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A proposed Next Generation Service Delivery Platform (NG-SDP) for eHealth domain

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***Abstract*—Nowadays, providing healthcare personalized services in user's intelligent space is an important issue for improving personal health, supporting predictive care and saving medical costs. In this paper, we propose an architecture for the Next Generation Service Delivery Platform (NG-SDP), suitable for composing and delivering personalized healthcare services. The core component of NG-SDP is a Context Decision Making Enabler (CDME) that assesses user contextual and bio information to yield personalized services. A prototype implementation of the proposed NG-SDP is also demonstrated. Finally a real case study demonstrates the CDME performance.**

I. Introduction

In the last decades, evolutions in IT and eHealth domains lead to the need of a new environment for delivering services. Novel Service Delivery Platform (SDP) enables efficient creation, deployment and execution of eHealth services that can be integrated easily and flexibly with legacy networks or Next Generation Networks (NGNs) [1, 2].

Several industry organizations and standard bodies, such as OMA, TMF, 3GPP, IETF, the Parlay Group, SIP Forum, and others, have highly contributed to the evolution of SDP. Today's the third generation SDP is built around the primitives of Service Oriented Architecture (SOA) which enable efficient service integration, orchestration and lifecycle management [3]. H. Lu et al in [4] have already proposed a conceptual model for the NG-SDP which will be constructed following SOA principles and integrated with 3rd party providers and IP Multimedia Subsystem (IMS). The general tendency of NG-SDP is all services to be automatically activated, without any manual interventions, evaluating user's contextual information. This autonomous mentality of NG-SDP is supported by intelligent and cognitive functionalities [4, 5].

Especially for the eHealth domain, the implementation of NG-SDP should be based upon well established interfaces for remote monitoring and alarming mechanisms. The Continua Health Alliance has already made progress on providing the appropriate interfaces for remote monitoring and alarming platform, coupling sensors and actuators to remote services, and interfacing these services to health-records systems [6].

On the other hand, the forthcoming next generation personalized healthcare and social services introduce new aspects in the overall service delivery status in eHealth domain as they have to assess patient's contextual information and to adopt the service's provision mode. Hence, it is required a new NG-SDP architecture that enables the efficient creation, deployment, execution, orchestration and management of one or more classes of these service.

This paper proposes an NG-SDP architecture and a prototype implementation for delivering personalized healthcare services. The fundamental entity of this architecture is a Context Decision Making Enabler (CDME) which assesses contextual and bio information to yield personalized services. The NG-SDP enhanced with the CDME provides autonomous functionality so as to be an open platform for delivering eHealth services.

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II. Next Generation Service Delivery Platform (NG-SDP)

An NG-SDP is a middleware software architecture that is composed of Functional Entities (FEs) in order to create the core functionality for the "autonomous" service delivery. By the term "autonomous" we define the capability of SDP to invoke and bind services directly by alarms, notifications or triggers yielded by user's context without any manual interventions from any user.

NG-SDP is aligned with the mentality of SOA and NGN so as to provide flexibility, fast services' creation, integration, and reusability of enablers and services and low total costs for 3rd party providers. Moreover, NG-SDP enhanced with open application programming interfaces (APIs) aiming to incorporate enablers which add per case functionality to the platform related with networking, context-aware, positioning, etc. [Parlay/ETSI [7]] Finally, it enables the deployment of personalized services through the evaluation of users' contextual information. In this section we analyze the FEs and the overall architecture of the proposed NG-SDP, so as to distinguish itself from the current SDPs (Fig. 1).

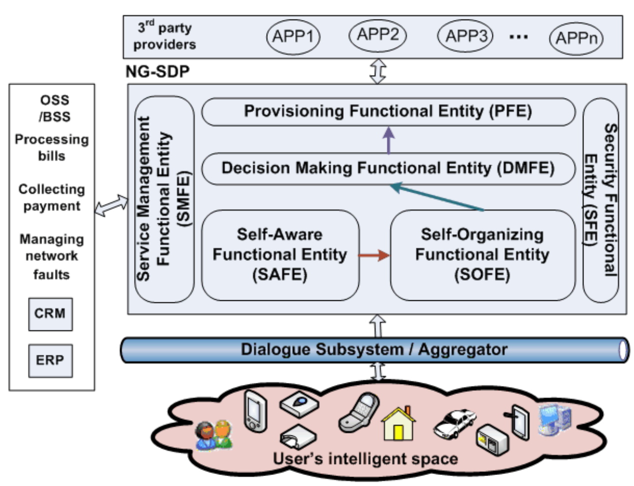

Figure 1. Generic overview of the proposed NG-SDP.

A. Functional Entities (FEs)

The functional model of NG-SDP describes six core FEs: provisioning (PFE), self-aware (SAFE), self-organizing (SOFE), decision making (DMFE), security (SFE) and service management (SMFE).

Provisioning Functional Entity (PFE) creates sessions between service providers and users. It performs registration, discovery, invocation and binding of services taking into account the capabilities of services and users. PFE is triggered by DMFE in order to select the adequate service according to the environment, preferences, quality of experience (QoE), and needs of the user. Following the SOA primitives, PFE orchestrates, integrates, manages and controls services offered by service and network providers. Finally through SFE and SMFE, PFE controls the whole process to ensure its safe and reliable provision and to guarantee the appropriate quality of service (QoS) in respect to user's characteristics, e.g. QoE. Whenever user's health status changes, PFE reassigns user's connectivity and service requirement and proceeds to the establishment of the appropriate session.

Self–Aware Functional Entity (SAFE) handles context aware and communication capabilities of the user and his/her caregivers (doctor, nurses, relatives, volunteers, etc). These capabilities are dispread in several NGNs (or clouds) and they are wrapped by the Dialogue Subsystem/Aggregators. The communication capabilities are related to static networking data (e.g. flow rates, charging) that are provided, mainly, by the underlying networking FEs, such as the NGN Operation Support System/ Business Support System (OSS/BSS) [1] and the Home Subscriber Server (HSS). The context aware capabilities are related with user's context and bio data that are collected by sensors, cameras, PDA, etc. These data represent users Activities of Daily Living (ADLs) and are essential for estimating user's medical condition(s).

Self–Organizing Functional Entity (SOFE) creates the healthcare profile of the user. SOFE evaluates processes, interprets and integrates both real time acquired information by SAFE and users' profile data and medical archives collected by Electronic Health Records (EHRs). Moreover, SOFE supports dynamically the self-organization of user's profile using contextual data. SOFE is under strict SMFE and SFE, not only for the threat of malicious intent but also for self–healing purposes.

Decision Making Functional Entity (DMFE) creates personalized models for healthcare provisioning, which will be executed by NG-SDP. DMFE makes a decision about the required services and entities (e.g. caregivers) tailored on the user's health status provided by SOFE, and user's networking capabilities, provided by SAFE. This model is selected, formulated, executed and interpreted with pre-defined rules of SMFE. This process leads to the creation and deployment of personalized services. Finally, DMFE provides notifications to PFE so as to bind the involved entities and execute the personalized service. DMFE is correlated with SMFE and SFE so as to protect and ensure the whole process.

Service Management Functional Entity (SMFE) provides a set of management capabilities related with services' life cycle, selected NGN-OSS/BSS functionality (e.g. services billing, payment, etc), as well as the cooperation with 3rd party providers through e.g. policy management, Service Level Agreement (SLA), Authentication, Authorization, and Accounting (AAA), etc.

Security Functional Entity (SFE) provides mechanisms for service authentication, authorization, admission and other security related tasks during the operation of PFE and SMFE. SFE enhances SDP autonomy by introducing self-healing and self–protecting mechanisms that lead to a system higher tolerant in faults and more robust.

B. Architecture of the proposed Healthcare NG-SDP

According to the FEs mentioned above, the architectural infrastructure of the NG-SDP is depicted on Fig. 2. In contrast to the traditional SDP architectures e.g. that in [2], the proposed NG-SDP establishes the "autonomous" functionality via an additional enabler, named as CDME.

Following we demonstrate the component of the proposed NG-SDP architecture. Note that there is not any one-to-one correspondence between these components and the FEs.

Communication/Context Enablers are generic functional components handling the capabilities provided by SAFE, and the common capabilities (e.g. VOD, email). All enablers are implemented as building blocks of reusable services. Special APIs allow seamless access to these enablers by multiple end-users and 3rd party applications and services [1, 2, and 7]. All the enablers interact with the CDME and Telemedicine Service Bus (TSB) [1].

Context Decision Making Enabler (CDME) incorporates SOFE and DMFE and it is extensively analyzed in the Section III.

Telemedicine Service Bus (TSB) is an event driven message broker that incorporates PFE and SMFE [1]. It is the appropriate messaging environment for efficient and consistent exchange of information / notifications or for session establishment among the NG-SDP components.

Service Registry (SR) is the main store of the system that includes the services, applications and other information, which are delivered through the NG-SDP.

Service Creation & Execution Handler (SCEH) is the environment with the appropriate tools and facilities for the creation (orchestration and integration), modification and execution of the NG-SDP delivered services. SCEH combines user preferences (included in user profile), contextual and other data (yielded by enablers) with registered services in order to creates personalized services. All services created by SCEH are published and stored to SR.

Policy Enforcement and Enhancement Management (PEEM) is responsible for covering both policies related to the subscriber (user) (e.g., subscriber preferences, Service Level Agreements (SLAs), Authentication, Authorization, etc.), and policies related with the OSS of the network (e.g. if a service enabler is already monitored, provisioned, and for whom subscriber, etc.). According to this information, not only policy repositories are unified, but also the management of newly composed services is automated. PEEM covers a broad spectrum of SMFE and mainly of SFE.

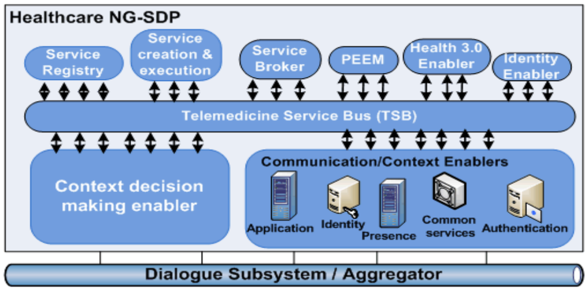

Figure 2. Proposed Architecture of Healthcare NG-SDP.

Service Broker incorporates the discovery and exposure features of PFE. It utilizes PEEM policies for the proper finding (from the SR), binding and invoking of the required services. It interacts with Health 3.0 and Identity Enablers to ensure the secure services' delivery.

Health 3.0 Enabler is an extension of Web 3.0 Enabler in health domain [8]. It enables service providers to: a) securely retrieve information from SR and b) contribute SCEH with the appropriate resources, as well as user's QoE, for the creation or modification of personalized services.

Identity Enabler (IE) is used as an additional mechanism for ensuring SFEs. IE supplies the single sign on mechanisms [9] for access control of multiple independent systems.

III. CONTEXT DECISION MAKING ENABLER (CDME)

The CDME is the essential component of the proposed architecture that incorporates SOFE and DMFE. CDME includes discrete modules for the acquisition and evaluation of user contextual information in order to provide user's personalized model. Fig. 3 depicts the modules of CDME.

User Profile and Archives contains all current and archived information of user, such as the user's scheduled activities, hobbies , identity context, social context, location and time, preferences, education, historical data, environmental context etc) [10]. This type of information is also known as primitive context information.

Context Acquisition Module (CAM) collects contextual data, through Dialogue Subsystem / Aggregator and correlates them with information stored in "User Profile and Archives", in order for CAM to detect all environmental and activity related parameters affecting user's health conditions. The resulted information of CAM process is stored in a dedicated data base within CAM, named Context Data Base.

User Status Discovery Module (USDM) accesses the Context Data Base of CAM to retrieve any information related to current user's situation. It contains *routine patterns* [11] that correspond to permanent indicators of user's health condition, habits, behavior and intentions. These patterns are compared with the user's situation and determine the current user's health status. This comparison process is supported by appropriate data mining tools (e.g. querying, classification and clustering).

Healthcare Scenarios Base contains for any patient, the appropriate operational healthcare scenarios that have to be followed by any entity (e.g. caregivers, medical units, etc) that is involved during the provision of the service.

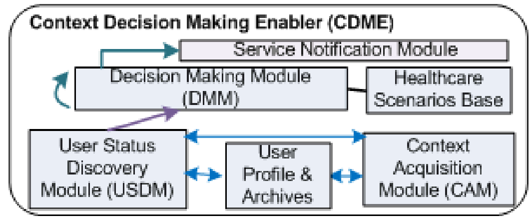

Figure 3. The structure of the CDME.

Based upon these scenarios, NG-SDP establishes multi entities sessions suitable to provide the personalized service. The delivery of such multi entities services requires the intelligent association of the current health status of the patient (provided by the DMM) with the content of this base.

Decision Making Module (DMM) makes decisions about the most suitable operational healthcare scenario and the group of entities which should be activated via NG-SDP in order to treat user. DMM is activated whenever USDM recovers changes in user's health status. According to that user status, DMM selects (by Healthcare Scenarios Base), formulates, executes and interprets the healthcare service according to negotiation algorithms and mathematical models so as to be optimized [11].

Service Notification Module is responsible for notifying TSB and Service Broker for the invocation and binding of the required service and the appropriate Communication / Context Enablers that will be activated for patient's treatment purposes.

IV. IMPLEMENTATION OF HEALTHCARE NG-SDP

The proposed Healthcare NG-SDP has been implemented as prototype to provide medical personalized services at the Department of Emergency Medicine, Rion University Hospital and Olympion General Hospital SA Clinic. Within NG-SDP, these organizations publish their services to be consumed. It integrates services (application and data access) via a TSB and supports different versions of standards, types of data, description languages etc. TSB is an extension of Enterprise Service Bus (ESB) with health specific capabilities and standards (e.g. HL7, CDA ANSI standards).

For the development of Healthcare NG-SDP we have evaluated several open source integration platforms (e.g. JBoss ESB, Apache ServiceMix, OpenESB (Sun (Oracle)) Mule ESB, etc) [12]. This implementation is based on OpenESB since it has an easy learning curve due to its solid integration with the GlassFish ESB 2.1 and Sun's NetBeans IDE 6.9. The Netbeans IDE provides countless integrated functions for administration and development. OpenESB's tools include WSDL and schema editors, a JPI manager integrated into the service manager, and Ant running in the background. Moreover, OpenESB contains the Composite Application Service Assembly (CASA) editor for creating SOAP/HTTP Binding Component Service Units and attach them into a new BPEL process. OpenESB uses intensively WSDL descriptions. Finally, OpenESB is based on OSGi which is an open-standard, centralized and hierarchical architecture. OSGi allows service and content providers, as well as software and hardware developers to deploy, integrate and manage their services to a wide range of environments (e.g. building, home and mobile) [13].

Our development environment was Windows XP SP2. We implemented TSB using the GlassFish ESB v2.2 enhanced with HL7. Moreover, we used the BPEL 2.0 Service Engine (Business Process Execution Language SE) to convert data/ files to HL7 messages. GlassFish ESB uses Encoders to transform data between XML and non-XML formats. Also, GlassFish ESB supports HL7 v2.x messaging in the form of the HL7 Encoder, which allows conversion between HL7 v2 and HL7 v2 XML message formats, and in the form of the HL7 Binding Component, which allow connectivity between the GlassFish ESB-based healthcare solutions and applications that support HL7 over TCP/IP connectivity. PHPMyAdmin software is used to: a) manage MySQL users (patient and caregivers) and their privileges, b) manage stored procedures and triggers, and c) transform stored data into any format using a set of predefined functions, such as displaying BLOB-data as image or download-link. The implemented Healthcare NG-SDP supports the Network Time Protocol (NTP) in order to synchronize time client (patient) with the GlassFish time server. Finally, Kerberos Authentication Server (RFC1510) is used as the Identity Enabler. The Kerberized Communication services are registered on the Kerberos Authentication Server according to the RFC1510 protocol.

V. Discussion/ Case Study

The correct operation of the CDME has been tested in a limited number of patients. Following we quote a case study of a 27 year patient who suffers from anxiety disorders (stress). Stress is a symptomatic disease that is expressed through the increased heart beats, lung function and the movements of patient [10]. The used devices supported by the European standards are: spirometer, real-time vital signs monitor, camera and an electrocardiograph. This case study was applied during two successive phases.

Phase 1: Creation of treatment scenarios. In this case study we consider four different healthcare scenarios, each one referring to a different stress level (Low, Medium, High, or Very High) as it is analyzed in [14]. We monitored the patient during a period of six months, and we collected the vital signs and the contextual data. The total collected measurements are included in 720 different files. These files and other older examinations from hospital and clinic, compose the patient's profile. The profile and other related data of patient's EHR were being sent to a medical doctor who was assigned to any stress level concrete symptoms and measurements. In each stress level a different number of symptoms were appeared and a different treatment was applied. A rule engine J2EE based on Java was used to assist the doctor to assign symptoms to stress levels. The resulted stress levels were used to create the treatment scenarios that were stored into Healthcare Scenarios Base of CDME.

Phase 2: Patient monitoring. In this phase the patient was monitored continuously for a period of eight (8) months. Using the symptoms and stress level patterns and context and stress level patterns [14] as well as the "autonomous" capabilities for detecting the above stress levels, CDME resulted that the patient suffered, during this period, twelve (12) times from High stress level and five (5) times from Very High stress level. Whenever NG-SDP detected triggers for these two stress levels then a session between doctor and patient was established immediately. The reliability of the system's output was assessed directly by a doctor who was monitoring the patient in his intelligent environment. The final diagnosis held by the doctor, confirmed five (5) and two (2) real incidents, respectively. (Performance of 40%).

The prototype implementation of NG-SDP proves that the encapsulation of CDME achieves a part of "autonomous" in SDP that is inherently a difficult project. In this implementation we compared several integration platforms. Despite the low performance score, this project demonstrated the overall capabilities of a NG-SDP and proved that the use of real time collecting contextual data and bio-signals add value in the healthcare delivery.

VI. Conclusion

This paper proposes the functional entities (FEs) and the architecture of the Healthcare NG-SDP architecture. We used real time acquired patient's contextual data and bio signals as the basis for the estimation of the patient's current health condition and the required service provision. We described how personalized services are deployed and delivered autonomous via an NG-SDP either from the users or from 3rd party providers. The future work will focus on the implementation of a more reliable NG-DSP with enhanced CDME functionalities.

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