Mobile Personal Health Systems for Patient Self-management: On Pervasive Information Logging and Sharing within Social Networks

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Abstract. Patient self-management is often considered as an important prerequisite towards effective healthcare. This viewpoint has recently been demonstrated by the introduction and adoption of approaches and tools, such as the Personal Health Record (PHR). In the current work, the design of a mobile personal health system for logging information corresponding to the patient status and sharing it within social networks is presented. By utilizing event-driven patterns, the pervasive sharing of the recorded information is enabled, under conditions specified by the mobile user. This "anytime-anywhere" information sharing may be valuable to senders (i.e. patients) and receivers (e.g. relatives, healthcare professionals, similar patients, etc.) in terms of emotional support, mutual understanding, sharing of experiences, seeking of advice and improved self-tracking. A prototype is implemented on a mobile device illustrating the feasibility and applicability of the presented work by adopting unobtrusive health monitoring with a wearable multi-sensing device, a Service Oriented Architecture (SOA) for handling communication issues, and popular micro-blogging services.

Keywords: Personal Health Records, Self-management, Mobile Healthcare Services, Social Networks, Micro-blogging.

1 Introduction

Lately, a number of personal health systems and tools have been demonstrated enabling health information management by the patient himself/herself [1]. Self-management is often regarded as an essential part of efficient disease management, enhancing the patient's role and participation in healthcare services delivery

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[2]. Especially, chronic patients may be benefited from self-management activities, in terms of understanding better their disease, enhancing their communication with their doctor, increasing their self-confidence, and so forth [3].

Self-management and quantitative self-tracking have been recently introduced as part of emerging on-line patient communities and social networks like those presented in PatientsLikeME [4]. In such networks, the patient is able to record certain information in regard with his/her health (e.g. a specific health condition) and share it with other patients of the community for purposes of emotional support, exchange of experiences and ideas, education, improved self-tracking etc. Patient willingness to share with others personal health data is a key prerequisite for achieving the afore-mentioned goals. However, the above-mentioned functionality is offered by certain sites requiring constant on-line connectivity, while the integration with health monitoring infrastructures around the mobile user is still in its infancy. In particular, the unobtrusive logging and optional sharing of health information by the mobile users may be of great assistance towards effective (in terms of "anytime–anywhere") and collaborative disease management.

This work presents a novel framework for the construction of mobile personal health systems based on the Personal Health Record (PHR) notion [5], utilizing the acquisition of sensor data from available devices for health monitoring, the recording of health information, and external social networking functionality for sharing personal health information. These systems are particularly targeted at chronic patients throughout their entire everyday activities, who are using portable health monitoring systems, are highly aware of their disease, and may wish to play a more active role in their disease management. The framework supports the configuration of event-driven patterns so as to enable pervasively sharing information within the user's social group. Thus, an environment enabling pervasive and seamless communication between the patient and different actors (e.g. health professionals, relatives, similar patients, etc.) is constructed. A prototype implementation is presented where unobtrusive health monitoring with a wearable multi-sensing device is applied, while a Service Oriented Architecture (SOA) [6] is adopted for the communication among the mobile device, the back-end server and the external social networking platform. Popular micro-blogging services [7] – a form of micro-journalism for posting small pieces of User-Generated Content (UGC) – are utilized in order to demonstrate the social networking functionality.

2 Personal Health Information: Dimensions and Sharing

Personal health information corresponds to the patient status in multiple dimensions as follows:

- ***Vital Sign Measurements & Alerts:*** Health parameters such as the heart rate, respiratory rate, skin temperature and activity are continuously measured by various portable multi-sensing devices [8]. Due to the appeared information overwhelm, event-driven patterns can be initialized by the patient or the health professional, so as to filter the sensed data and record only information of possible value to the patient, as defined according to the configuration of personalized monitoring schemas [9]. For example, an alert of high heart rate may be reported as a result of an average heart rate value within a time-window exceeding a specified threshold.

- ***Health Problems/Symptoms:*** Patients can record various health problems or symptoms met during their daily activities. Examples of such subjective type of information originated from the patient include dizziness, nausea, stress, etc.
- ***Patient Situation:*** Patient situation is manually recorded, e.g. shopping, driving, reading, working, exercising, resting etc., and is characterized by the situation onset and the situation end.
- ***Time and Location:*** Additionally, the time of the day and the location (if available) are crucial parts of contextual information.

Thus, by combining subjective (i.e. patient provided) and objective (i.e. sensor measurements) information, a detailed view of the patient health status is provided for both patients and healthcare professionals. The aggregation of the afore-mentioned information dimensions is considered of particular significance for effective personalized health service delivery. Visualization capabilities of these dimensions during time are offered to the user so as to enable possible discovery of health patterns and improve the self-tracking possibilities in general.

Patients are able to aggregate the diverse recorded building blocks of their personal health information and share it within their social network. Information sharing is taking place either manually or in an event-driven manner. For the latter case, the required conditions for triggering event sharing are encapsulated in the afore-mentioned health information dimensions and are initially configured by the patients according to their needs and preferences. In a next step, they can choose the receivers of the information (e.g. other patients, relatives or health professionals), while finally they can decide on the way of disseminating information choosing between the instant (i.e. information is sent only once) and the continuous mode (i.e. information is always sent, whenever the required conditions are met).

3 System Architecture

In Fig. 1, the overall system architecture is depicted, having the mobile PHR as its core part. The mobile device referred as Mobile Base Unit (MBU) is connected wirelessly with sensors and its *Personal Health Information Controller* regulates various sensor alerts and other types of information dimensions which reflect the patient's status. The MBU is used for recording typical personal health information in the *Personal Health Information Repository*, such as various conditions or problems met, along with various patient situations and alerts (example information recorded by the user is presented in Fig. 2 (a)). All captured information is replicated to the back-end server for safety reasons. Moreover, since the typical mobile device can be still considered as a poor platform for advanced data/information processing, health information persisted in the back-end infrastructure can enable the employment of sophisticated data mining methods for pattern and trend discovery/analysis.

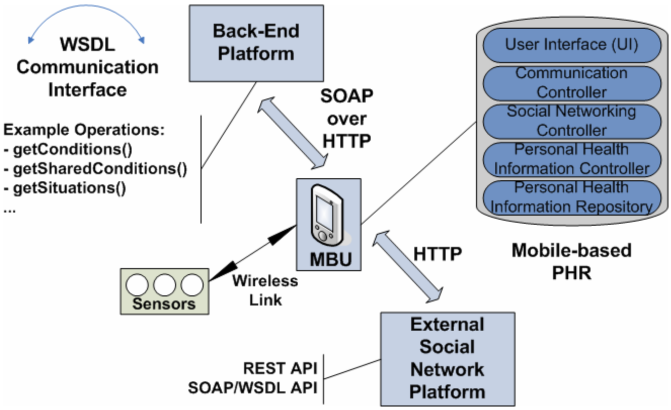

Fig. 1 General overview of the proposed system architecture

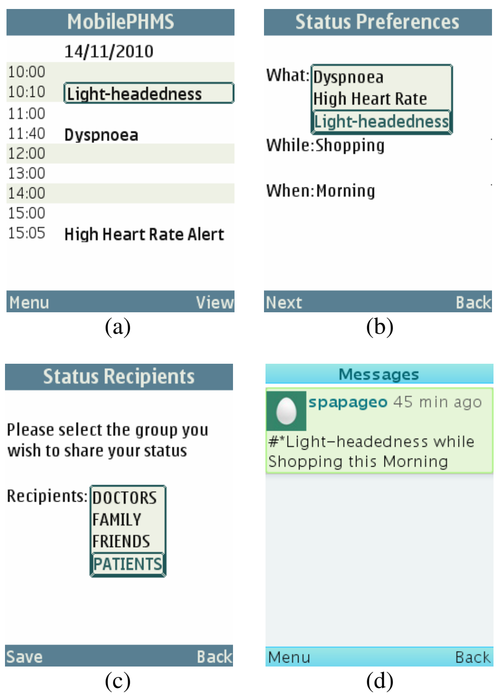

Fig. 2 (a) View of the recorded health conditions in the user's mobile PHR, (b) conditions which trigger status sharing, (c) selected recipients of the shared status, (d) message (sent from user "spapageo") shown to the recipient (via a twitter client application).

Communication between the MBU and the back-end server is achieved via a set of communication interfaces defined and implemented according to the SOA paradigm. SOA has been found to bring significant advantages compared to other architectures, such as interoperability and extensibility [6]. In particular, Simple Object Access Protocol (SOAP)[1] messages over HTTP are transmitted from the MBU, after calling the pre-defined Web service operations related to health information management, e.g. *getConditions()*, *getSituations(),* etc., via communication stubs corresponding to the Web Service Description Language (WSDL)[2] interface. The *Communication Controller* module is responsible for utilizing and controlling the entire client communication with the back-end infrastructure, persisting also unsent information due to potential network unavailability for later transmission.

The MBU communicates with the *External Social Network Platform* via a Representational State Transfer (REST) [10] Application Programming Interface (API) or SOAP/WSDL API, as commonly found in platforms such as Twitter[3]. These APIs provide a way for accessing and using externally the most typical functionalities provided by the platform, while providing also the necessary mechanisms for authentication and privacy via the adoption of protocols such as OAuth[4]. Thus, the MBU may safely connect to the external social network via the design and implementation of appropriate client methods incorporated in the *Social Networking Controller* module.

4 Micro-blogging Services

The proposed system's social networking functionality is realized by utilizing external Web-based micro-blogging services such as those provided by Twitter [11]. In this context, individuals are allowed to construct a public or semi-public profile and articulate social groups within which they share information. UGC is typically in the form of free text messages communicated to subscribers and followers of the message author. Such messages are usually within the limit of 140-160 characters and may optionally provide external links to additional information. In Twitter, a message may additionally be labeled with words followed after a hash so as to ease the message search mechanisms.

In the current implementation, we have elaborated on the event-driven sharing of messages, which are constructed according to the described health information dimensions. In this context, the user is able to create conditional patterns, currently applied in the form of typical IF-THEN rules, according to which the sharing of health information is automated. Initially, the condition (symptoms and alerts) and the situation in which the mobile user is in are manually selected from pre-defined lists (Fig. 2(b)). Alerts originating from sensor data are defined after the initial alert configuration (e.g. thresholds fine-tuning) by the user, as described

[1] http://www.w3.org/TR/soap/
[2] http://www.w3.org/TR/wsdl
[3] http://twitter.com/
[4] http://oauth.net/

in detail in [9]. The resolution of conditions is according to formal medical concepts derived from the Systematized Nomenclature of Medicine - Clinical Terms (SNOMED-CT) terminology with the aid of the API provided by the Unified Medical Language System (UMLS) metathesaurus [12]. Finally, the selection of the particular social group corresponding to the recipients of the shared patient status is taking place, as seen in Fig. 2(c).

Messaging within micro-blogging services is realized by combining predefined tags (information labels) and optional free text (e.g., *#*Light-headedness while Shopping this Morning* as depicted in Fig. 2 (d)). The tags provide a convenient way to discover messages of interest in one's social network. For example, within the constructed messages, the asterisk (*) character is used after the hash, in order to distinguish the condition-related terms provided within our system. Moreover, social analytics and processing may be supported and employed [13], due to the availability of this semi-structured information, without the need for applying complex natural language processing mechanisms. The user is enabled, besides sending UGC with alert, condition or situation-related information, to read messages within a group of subscribers, as sorted by condition or provided after a condition search, making it easy to track messages of interest.

5 Prototype Implementation

A prototype has been implemented on a Nokia N86 smartphone, in order to illustrate the feasibility of the proposed architecture. Java Micro Edition (JavaME) was the chosen development platform, which enabled us to implement and test the described functionality. JavaME provides high-level APIs dealing with the small memory footprint and the limited processing capabilities typically offered by mobile devices. More specifically, in regard with the MBU communication with the back-end, the Java Specification Request (JSR) 172 API was used, in order to provide the Web service functionality based on the SOAP/WSDL approach. In the back-end infrastructure, Apache Tomcat was used as application container and server, MySQL for data persistence and Apache Axis as the underlying Web service engine based on SOAP.

The Zephyr BioHarness[5] physiological monitoring system was used for vital signs monitoring. Zephyr BioHarness is a wearable multi-sensing device incorporating various sensors on a strap placed on the patient's chest for continuous unobtrusive monitoring of the heart rate, activity, posture, respiration rate, and skin temperature. The Zephyr BioHarness provided us with Bluetooth communication capabilities and an API for the transmission of the sensor measurements to the MBU.

The Twitter API[6] relying on REST was used in order to demonstrate the microblogging functionality via the MBU. HTTP basic authentication [14] was utilized for authentication purposes, while the kXML[7] package was employed, in order to

[5] http://www.zephyr-technology.com/products/bioharness-bt
[6] http://apiwiki.twitter.com/
[7] http://kobjects.org/kxml/

de-serialize information from the XML-based returned messages of most API calls. For privacy reasons, a private twitter list of people has been created with its subscribers being only the potential system's users.

After the conduction of various performance experiments, Web service invocations from the MBU for communicating with the back-end infrastructure were found to last on average 1.45 sec until reception of the response. The Twitter API calls lasted on average 1.9 sec for message transmission to the social group while the reading of the subscribers' messages within the list lasted on average 4.2 sec for 10 new messages with XML de-serialization time included in the final result. Thus, system performance was found to be sufficient enough in terms of communication and XML processing cost, although further tests are needed to fully explore all the performance evaluation aspects.

6 Conclusion

This paper proposed an approach towards chronic patients' self-management based on a mobile personal system encapsulating services to support patients in health information management and sharing. The primary focus of this work was on the implementation of a mobile solution to achieve pervasive and seamless communication among patients and their networked community.

At the current stage, our prototype implementation constituted a technical proof-of-concept as regards the feasibility and applicability of the proposed approach. It is evident that the presented system is primarily targeting at patients willing to play a more active role in managing their disease. The ultimate goal of this approach is further enhancing the patient's personal role in healthcare information management and promoting collaborative healthcare.

Privacy policies in regard with protecting personal health data need to be further explored [15] while evaluation of the presented system is necessary to assess user acceptance, as well as the extent of its contribution in patient self-management. Moreover, our future work involves the further development of methodologies for handling contextual data, behavioral monitoring based on user-to-system interactions, and appropriate methods for the collaborative filtering of information and discovery of patterns.

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References

1. Mattila, E., et al.: Empowering citizens for well-being and chronic disease management with wellness diary. IEEE Trans. Inf. Technol. Biomed 14(2), 456–463 (2010)
2. Mosen, D.M., Schmittdiel, J., Hibbard, J., Sobel, D., Remmers, C., Bellows, J.: Is patient activation associated with outcomes of care for adults with chronic conditions? J. Ambul Care Manage. 30(1), 21–29 (2007)

3. Lorig, K.R., Sobel, D.S., Ritter, P.L., Laurent, D., Hobbs, M.: Effect of a self-management program on patients with chronic disease. Eff. Clin. Pract. 4(6), 256–262 (2001)
4. Frost, J.H., Massagli, M.P.: Social uses of personal health information within PatientsLikeMe, an online patient community: What can happen when patients have access to one another's data. J. Med. Internet Res. 10:e15 (2008)
5. Tang, P.C., Ash, J.S., Bates, D.W., Overhage, J.M., Sands, D.Z.: Personal health records: Definitions, benefits, and strategies for over-coming barriers to adoption. J. Am. Med. Inform. Assoc. 13(2), 121–126 (2006)
6. Singh, M.P., Huhns, M.N.: Service-oriented computing: Semantics, processes, agents. J. Wiley and Sons, Chichester (2005)
7. Ebner, M., Schiefner, M.: Microblogging - more than fun? In: Proceedings of IADIS Mobile Learning Conference, pp. 155–159 (2008)
8. Konstantas, D.: An overview of wearable and implantable medical sensors. IMIA Yearbook 2007 2(1), 66–69 (2007)
9. Triantafyllidis, A., Koutkias, V., Chouvarda, I., Maglaveras, N.: An open and reconfigurable wireless sensor network for pervasive health monitoring. Methods Inf. Med. 47(3), 229–234 (2008)
10. Leonard Richardson, S.R.: RESTFul web services. O'Reilly, Sebastopol (2007)
11. Java, A., Song, X., Finin, T., Tseng, B.: Why we twitter: Understanding microblogging usage and communities. In: Proceedings of the Joint 9th WEBKDD and 1st SNA-KDD Workshop (2007)
12. Bangalore, A., Thorn, K.E., Tilley, C., Peters, L.: The UMLS Knowledge Source Server: An object model for delivering UMLS data. In: Proceedings of AMIA Annual Symposium, pp. 51–55 (2003)
13. Kleinberg, J.M.: Challenges in mining social network data: processes, privacy, and paradoxes. In: Proceedings of the 13th ACM SIGKDD, pp. 4–5 (2007)
14. Franks, J., Hallam-Baker, P., Hostetler, J., Lawrence, S., Leach, P., Luoto-nene, A., Stewart, L.: HTTP authentication: Basic and digest access authentication. IETF RFC2617 (1999)
15. Martino, L., Ahuja, S.: Privacy policies of personal health records: An evaluation of their effectiveness in protecting patient information. In: Proceedings of the 1st ACM International Health Informatics Symposium, pp. 191–200 (2010)