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A LOOSELY-INTEGRATED SUITE OF SERVICES FOR mHEALTH FORMED BY WIRELESS SENSOR NETWORKS

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Abstract - ***Mobile health (hereafter “mHealth”) covers “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices”. This paper provides a roadmap of development of low power wireless sensor networks (WSN) paired with smartphone technologies as an effective patients’ monitoring tool, based on Service-oriented computing (SOC). Using this technology, the aim is to retain the disease in a controlled state with minimal effort, invasiveness and cost, and assess patient’s condition objectively.***

Keywords - components: Service-oriented computing (SOC), body sensor network, Web-services, Cloud Computing

1. INTRODUCTION

Healthcare has slowly been progressing through three stages of data management: ***data collection, data sharing,*** and ***data analytics***. In healthcare, the first phase is characterized by widespread *Electronic Health Record* (EHR) adoption. In the second stage, the need for sharing data among members of the workflow team becomes apparent. In the case of a healthcare, this phase is characterized by health information exchange. Healthcare is now entering the third stage, the data analysis phase, which shall be characterized by the adoption of *Enterprise Data Warehouses* (EDW), when the data collected and shared, can be used to analyze aspects of the workflow that are reflected in the patterns of the aggregated data.

The drive now is to understand about a patient as much as possible and at their earliest life stages possible – hopefully picking up the warning signs of a serious illness at an early stage so the that treatment is far more simple (and less expensive) than when it is spotted at a later stage. The aim is to data from various sources (such as *medical and insurance records, wearable sensors, genetic data and even social media use*) to draw a comprehensive picture of the patient as of an individual, in order to offer a tailored healthcare package. This requires the capability to link data and extract potentially valuable information from unstructured data in an automated cost-effective way by applying mobile applications, disease management applications, social integration platforms, broad band communication, Internet of things, cloud computing [1-3].

Many specialists in the world believe that patient monitoring can transform medical care. Wireless sensors, smartphones modernized clinical trials, internet connectivity, advanced diagnostics, targeted therapies, cloud computing, and other science enable the individualization of medicine and force overdue radical change in how medicine is delivered, regulated and reimbursed. Mobile devices are being used to capture data at the point of care and to keep the lines of communication open no matter where the doctor is, and they’re being used at home to record and send vital health data back to the caregiver and, in turn, to send important healthcare management information back to the patient. The personal data is used to track the ups and downs of patient’s conditions as they go about their lives.

It was proposed to build the smart healthcare ecosystem where patients' health parameters can be permanently monitored by the networked medical heterogeneous devices, and then used for decision making together with structured EHR data, unstructured clinical notes, medical imaging data, etc. [4]. Let’s imagine that every medical sensor (or another data resource) of that ecosystem has its own URI allowing doctors and patients to interact with it via the web browser, and at the same time every sensor can have the software interface – a set of web services allowing intelligent software agents to interact with it (analyze the data etc.) on behalf of doctors and patients. Certainly the integration of that with the classical medical record is vital.

Healthcare was once about trying to heal the sick patient. Healthcare organizations around the world now have an opportunity to shift this focus to one of keeping the public healthy and anticipating health issues before they become a problem. Physicians and other providers seek to monitor patients remotely through new technologies, aiming to identify problems early and cut costs and inefficiencies in the healthcare system. Identifying people at risk of becoming ill or developing a serious condition and providing the foresight to prescribe preventive measures is a very real possibility.

II. DESCRIPTION OF A PROBLEM SOLUTION

Our proposal is the semantically-enhanced event-driven service-oriented architectural model (SEDSOA), which can facilitate the development of the intelligent software agents discovering and interacting with heterogeneous devices (Fig.1).

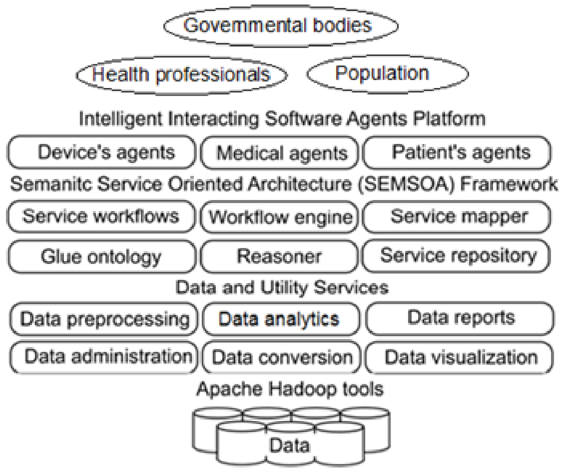

Figure 1. Key points of the proposed architecture

In other words, the framework will hide low-level details of interaction with specific web services representing concrete devices and their data the means of semantic middle layer. SEDSOA-powered platform should help to minimize the efforts in the development of the new medical software capable to inter-operate with the joined cloud of networked devices. The main goals are the automation of the discovery of the devices and their data and the automation of mapping between different interfaces and data formats. This will make possible to create, improve, maintain and share medical data processing workflows expressed in the abstract terms of some 'glue' high-level ontology rather than in low-level details of interaction with concrete SOAP and REST web services. It is a far more flexible and scalable way which should boost the implementation of that smart ecosystem mentioned above.

In comparison with existing FHIR (Fast Health Interoperability Resources) tools [5], the proposed framework will be more about ***ontology development*** (that will help to integrate data formats, software tools, and data gathering devices) and mining the medical Big Data to contribute to the quality of the individual patient care and population health management. In this case people are more than patients. They are individual health consumers, and they are becoming empowered and engaged as healthcare becomes more personalized and convenient.

Projects goals are planned to achieve by:

- Investigating a variety of healthcare-related data sources (EHR data, unstructured clinical notes, claims, medical imaging data, mobile devices output, other sectors data, social platforms and membership portals, etc.), comparing their feathers and providing means for converting all data to digital forms (say, by scanning paper documents), and *developing ontologies* for different data source classes [6]. *Semantic descriptions are introduced as for data sources, so for data processing services.*
- Studying portable personal devices, used for *biometrical data collection*, comparing their features and parameters, and *developing ontologies* for different devices outcomes.
- Using *behavioral and environmental data* which are the newest and possibly fastest-growing in health care thanks to improving patients' monitoring by wearable or implantable sensors for capturing context of patients at any given time: their location (indoor / outdoor), activity (sleeping, walking, performing a particular task), emotional state (i.e. stress, depression, etc.), social state (i.e. degree of interaction, communication style, etc.) and environmental surroundings (weather conditions, air pollution, noises, etc.).
- Developing the repository of services which are related to *processes of data collection* and *storing* from all data sources (and developing the ontology of these services).
- Establishing connection between data sources, patients, doctors and healthcare organizations by developing a healthcare ecosystem in Cloud for *data sharing* across the entire ecosystem, using SaaS and IaaS technologies.
- Developing the repository of services which are related to *analytics processing of data* across the healthcare ecosystem for extracting valuable intelligence from data (and developing the ontology of these services). They include also insights and inform actions for patients, care providers, health payers and insurers, and life science companies.
- Using *semantically-enhanced event-driven service-oriented architectural model (SEMSOA)* to develop an open ecosystem for providing wider interoperability of healthcare services for patients' groups with different illnesses and for supporting a policy of standardization of these healthcare services. Events in this ecosystem can be initiated by patients, doctors, and devices outcomes. *Due to such ecosystem, healthcare is migrating from episodic and fragmented illness response to a patient-centric model of care delivery*.
- Proving the mechanism of *customer-driven medical applied software development* by

compositing and orchestrating dynamically discovered services from developed repositories to *form the individual patient pathway (patient-specific workflows)* of monitoring and treatment, taking into account different existing rules, regulations and standards [7].

- Providing opportunities for patients *to communicate with others* who have the same disease or condition, track and share their own experiences, see what treatments have helped other patients like them, gain insights and identify any patterns.

Using mHealth services allows to:

• put the patient in control, giving greater independence, and helping to prevent health problems

• make a more efficient healthcare system, with vast potential for cost-savings

• create huge opportunities for innovative services, start-ups and the app economy.

The key requirements for such usage are integration of services and interoperability of e-Infrastructures. The main e-Infrastructure components and services include networking, high-throughput and high-performance computing, data infrastructures, software/middleware, including authentication and authorization infrastructures, and virtual research environments that are to be used by international virtual research communities.

All e-infrastructure service providers serve the same community of users. It is clear that today no single e-infrastructure provider provides a full portfolio of e-infra-services needed to the end users. However, it is also clear that users want a single and easy to use interface to all e-Infrastructure services they need. They need services that are coherent, managed and above all integrated so that they can get on with the diseases treatment. But they also need a constant innovation of these services, way ahead of what commercial providers can offer. So we must be careful to not become constrained and stifle innovation in the development, provision and use of these services.

III.EXAMPLES OF THE SERVICE REPOSITORY CONTENT

Treatment of chronically ill patients is personalized and customized by establishing Repository of services (web-applications with a unified interface) for patient care (care services), for planning and carrying out of treatment (treatment services) and to ensure the functioning of the entire system (management services).

Patients' web services

Together with diabetes and chronic hearth diseases, chronic pulmonary diseases are mostly common group of chronic diseases. Among pulmonary disorders, asthma is one of the mostly highly represented. The World Health Organization (WHO) estimates that about 300 million people have asthma worldwide, and the asthma population is expected to increase to 1 billion people by 2025. About 70% of asthmatics suffer from allergies. Asthma is a significant cost to the society, as annual expenditures for health and lost productivity due to asthma are estimated only at the USA at over $20 billion [8]. In the world today there are also approximately 346 million patients with Diabetes 1st and 2nd kind (respectively about 10% and 90% of the total number of patients), the disease severity of which varies upon the level of sugar in the their blood. Approximately 10% of them die each year, with 80% of deaths occur in countries with weak economies, and (as a consequence) poor organization of health care. High blood pressure (hypertension), also known as the "silent killer", is often a harbinger of more serious diseases such as stroke, myocardial infarction, arterial disease, diabetes and more. People, who have high blood pressure, are often unaware of their condition, which is difficult to detect without constant monitoring.

The solution of these tasks can be taken by a mobile system that will measure and automatically send the results to the doctor. To build a single, integrated, multi-functional and adaptive healthcare application that supports the self-monitoring and treatment of chronic patients, we suggest implementing following patient's services, which best meet the recommendations of medical experts:

• Measuring disease indicators at home by connecting some devices (blood glucose meters, blood pressure meter, Peak Flow Meter, etc.) to patient's smartphone or tablet;

• Data collection, aggregation and processing with forming doctor's recommendations for proper disease treatment and evaluating changes in the dynamics patient's health status;

• Providing health information and patient's actions in emergency situations when he needs consultation or contact with health centers and clinics;

• Remote treatment monitoring with help of sensitized glucometer-insulin pumps- Inhaler, equipping them with GPS/GPRS modules;

• Monitoring of the air quality by sensing concentration of formaldehyde, carbon dioxide, ozone, nitrogen dioxide, temperature, relative humidity, and total volatile organic compounds for avoiding asthma triggers;

• Integration into social networking for receiving by a patient comprehensive information on treatment of disease and share own expertise in this area;

• Synchronizing with an Electronic Health Records (EHR), waged by patients and doctors;

• Extreme Warning and Emergency Information, when a doctor (and / or ambulance staff) will be immediately informed if vital patient's parameters get close to a dangerous point.

Treatment web services

To ensure effective communication the patient with the physician it is expected to develop a special application and down load it to doctor's smartphone

(tablet). It is recommended to implement the following treatment services, listed below:
• Remote monitoring of the patient’s status in any place and at any time;
• Preparing the Treatment Plan (roadmap) and placing it on the server, taking in to account individual feathers of patients and the personal allergy records;
• Communicating with a patient and possibility to arrange a personal meeting with the patient at his home or in a medical facility;
• Providing medical information about recommendations on the treatment of diabetes and patient’s actions in emergency situations;
• Using EHR for circulation and accessibility of medical data about the patient.

Services for server management and running

The functioning of the mobile platform, including the Cloud server, is provided an adequate choice and implementation of following management services:
• Accessing to the data of portative diagnostic devices and their transmitting to and storing in a server;
• Supporting EHR, filling its fields and read data from PHR;
• Service compositing and editing formal description of the treatment process graph;
• Transiting from the formal description of the chosen sequence of services composition to the flow of the tasks performed by the application in hand, taking into account the data required for the implementation of individual services (services) and using established protocols and standards information;
• Support for the electronic prescription (ePrescription) when patients bay medicines, been prescribed by a doctor, at home through any pharmacy, which will has access to ePrescription.

Services for Data Analytics

The goals of Personal Health Systems are prediction, prevention, and treatment been customized to each individual patient. Technological capability to aggregate and analyze data from wearable diagnostic devices and information about treatment dynamics contribute to providing patient-specific diagnosis and treatments. If home self-measurements are made by patients over equal time intervals, the time series are formed as a sequence of data points. Time series are explored with a variety of purposes. In some cases it is enough to get a description of the feathers of the time series, and in another cases it is required not only to predict the future values of a time series, but also to control its behavior. Method for analysis of the time series is defined, on the one hand, by analysis purposes, and on the other hand, by the probabilistic nature of time series values. They suggest that a time series consists of a number of systematic components and random components as the residue. Systematic components usually include regular trend and cyclical components. The residue is usually considered as a random error, or noise.

The result of time series analysis is its expansion into simpler components: slow trends, seasonal and other periodic or oscillatory components and noise components. This expansion can serve as a basis for predicting both as the original time series so its relative individual components, in particular, trends.
• Spectral analysis, which allows finding the periodic components of the time series;
• Correlation analysis, which deals with identification of significant periodic dependence and the correspond-ding delay (lag) within one series (autocorrelation), and between several series (cross-correlation);
• Seasonal Box-Jenkins model, which allows you to predict the future values of the series;
• Seasonal and non-seasonal exponential smoothing, which is the simplest model of forecasting time series;
• Time series data mining, this deal with the identification of temporal patterns for characterization and prediction of time series events;
• Model of dynamic Bayesian network;
• Neural network forecasting model;
• Methodologies for the detection and analysis of data outliers.

It can be seen from above that the Repository contains services which belong mostly to ***Specific (application support) services (SS)***, which had to be developed. Although between them there are some ***Generic (environment supporting) services (GS***): measuring indicators of disease at home and transmitting them, data collection and data aggregation, remote monitoring. The last ones can be based on Generic Internet of Things (IoT) services databases provided by other service producers (for example, EGI [9], Flatworld [10], FI-WARE [11], SAP [12], ESRC [13], etc. The most Web service for decision support systems are also Specific (application support) services (SS) which had to be developed. The most Web service for medical data analytics are also Genetic or Specific services which had to be developed [14-19]. A personalized predictive health profile is then generated, using EHR data, to assist healthcare providers and their patients work together to improve an individual's health and help prevent the onset of certain diseases whenever possible

IV. WEB SERVICES MANAGEMENT

Beside SOA which is much about pulling the needed medical information elements of EDA (Even-driven Architecture) are used also for focusing on pushing right information to right people at the right time. Events may be generated because of things that happen or things that don’t happen within a specified time period. Examples of potential event (and non-event) sources include doctors’ portals, EHR Alarms data or Data Analytics messages, infrastructure management tools, integrations servers, databases, and many more. EDA is promoting instant identification and responding to the event/information that drives the healthcare. Information is distributed in real- time to the ones who are interested in that information. Compared to SOA, EDA is using information in a more proactive manner encouraging real-time information sharing. Event processing includes several services e.g. event generation, event response initiation, and event response processing. Events connect services by transferring process state and data from one service that detects and publishes events to other services that are triggered by specific events. From other side services connect events by transferring the process from one state to another. In other words the event is holding the state and the service is changing the state.

Event processing infrastructure, like complex event processing (CEP), correlates and analyzes event flows and initiates event responses which may be either automated responses or workflow items for human review and processing. They arrive at the Message Broker which routes them to the relevant Health Monitoring Servers. These events may contain beside medical data also context information (patient location outside the house, patient current activity, taken medicine, the presence of someone close). One of the policies may be to automatically forward a selected subset of events to the patient's family doctor in order to keep him/her fully briefed. The location context information makes it possible for the emergency response to select the closest ambulance. The combined SOA (synchronous one-to-one approach) and EDA (asynchronous many-to-many approach) architecture is characterized by the following [19,20]:

• Functionality is distributed across the ecosystem of both web services and events (enabling utilization of events resources);

• It is compatible with adopted standards and protocols;

• It supports customers' analysis scenario development and execution;

• It provides flexible and intelligent configuration and translation of continuous data streams from sensors into patients' EHRs, which are monitored using specific services and events.

• It hides the complexity of web-service interaction from user with abstract workflow concept and simple graphical workflow editor.

Implementation of the SEDSOC concept means generating mobile medical applications based on dynamic composition and orchestration of web services workflows. A workflow describes how tasks are orchestrated, what components performs them, what their relative order is, how they are synchronized, how information flows to support the tasks and how tasks are being tracked. Currently, the industry standard for service orchestration is the Business Process Execution Language (BPEL) and it will be used. BPEL provides a standard XML schema for workflow composition of web services that are based on SOAP. This standardized composition description is eventually deployed on a BPEL engines. The Active BPEL Designer requires too much in-depth knowledge of BPEL definitions to be useful for computing users. The stages of data processing during web services composition and orchestration by BPEL means are shown on fig.2.

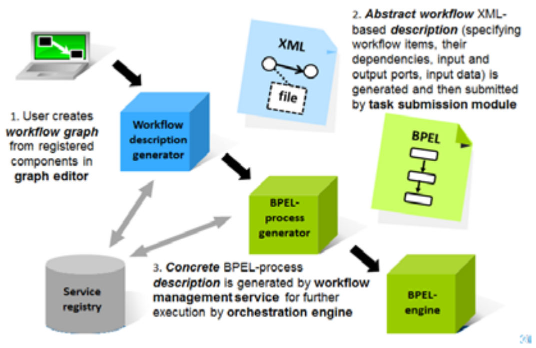

Figure 2. Data diagram of services workflow setting

Data diagram present transiting from the formal description of the chosen sequence of services composition to the flow of the tasks performed by the application, taking into account the data required for the implementation of individual services and using established protocols and standards information. To assist users in composing services and events, the graphical composition tool to work in this environment was adopted.

IY. PRELIMINARY EXPERIMENTAL RESULTS

It is understood that the full implementation of the proposed mobile health platform requires considerable effort and substantial funding, perhaps within some new Horizon 2020 project. Today, developing and testing individual functional services are conducted by the group of graduate students of the System Design Department. These services were used by them for prototyping some medical multiplatform applications such as the self-management Mobile Spirometry for Asthma Care, using a smartphone's Microphone to Measure Lung Function, and the Anti-Asthma Mobile Application, using a peak flow meter. The mobile application for diabetics was developed also which serves as the diary of glucose in the blood by storing measured results and building interactive graphics intervals (fig.3). It is based on Apache Cordova for the Apple iOS platform and uses the Align BG1 mobile glucometer of the company iHealth been connected to a smartphone through the developed module SDK. This application in its' parameters and capabilities is not inferior to the best known today mobile application developed for Apple's iPhone, Google's Android, BlackBerry, Microsoft Windows Phone and Nokia Symbian and available today for people with diabetes [21].

V. CONCLUSIONS

The proposed mobile medical platform allows easily developing interoperable healthcare means with a wide range of self-care services for chronic patients and which differs from existing holistic solutions in the following important features (invention) by using service systems approach.

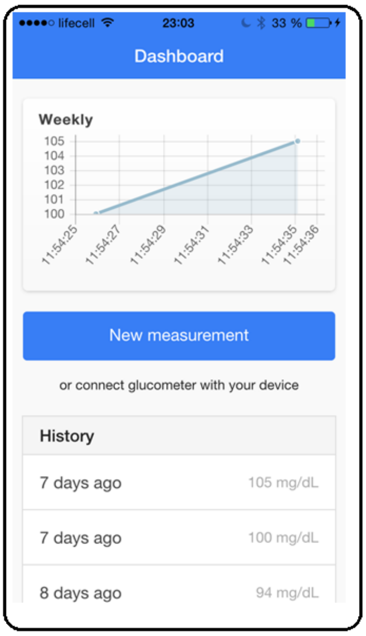

Figure 3. Home screen of developed mobile application

The proposed mobile medical platform allows easily developing interoperable healthcare means with a wide range of self-care services for chronic patients and which differs from existing holistic solutions in the following important features (invention) by using service systems approach. It takes into account the need to design complex architectures relating together people (patients, caregivers, and others), organizational structures and processes (Centers of Health Monitoring with a doctor on duty, etc.) and IT possibilities and service system design innovation.
Such more personalized patient-focused healthcare platform is more targeted, effective and efficient and supports the self-control of health.

We would be very happy if during this conference a group of enthusiasts would be formed who agree to join their research forces in order to prepare a project proposal for the Horizon- 2020.

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