Personal healthcare platform for chronic diseases with mobile self-management support

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***Abstract*—It is proposed the way of eliminating two major mHealth barriers: the lack of availability of interoperable services and the lack of their standardizing. For this purpose, service-oriented approach is used with developing the Repository of services from which any necessary personal healthcare platform for chronic diseases (PHPCD) can be composed. Monitoring of patients' vital signs parameters (measured at home) is achieved by using modern Internet of Things technology which provides networkable connections between portable diagnostic sensors, their cell phones, cloud data storage with patients' Personal Health Records and professional health providers.**

***Keywords*: mHealth, self-care, Personal Health Systems, mobile phone, SOC, EDA, Cloud services, decision support systems, Web-services**

I. INTRODUCTION

The healthcare systems in Europe are going to become more patient-focused healthcare with shifting towards prevention while at the same time improving the efficiency of the system as it was declared in the GREEN PAPER on mobile Health (mHealth) [1] and the Action Plan 2012-2020 [2]. mHealth allows the collection of considerable medical, physiological, lifestyle, daily activity and environmental data. This could serve as a basis for evidence-driven care practice and research activities, while facilitating patients' access to their health information anywhere and at any time. mHealth could also support the delivery of high-quality healthcare, and enable more accurate diagnosis and treatment, contribute to the *empowerment of patients* as they could manage their health more actively. It can support also healthcare professionals in treating patients more efficiently, resulting in more personalized medication and treatment.

On the 12th of January 2015, EC published a Summary Report with overview of public responses on its Green Paper ('mHealth'), in which two main tasks have been underlined: the *need of standardisation* of personal health information across Europe and a trend of "moving away from procuring large, single source IT systems to focusing on *smaller systems built to a specification* that requires the use of standardised datasets (repositories) and open communication protocol" resulting in possibility of interoperability of mHealth services.

mHealth is supported mostly by Personal Health Systems (PHS).The paper in hand describes the attempt to realize an adaptive interoperable PHS with service-oriented architecture driven be events.

II.RELATED WORK

There were some remarkable projects on PHS topic, co-funded by the European Commission within the Seventh Framework Programme [3,6-8]. The report on the project named "Personal Health Systems Foresight" [3] contains a review and characterization of PHS activities in Europe. In total of 39 cases were examined around Europe in the attachment to this repost, which deployed various kinds of analyses: a bibliometric analysis, a patent analysis, a social network analysis. The section on typologies of PHS scanned projects and analyses of PHS with respect to their way to structure and capture personal health systems. The characteristics of markets for personalized health systems were investigated also.

The project deliverables of another project PHS2020 [7,8] cover in great details all the methodological steps of PHS developing from the State of Play, to the construction of future Scenarios, to the Gap Analysis and the final Road Maps. They confirmed that development has supported the paradigm shift from the traditional hospital-centred and reactive healthcare delivery model toward a person-centred and preventive one.

Authors of above mentioned projects have examined the PHS research, innovation and policy areas to attain deeper understanding of mismatches between the potential of, and need for, PHS, and current policy and innovation initiatives and framework conditions (e.g. in terms of future technological opportunities and societal demands). They have pointed to the *significance of the service systems approach* and explain why this can improve the holistic understanding of the PHS sector [7].

In April 2015 IBM announced its Health Cloud and Watson cognitive computing capabilities will support health data entered by customers in iOS apps using

Apple's ResearchKit and HealthKit frameworks [8]. The move, which complements IBM's new Watson Health business unit, will arm medical researchers with a secure, open data storage solution, as well as access to IBM's most sophisticated data analytics capabilities. Mobile devices capture vast amounts of valuable health data from today's consumers. HealthKit and ResearchKit harness that data so it can be used to improve health and accelerate medical research.

IBM will de-identify and store health data in a secure, scalable cloud system that enables researchers to access and share data in an open ecosystem environment, as well as have access to IBM's data-mining and predictive analytics capabilities. Health and fitness app developers and medical researchers will be able to draw on data at a scale that until now has never been available. For apps using HealthKit and ResearchKit, IBM will provide a delivery platform through Health Cloud to easily store, aggregate and model data, combining it with other data sources and types to enrich research findings and identify the next frontiers of medical discovery.

III. ACTIVITY OVERVIEW

We are going to achieve interoperability (compatibility) of healthcare services for patients' groups with different illnesses by developing the *Self-Helper Platform* on the base of service-oriented approach and using service-oriented computing (SOC) [9]. Under pressure of the market the complexity of healthcare means is rapidly growing. Modern healthcare tools are no more holistic units, designed for treatment a single disease, but rather they are sets of dynamically changing modules for the treatment of the whole body. Service-oriented architecture concept was developed together with development of the Web. This modular approach to applications development is based on the use of distributed loosely coupled replaceable components with standardized interfaces for communication via standardized protocols. SOC paradigm represents the new creative methodology that utilizes services with unified interfaces as the basic constructs to support the development of rapid, low-cost and easy composition of distributed applications even in heterogeneous environments.

Such approach provides a horizontal development area across variety of patients, clinical specialties, technology fields and health services. By creating an open Repository of services and by compositing them into necessary applications our project expands its results across different healthcare areas such as chronic disease management, life-style management, independent living and emergency services within and beyond the European Union

According to SOC paradigm the building of applications from services requires loose coupling between used services in such a way that the services have little knowledge about each another. For creating a new application customers have to develop the GUI and the business logic which is needed to orchestrate and configure the selected services. All services that need to be configured can be divided to *Generic* (environment supporting) *services* (GS) and *Specific* (application support) *services* (SS). The Generic services (GS) belong to the "backbone" of data aware federation-enabling services and offer the standard operations for service management and hosting (e.g. services hosting, event processing and management, mediation and data services, services composition and workflow, security, connectivity, messaging, storage etc.). The Specific services (SS) are created by investigating the PHS workflow and selecting appropriate supporting services (i.e. identity management services) and infrastructure to support execution. It is possible also to analyse the existing mathematical modelling and PHS software for the possible re-use of the best algorithms and design procedures implementations in the creating the Repository of Specific services (SS). The Self-Helper Platform consists of the:

- Patient's services and portable diagnostics devices part
- Cloud platform for storage and processing of PHR data
- Healthcare providers' services part (Fig. 1).

Figure 1. The Self-Helper Platform Architecture

The basic Platform's component is a Cloud server with services of transfer, storage and processing data of the status and stage of the patients' disease. It aggregates the data about the patient's health parameters, taken by patients at home using portable diagnostics device connected to their smartphones (tablets). Data from the mobile phone to the server are sent via a secured sockets layer (SSL) of web connection, providing a standard industrial level of security inherent in the mobile data network. The server also contains patients' Electronic Health Records (EHR) with individual treatment recommendations, compiled and constantly corrected by doctors.

A plurality of portable diagnostics device in Patient's services part depends on the type of disease and may include, in particular, blood glucose meters, blood pressure monitors that measure blood pressure and pulse or peak flowmeter (Fig. 2). They also include devices used by patients for home treatment: inhalers, scales, heart rate monitors and insulin pumps.

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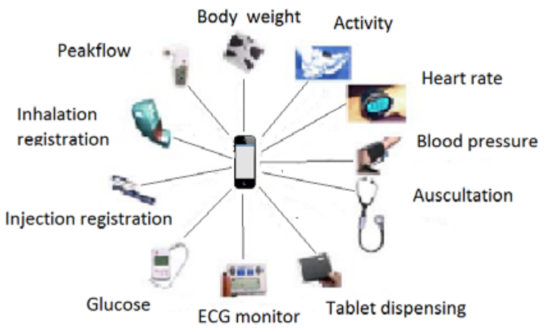

Figure 2. The range of portable diagnostic devices [5]

The real-time continuous monitoring is very important for patient at their home treatment, recovery from illness or rehabilitation and even for risky people who want to monitor their activity of cardiac-pulmonary at different positions for early detection of unexpected problem.

IY. APPROACH AND METHODOLOGY

Service - oriented approach driven by events to the design of mobile health applications provides:

- Increase developer productivity
- Less expensive services integration in the application;
- Increased reuse of services;
- Development independent platform, tools and development languages;
- Increased scalability to create mobile applications;
- Improved manageability created applications.

The solution in hand is proposed primarily to meet the needs of small and medium medical organizations and research institutes in the modern toolkit for developing applications for Personal Health Systems, as well as the private physicians. As the desired outcome, the European Healthcare community will receive powerful cloud virtual platform with software developing tools based on SOC for operation in distributed computing environments. It requires reorganization of such applications in the form of a set of separate interacting modules or services. In that case, the healthcare provider’s work is to compose a scenario of service interaction, i.e. the set of concepts, principles, and methods that represent patient’s treatment as a collection of loosely coupled services.
Service-oriented applications governance involves knowledge about services, providers and users. Development is divided between a service provider and an application builder. This separation enables application builders to focus on research logic of his healthcare application while leaving the technical details to service providers. If a *large multidisciplinary and multinational Repository of Application support* services is created, the end-users can tailor the services to their own personal requirements and expectations by incorporating functionalities of available services into large-scale Internet-based distributed application software.

V. 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).

5.1. Patients’ web services

Use cases selected by partners deal with helping people with chronic diseases. 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 [11-20].The cornerstone of modern asthma care is self-management, allowing the patients to monitor their disease severity continuously and to adjust the dose of inhaled corticosteroid based on symptoms, lung function and the use of rescue medication. Self-management improves asthma outcomes significantly, including patients' and doctors' experience with a web-based asthma diary. Doctors can access patient diary data online, thus facilitating the cooperation between doctors and patients.

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 a Personalized e- Health Records (PHR), 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.

5.2. *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.

5.3. Services for server management and running

The functioning of the PHPCD 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 EHR;
- 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.

5.4. Services for MSS

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 is a time ordered sequence of values of a random variable. Each individual value of this variable is called the readout time series. Thereby, the time series is substantially different from simple data retrieval.

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, which deals 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 IoT services databases provided by other service producers (for example, EGI [22], Flatworld [23], FI-WARE [24], SAP [25], ESRC [28], etc. The most Web service for decision support systems are also Specific (application support) services (SS) which had to be developed.

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

5.5. Web services Management

Beside SOA which is much about pulling the needed medical information elements of EDA (Even-driven Architecture) s 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, PHR Alarms data or DSS 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 analyses 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 [35, 37]:

- 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.

To assist users in composing services and events, Self-Helper adapts a graphical composition tool to work in this environment.

VI. CONCLUSIONS

The proposed Self-Helper 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.

In 2017 near 3.4 billion people worldwide will own a smartphone and half of them will be using mHealth apps. If its potential is fully unlocked, mHealth could save €99 billion in healthcare costs in the EU [36].

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