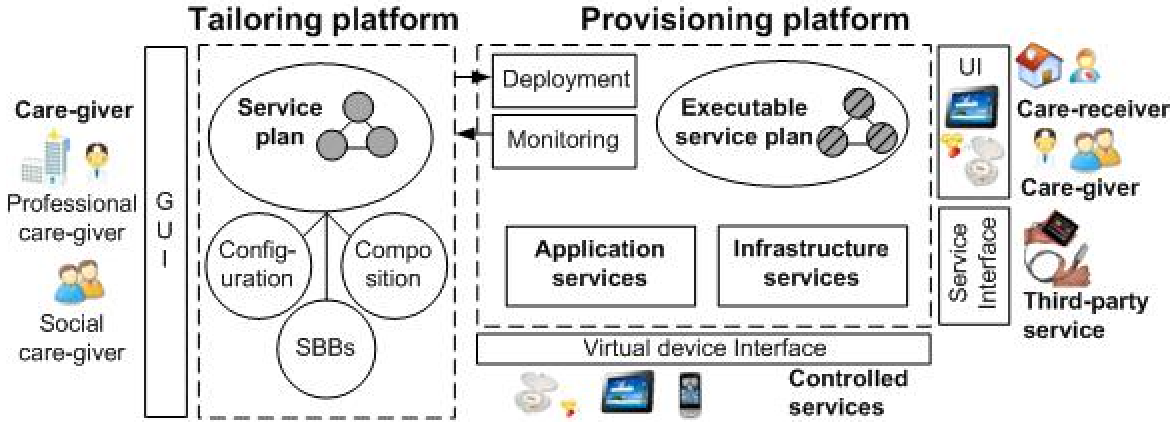

Fig. 1. The overall view of the tailoring and the provisioning platforms

Since we aim to support dynamic service composition, we follow the late binding mechanism which is more adaptable in compared with early binding [10] [11]. The late binding abstracts concrete details of SBBs from the care-givers and enables them to create and tailor the service plan in a straightforward way. Later, in the provisioning platform, the SBBs of the service plans will be binded to the *application services*. Hence, the service plan should be detailed enough to enable the provisioning platform to convert them to executable format.

By service provisioning, we mean the execution of the service plan based on functionality offered by available services at runtime. The provisioning platform should bind the abstract SBBs used in the service plan to the *application services*. The late binding and execution of the *application services* based on the service plans are supported by the *Infrastructure services* like discovery and messaging, which are provided by the provisioning platform. Since we focus on the service plan specification and its desired dynamic service provisioning approach, the *Infrastructure services* are not discussed in this paper. The *application services* are provided either by the third-party service providers located outside the care home or the controlled services installed inside the care home. Based on our application scenario, MobiHealth provides the oxygen saturation meter as a third-party service which is accessible for other services trough the Internet. As an example for the controlled services, we have medicine dispenser which can be represented by a virtual device inside the provisioning platform and then, its virtual device realize the medicine functionality as a set of application services which can be employed by other services.

We define a bidirectional communication between the tailoring and provisioning platforms. On the one hand, the service plan coming from the tailoring platform will be deployed to the provisioning platform through its *Deployment* component. On the other hand, the provisioning platform provides feedback to the tailoring platform through the *Monitoring* component based on the behaviour of the homecare services as well as the care-receivers. For example, the feedback about too many failed reminder can acknowledge *Nancy* to increase the default voice volume of the reminder service for *John* due to his hearing impairment development. The provisioning platform interacts with care-receivers and needs to be installed per care home to execute its own services. In contrast, the tailoring platform interacts with the care-givers and one tailoring platform can be employed for a care center of several care homes. Care homes are either private homes located outside of a care center or units located inside a care center.

IV. Dynamicity in the Homecare Environment

In general, the dynamicity in workflow and consequently in service composition refers to the need of adapting the workflow process instances to the changes while they are being executed [12]. In the homecare domain, the provisioning platform must automatically perform the changes, originated by external entities, in homecare service instances, i.e., service plan instances with respect to constraints which are also imposed by the external entities.

We define the homecare provisioning platform as a real-time safety-critical reactive system [13] which is in continues interaction with its environment and based on the external stimuli enables, enforces or prevents a behaviour in its environment. By real-time system, we mean the correctness of the system response depends on the time of being produced. By the safety-critical [14], we mean that any system malfunctioning could lead to loss of life. For example, the alarm must be sent exactly at the time *John* is leaving the care home without attaching the oxygen saturation meter; if it happens later or send to a wrong person, it might leads to serious hazard situations. To provide an appropriate homecare dynamic service provisioning approach, we should identify different types of changes caused by the external entities. We should investigate which of these changes must be addressed by the provisioning platform and which one must be addressed by the tailoring platform. In addition, we should take into account the characteristics of the external entities that might constrain the homecare service provisioning approach.

A. The Types of Changes Caused by the External Entities

To see what type of changes can happen, we need a context diagram to consider all the external entities which can communicate with the provisioning platform. Based on the definition, *"the context diagram represents the system ... and the entities and the communication in its context. The diagram represents the entities given to us, not designed by us"* [13]. Figure 2 shows the context diagram of the homecare provisioning platform based on the application scenario mentioned in Section II. It shows the external entities as the source of the changes and their communication with the system which are explained as follows:

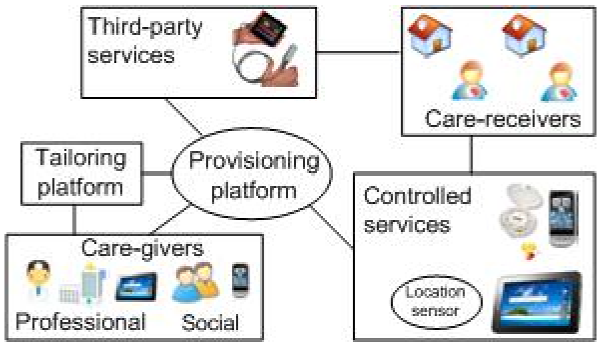

Fig. 2. The context diagram of the provisioning platform

- *Controlled services*: are hardware and software components which are controlled by the provisioning platform. The virtual devices, as the representatives of the hardware components, are installed inside the platform. The provisioning platform should provide appropriate interface for the virtual devices to interact with their corresponding hardware devices like medicine dispenser which are installed in the care home. The installation and interaction should be done with respect to their dynamic life cycle without interfering the operation of other components. Their contextual information like location, and their QoS like availability can change at runtime. The QoS of the controlled services might be affected by their dynamic life cycle. They might also have different functionalities over time; both at design and runtime. For instance, the PDA can be muted and therefore, does not support the audio functionality anymore or a medicine dispenser is out of medicine and can not be enabled, as runtime example, and an existing PDA inside the care home may be replaced by another PDA possibly with differences functionalities, as design time example.
- *Third-party services*: provide the services which are accessible through the Internet and can be employed by other services running on the provisioning platform. As such, they might use the hardware components inside the care home like the oxygen saturation meter. Unlike the controlled services, they have their own infrastructure to mange their hardware component independent of the provisioning platform. The provisioning platform only provide their services interface and make them available for other services. The QoS of third-party services like their response time might be affected at runtime either by their providers themselves or the communication infrastructure between their providers and the platform. Similar to the controlled services, their functionality, by replacing an third-party service by another one, might need to be adapted at design time. Because of their external communication, they might change their communication protocol, for instance, using an encryption protocols for the oxygen saturation data before sending over the Internet.
- *Care-receivers*: live at their care homes, i.e., where the provisioning platform has been installed. They use a set of interfaces either provided by the controlled services like PC Tablet, PDA, medicine dispenser or provided by the third-party services like the oxygen saturation meter to interact with the system. In addition, the location sensors, provided by the controlled services, implicitly monitor and inform their location to the system. Their contextual information like location can change both at design and runtime. They can have different behaviour like willing or not willing to take medicine on time. Many of these behaviour patterns, like the time of responding to a medicine reminder is not known until the provisioning system is running for a while and sends feedback about the care-receiver's behaviour. Due to their behaviour change, they might change their preferences over time like the preferred reminder device in different context (for example, *John* prefers vibration instead of voice if he is not alone) which should be taken into account. Their health condition can also change and therefore their care-giver should be able to modify the homecare services, for example, changing the medicine intake reminder. Their impairment, like John's hearing impairment, can develop over time and therefore the homecare services must be adapted by the care-givers, for instance, by increasing the default voice volume for the reminder sent on the Tablet or PDA.
- *Care-givers*: either professional care-givers from the care center or social care-givers like the neighbors, house-mates and friends, create and tailor the homecare services through the tailoring platform based on their predefined authority. They are also responsible for reacting on the alarm sent by the homecare services running on the provisioning platform. All the design time changes mentioned in other three types of external entities must be addressed by the tailoring platform. As such, the service plan can be updated trough the tailoring platform. Although these changes happen at design time, the corresponding service plans might change while the provisioning platform is executing an instance of them. For instance, a medicine reminder service is running for several days and Nancy modifies its corresponding service plan because of John's health condition for a particular day. In addition, the QoS of services provided by a care-giver like his/her response time to the alarm, might change at runtime. For instance, a professional care-giver does not answer and thus, a social care-giver should take the responsibility of responding to the alarm.

There are also some changes originated by the care-givers themselves. It might be the case that they change their care services agenda like the medicine schedule and based on that, the homecare services must be adapted at design time. Tableřeftab:changes summarize the types of changes which have been discussed.

TABLE I
THE TYPES OF CHANGES CAUSED BY THE EXTERNAL ENTITIES

	Types of changes	
External entities	*Provisioning (runtime)*	*Tailoring (design time)*
Controlled services	Context QoS Functionality	Functionality
Third-party service	QoS	Functionality Communication protocols
Care-receiver	Context	Health condition Prefereces Impairment
Care-giver	Service plan QoS	Service plan Care services

B. The Characteristics of the External Entities

We identify different types of changes imposed by the external entities of the provisioning platform in the previous subsection. However, beside these changes which the homecare tailoring and provisioning platform must be able to satisfy them, there are several constraints which also imposed by the external entities. Based on our interviews with the couple of care-receivers and care-givers within the U-care project as well as our literature study, we identify several characteristics of the external entities which should be taken into account to address the dynamicity as the constraints. These characteristics are explained as follows:

- *Controlled services*: are possibly provided by various physical devices with limited resources (for example, memory size, computation power) which leads to several constraints on their usage. For instance, an example location sensor is not able to implement TCP/IP protocol stack and thus, if the provisioning platform is located outside the care home, this sensor can not directly communicate with the platform. Providing a cooperation environment for the homecare services is required to enable the controlled service providers to manage their hardware component (for example, install and configure) without interfering other components' operations. Therefore, QoS of the virtual devices, in homecare environment, is not guaranteed.
- *Third-party services*: are services implement outside the provisioning platform. The communication infrastructure between the external services and the provisioning platform can have huge impact on their QoS. For instance, in our scenario the oxygen saturation meter is connected through GPRS (General packet radio service) which can cause delay in the service response. These impacts should be taken into account during the service plan creation.
- *Care-receivers*: usually are elderly possibly with functional loss from multiple disabilities [15]. Therefore, the assumption about interference of end-user to correct the system behaviour, in other application domains, is not true in the homecare domain. The homecare services should be self-adaptive and non-intrusive, i.e., less interference with the care-receivers to check weather a particular behaviour is desired or not. On the other hand, due to safety-critical environment [14] any homecare services malfunctioning could lead to loss of life [14]. To this end, the service plan of homecare services should be accurate and also as complete as possible in order to decide about the correct services behaviour.
- *Care-givers*: is a non-expert user from IT perspective and therefore, prefers to create and tailor the service plans as simple as possible. This tendency contradicts with the nature of creating a service plan. A service plan, consisting of the SBBs, their configuration and composition information have to deal with frequently changes identified in above such as unexpected care-receivers' contextual information. It becomes even more complex when foreseeing all of the changes is not possible at design time. Moreover, the care centers usually have limited manpower as well as ICT infrastructure to provide the care services. For instance, for the manpower constraint, the tailoring should take as less time as possible and for the ICT infrastructure limitation, since there is usually one or two care-receivers per each care home, assuming a dedicated provisioning server for each care home to host the provisioning platform is not realistic. The care-givers are also obliged to follow the existing medical guidelines and protocols employed by the care centers. The use of medical protocols and guidelines improves the care services for a care-receiver [16]. It becomes very important when the use of clinical assessment and information for the homecare services is a essential need for realistic homecare solutions [15]. Table II summarize the characteristics which have been discussed.

TABLE II
THE CHARACTERISTICS OF THE EXTERNAL ENTITIES

External entities	Characteristics
Controlled services	Resource-constrained devices Dyanamic availability
Third-party service	Limited communication support
Care-receiver	Limited ability to use services Safety-critical
Care-giver *(and care center)*	Limited technical skills Limited recourses Bounded to medical protocols

V. EXISTING DYNAMIC SERVICE COMPOSITION APPROACHES

As mentioned before, the provisioning platform should be able to adapt the homecare services to the runtime changes. The adaption is done based on the configuration information of SBBs and their composition schema in the service plan. As such, two research fields, automatic (a.k.a. adaptive or dynamic) service composition [6] [7] and dynamic configuration can be considered as the related works. In this paper, we focus on the automatic service composition to investigate the existing approaches which can be used for the homecare domain.

Several automatic service composition approaches have been designed and implemented [6]. These approaches in general can be classified in three categories: (1) Workflow composition (2) AI-planing and (3) hybrid of workflow composition and AI-planing. With respect to our definition of the service plan, in workflow composition, the service plan contains a set of SBBs together with the control and data flow among them. This can be done at two levels: static and dynamic workflow generation. In the static workflow generation, the provisioning platform only discover and bind the concrete services to the SBBs at runtime without changing the control and data flow. Graph is the most commonly used method for the static workflow generation [17]. In contrast, in the dynamic workflow generation, both the flows and binding are accomplished by the provisioning platform at runtime. Therefore, the SBBs' constraints including their dependency must be determined by the service plan for the provisioning platform.

In AI-planing approach, the service plan contains a set of SBBs including their precondition and effect in the environment [18]. From the system point of view, each SBB is a software component that has input and output data. Therefore, their precondition and effects are their input and output parameters. From the environment point of view, a SBBs is an action which can alters the state of the world after its execution. So the world state which is required before the execution of a SBB is its precondition and the state of the world after the execution is its effect. The provisioning platform, based on these two views of precondition and effect for SBBs, conduct runtime reasoning to generate the executable service plan. There are several AI-planning methods to define the precondition and effects of the SBBs such as rule-based method. The rule-based method use composability rules to determine whether two SBBs are composable or not [19].

The hybrid service composition approach uses both the workflow composition and AI-planing methods. A combination of workflow and rules has been introduced in [20]. By applying this method in our provisioning platform, the service plan is broken down into two parts. (A) The first part shows a basic and simple process model of the SBBs and it includes their data and control flows. (B) The second part has a set of rules to determine based on the changes at runtime how the basic process model can be updated. These rules includes both composition and configuration information. As an example of the first part of the service plan, we have an expected desire behaviour process model for the medicine reminder service for John. It shows that the provisioning platform must (A1) enable the medicine dispenser, (A2) send reminder, (A3) check weather the medicine is taken or not, (A4) send the alarm if the medicine is not taken. As the second part, we have a set of rules to determine (B1) how many time the reminder should be sent, (B2) how long the service should wait for sending the next alarm.

VI. Motivation for hybrid service composition in the Homecare Domain

In this section, we explain why we are willing to use the hybrid service composition approach as our basis for the homecare provisioning platform. The hybrid service composition approach employs both workflow and rule-based decision support (as one of the AI-planing methods) to create the service plan for the homecare services. The provisioning platform is able to adapt the basic process model due to the changes which can happen at runtime, by exploiting the rule-based decision support. With respect to the types of changes caused by the external entities and their characteristics, identified in Section IV, our motivations are explained as follows:

A. Well-suited with medical protocols

Medical guideline and protocols have been exploited by the care-givers to provide a care service to a care-receiver in a standard way [16]. There are several methods to support computer-based modelling medical protocols: (1) Rule-based (2) workflow, i.e., careflow (3) task network [21].

(1) Rule-based medical protocols like Arden Syntax for Medical Logic Modules (MLM), which is part of Health Level Seven (HL7), has been employed to facilitate knowledge sharing among care-givers, for instance, for COPD treatment [22]. With respect to our application scenario, MLM can be used for COPD treatment to evaluate medical criteria, and, if appropriate, perform an action such as sending a message to a care-giver [22].

(2) Careflow as a process defines which task needs to be executed in which order [21]. To implement a careflow complaint system, workflow management system is considered as a solution [5].

(3) Task network languages are defined based on an ontology of task. Several task network languages like PROforma, are based on a process definition langauge which make them similar to the careflow languages method [21]. However, they have their own components ontology such as tasks and decisions.

To conclude, there is significant similarity between the hybrid service composition approach and the existing technologies to model computer-based medical protocols.

B. Accurate and non-intrusive adaptation

The homecare provisioning platform and the services running on top of it, are classified as safety-critical [14] systems. It means that any system malfunctioning could lead to loss of life. The malfunctioning can arise from the hardware failure as well as wrong decision which are made based on the service plan to adapt the homecare services at runtime. Therefore, care-givers must be able to accurately control the behaviour of the system at runtime. Due to boolean logic of rule-based adaptation, the care-givers can accurately control the behaviour of the system. For instance, Nancy can explicitly determine in the service plan, if John leaves the home without attaching oxygen saturation meter, send an alarm to the care center.

In homecare domain, due to the limited ability of the care-receivers to use ICT-based services, the homecare services should be non-intrusive, which means not to ask care-receivers for any interference like whether they prefer a system decision or not. In other type of AI-planing approach like TLPlan [23], the runtime reasoning is based on the real world model. This provides a highly complete adapting method to the unexpected changes. In this approach, inquiry from the end-users to make sure about the correctness of the runtime decisions, plays an important role. In contrast, the rule-based approach, although may compromise the completeness of the runtime adaptation, the service plan can be defined accurately and thus, does not need to ask the care-receivers to interfere. We believe that, in the homecare domain, the accuracy and non-intrusiveness of the service provisioning has higher value than being complete.

C. Existing context-aware and QoS-aware solutions

Adaptation to frequently occurring contextual changes of both the care-receivers and controlled services is one of the main requirement of the homecare provisioning platforms. The feasibility of Logic Based Models like rule-based logic, to provide context-aware service composition have been shown in several works [8] [24] [25]. We believe that the context model of a limited environment like a care home can be modeled by a simple contextual modelling approach like Key-Values model and Markup Scheme Models which are in compliance with rule-based approach [25].

The QoS of the homecare services especially the controlled services is subject to change. Like context, exploiting rules is considered as a solution to provide QoS-aware behaviour [26]. At runtime, if there is no preferences on different alternative concrete services for a specific SBB, the history of QoS can be employed to choose the most reliable concrete service. For instance, if John has no preferences, Nancy can define a decision rule in which the provisioning platform in order to bind a concrete service to reminder SBB, choose Tablet over PDA due to its better QoS.

VII. Future Work and Implementation

We plan to operationalize our homecare provisioning platform in a real care center provided by Orbis[2]. We will identify the common homecare problems and their corresponding service plans through performing interviews with the care-givers. Then, we investigate how these service plans can be modeled as workflow and to what extent the rule-based decision support can add flexibility to deal with the changes at runtime.

With respect to our application scenario, Figure 3 shows a hybrid service plan for oxygen saturation monitoring as one of the common homecare problems. The service plan consists of several activities referring to the use of SBBs and their configuration parameters (annotated as data item to each activity), and decision rules to specify the behaviour of the service plan. The provisioning platform executes and adapts the service plan based on runtime circumstances. For instance,

[2]http://www.orbisconcern.nl/

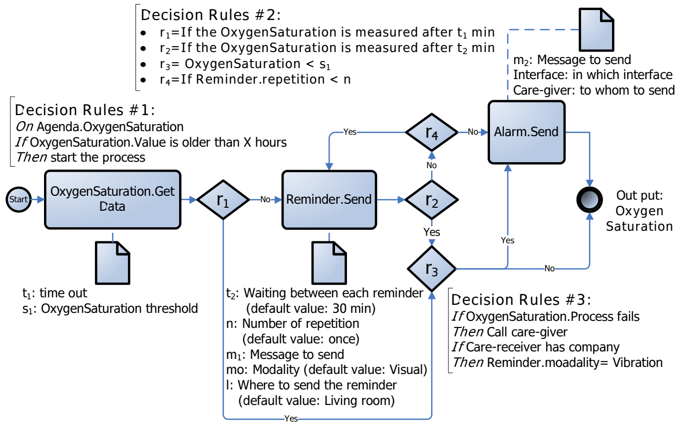

Fig. 3. The service plan of oxygen saturation monitoring

if *John* has a company, a correspondent rule specifies that the reminder should be sent to the PDA via the *vibration* modality. The service plan will be executed based on the care-receivers' agenda if there is no valid measurement within the past few hours. Based on the service plan, the provisioning platform sends a reminder to the care-receivers to measure their oxygen saturation. If the care-receivers forget to do the measurement or their oxygen saturation are blow the threshold s_1 (specified by medical protocols), the provisioning platform sends an alarm to the care-giver.

Regarding the implementation of our proposed solution, we conduct a survey to see available existing tools which are in compliance with the hybrid service composition approach. We have found several process and rule engines which can be used together to add flexibility to the business processes. The idea of combining process and rules is similar to our idea of the hybrid service composition approach. Table III shows a number of available process and rule engines.

TABLE III
Some of the available process and rule engines

Process engine
WebSphere Process Server
Drools Flow
Apache ServiceMix(Apache ODE)
WebSphere Lombardi Edition

Rule engine
WebSphere ILOG JRules
Drools Expert

We plan to use WebSphere Lombardi Edition[3] to model the orchestration of homecare services. We assume homecare services like the controlled services can provide the high-level communication protocols in order to connect to Lombardi process engine like Restful web services and Java messaging service. In case this assumption fails, we plan to employ Apache ServiceMix[4] as a lightweight service bus to support resource-constrained devices installed at the care homes. It supports Apache ODE[5] for the process engine. We also plan to use WebSphere ILOG JRules[6] to model our configuration

[3]http://www-01.ibm.com/software/integration/lombardi-edition/
[4]http://servicemix.apache.org/home.html
[5]http://ode.apache.org/
[6]http://publib.boulder.ibm.com/infocenter/brjrules/v7r1/index.jsp

and composition rules. The WebSphere ILOG JRules has been exploited to model the rule-based medical protocols such as Arden Syntax for MLM [22]. It enables us to define the rules in natural language which is suitable for non-technical care-givers.

VIII. Conclusion

In this paper, we discuss the dynamicity demands of the homecare domain, which call for adaptability of (orchestration of) services in response to several changes caused by external entities such as care-receivers and care-givers. Two types of changes have been identified: frequently occurring and slowly developing changes. Some of these changes can be addressed at design time by tailoring the services through a tailoring platform utilized by a care-giver. Some others need to be handled at runtime by adapting the services through a provisioning platform. The role of tailoring platform and provisioning platform, and their interactions with each other as well as the external entities have been elaborated. Moreover, we identify the characteristics of the external entities which impose several constrains on providing solutions to address the dynamicity demands.

We investigated existing automatic service composition approaches with respect to the identified demands and constrains and conclude that dynamicity in homecare domain can be addressed through a hybrid service composition approach which employs both workflow and rule-based service composition methods. This approach is well-suited to be used with the medical protocols and can be executed at accurate and non-intrusive fashion. A survey has been accomplished to identify the tools which can support the hybrid service composition approach. We plan to implement our work in a real life case at a care center. This can help us to validate the proposed solution and to improve it.

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