Provision of Personalized Data via Mobile Web Services in eHealth Scenarios

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Abstract: In societies where the demographic change leads to a more and more unbalanced state between the elderly and all other different age groups, there, health management becomes one of the most significant problems, e.g., in order to allow what is often called successful aging. Ubiquitous use of smart mobile devices enables gathering of personalized data enriched with contextual information. This information can ideally be used in modern eHealth scenarios, resulting in mobile health (mHealth) scenarios. This paper describes how highly personalized and sensitive information, such as vital signs enriched with contextual information of a patient, can be stored at mobile devices and provided via modern web technologies for later-on analysis and health monitoring. Therefore, this paper presents a number of different scenarios in which such mobile technology provides certain benefits, discusses benefits, drawbacks and challenges of such an approach and describes an example implementation of an mHealth scenario.

1 INTRODUCTION

Nowadays, smartphones and other mobile devices are used tremendously and this trend is still growing rapidly. Here, the functions of smartphones in use are much more than simple voice calling and text messaging. The mobile users use mobile phones to access their mail accounts, to share their calendars or to even use their devices as a routing device (i.e., the ones equipped with the GPS). Therefore, smart mobile devices collect various information about their users such as personalized information, personal/business contacts, messages (emails, short text messages like SMS, …), social interaction and social contacts, calling history, work history and footprints of internet usage (e.g., the browsing history of a mobile web browser). Additionally, the set of applications, a user has installed on his device, provide a rough profile of usage of the device itself.

Two major advantages from the increased usage of mobile devices are: On the one hand, the devices are mobile and could therefore ideally be used to follow their users round the clock and ubiquitously. And on the other hand, a modern internet connection is provided with most of the smart mobile devices, this makes such kind of mobile devices a powerful

and valuable tool. The second reason for the success of smart mobile devices is, that these devices are usually equipped with a large set of different sensors, allowing to contextualize the users' current tasks, e.g., by using the GPS sensor of a modern mobile device, the current position of a user could also be determined accurately, so that additional information about the task could be gathered, either to provide better support to users during the task or to store additional contextualization data for later analysis. In addition to GPS sensors, other sensors like acceleration sensor, motion sensors, a digital compass and alike, could be used on modern mobile devices. In the context of eHealth scenarios, additional sensors for monitoring current vital signs of the user could be connected to a mobile device.

The idea presented in this paper is twofold, on the one hand an architecture is presented that allows to store the data on ones' own device and not in some central database. Here we argue that this is a big advantage (in contrast to modern Cloud Computing and Web 2.0 scenarios in which more and more data is stored centrally), having in mind that health data is always personalized data with a big demand for security. The second idea is provided in this paper is to combine vital data (gathered by

specialized eHealth sensors connected to a standard mobile device) and contextualization data (gathered by standard sensors of a mobile device) and to provide it in an authentic and secure way, which without the usage of mobile devices could hardly be achieved. Additionally, two scenarios are presented in detail to demonstrate the use of that kind of technology. For one of the scenarios, an already existing implementation is described. Here, both on the implemented middleware and on the client side, web based technologies have been used in order to provide a user friendly implementation.

The rest of this paper is organized as follows: first we provide an overview of related work in the next section. After this we describe our approach in section three, followed by a discussion of the presented approach in section four. Section five describes two scenarios in which the presented approach provides benefits and section six describes the web based implementation of one of these scenarios. Finally, section seven provides a conclusion and an outlook to future work.

2 RELATED WORK

Providing Web Services on mobile devices was probably presented first by IBM (McFadden, et al., 2003). In this work a solution is presented for a specific scenario in which Web Services are hosted on mobile devices. A more general approach for providing Web Services on mobile devices is presented in (Srirama, et al., 2006 and AlShawan, et al., 2010). In (Li and Chou, 2011) the authors suggest a different approach, focusing on the optimization of the HTTP protocol for mobile Web Services provisioning. Importantly, none of the mentioned approaches manages to overcome certain limitations of mobile devices, e.g., permanently changing networks, IP addresses from networks with network address translation (NAT) or the fact that mobile devices are usually not designed to be always online (might be switched off, might have not network connection, …).

An additional approach that manages to overcome these problems, is presented in (Jansen, 2013a). This approach utilizes a central proxy infrastructure, that allows on the one hand to tackle the mentioned challenges and on the other hand provides a stable infrastructure for mobile device to provide standardized Web Services. Furthermore, the central proxy provides the major part of the technical infrastructure that allows to use standardized protocols for the deployed Web Service

at the mobile devices.

Additionally, the work presented in (Jansen, 2013b) argues for a new perspective to Web Services especially if those services are deployed to mobile devices. Here, the author argues that one of the major benefits of mobile devices is the fact that they are mobile. In connection especially to mHealth scenarios, this fact allows to gather different kinds of data from the sensors of a mobile devices that allows to easily contextualize the user (in most mHealth scenarios, the patient) in his/her current task/situation.

3 APPROACH AND DISCUSSION

The approach we used for the implementation of the example scenarios is based on a standardized Web Services. As already explained, a number of different approaches exist that allow the provision of Web Services on mobile devices. Since from our point of view, the approach described in (Jansen, 2013a), solves the most pressuring problems, we decided to base our implementation on this approach.

In addition to this, we implemented a middleware layer allowing a loose coupling between the provider of the mobile Web Services and the consumer service in our case a web-based application that visualizes the data measured by different sensors and in different training sessions.

Another advantage of the approach described in (Jansen, 2013a) is that it allows to store requests at the central proxy, e.g., if the device that provides the mobile Web Service is not connected to a network. As soon as the device is connected again, the request could be performed by the device and the result is available for the client.

Additionally, this approach implements Web Services for mobile devices based on standardized protocols, so that developers who are familiar in using Web Services do not need to learn a whole new technology, but can rely on knowledge they already have. Furthermore, also on the mobile Web Service provider side, the approach utilizes annotations pretty much in the same way as for the implementation of Web Service on non-mobile devices, providing again a very flat learning curve for the new technology.

The chosen approach provides a number of benefits, e.g., since the measured eHealth data only remains on the mobile device of the patient, there is no need for a central server infrastructure. This results in lower management costs, easier to achieve

security and no additional costs for central backups. Additionally, there is no need for central personnel, space, hardware and software provisioning and no central costs for energy.

On the other hand, this de-centralized approach also provides some drawbacks. Since the data is not stored centrally, hence, no central backup strategy is applicable, but the patient him-/herself is responsible for his/her data. Also security management would be easier to accomplish in an architecture with central data storage. Additionally, new questions with respect to the security of the data come into play while the data remains on mobile devices: what happens if the device gets lost or stolen? Therefore, of course, the personal data should be stored encrypted on the device of the patient. Still, encryption would just solve the problem of privacy (no one else but the owner of the mobile device would be able to access the data), but not the problem of availability of the data. Once the device is no longer in reach of its owner, the data would no longer be accessible for future analysis.

Besides the challenges that come from the described drawbacks, an additional challenge comes into play considering the target group for this kind of mHealth applications. The usual target group for this kind of applications consists of elderly. Since this target group is usually not specifically well used to handle mobile devices, a clear and precise explanation of the necessary steps and the used technology is more than ever necessary.

4 TWO EHEALTH SCENARIOS

Key strengths of mHealth system architectures based on mobile Web Services encompass the following aspects:

1. On-demand transmission of data to Health professionals: the doctor receives only the data that really interests him and especially at the point in time he is interested in.
2. Data remains in the direct disposal area of the patient: the need for informational self-determination is thus optimally fulfilled.

The following two scenarios, describe the use of Web Service based mHealth applications by illustrating the two aforementioned strengths.

4.1 Scenario 1: Surgical Preparation

The central source of revenue for hospitals is the surgical area. This is the actual place where the decision is taken whether a hospital makes profit or deficit. Therefore, usually all hospital processes are aligned to the optimal utilization of the surgical area. Any delay in the process or even surgeries that need to be canceled or postponed at short notice, cause a more or less considerable economic loss.

Prior to surgery, patients usually must follow certain rules of conduct and take or discontinue certain medicine for several days or weeks. Has he/she not done so (e.g., medication for blood clotting was not discontinued), the sugery has to be canceled at a short notice. This may lead to an underutilization of the surgical area and consequently the associated economic losses.

A 78-year-old patient is to receive a new right hip joint. She suffers from a lighter hypertension and type II diabetes. At the same time she tends to water retention, which manifests in an abrupt increase in her weight. Normally hip replacement operations rank among "standard" operations with less risk involved. But, because of the patients' secondary diagnoses, however, there is a significant surgical risk. Prior to the operation her risk factors must therefore be closely monitored. To shorten the period of rehabilitation after the surgery, the patient should move as much as possible in advance to the surgery and complete a specific exercise program to strengthen certain muscle groups.

For several months already, the patient has a smartphone. At her last doctor's appointment, four weeks before the surgery, a mobile mHealth application for collecting and managing various sensor data (in this case, blood pressure meter, blood glucose meter and scale connected via bluetooth), is installed and configured on her mobile phone. The data is provided via a mobile Web Service, which is also installed on the device. At the same time the female patient receives an introduction into a sensor package that will be handed out to her. Part of the mHealth application are also information films, in which the preliminary physical exercises are provided to her and she gets also informed about the risks and the progress of the medical intervention.

In the following four weeks, the female patient regularly measures her blood pressure, blood sugar and weight. This data is automatically enriched with location, time, and motion information from her mobile phones sensors (GPS, accelerometer, proximity sensor, etc.), allowing to contextualize the data gathered by the medical sensors.

Thus, noticeable measured values (e.g. increased heart rate and blood pressure due to sports activities) can be interpreted, according to the context in which they are occurred.

The data is generated using the internal sensors of smart phones and possibly even enriched by data from external web services (e.g. historical weather data). By using a feedback function, the patient may give feedback, for example how she felt during the exercise and the measurements. The logged feedback and sensor data can be queried by the hospital on-demand. When retrieving the data the hospital doctors can decide if they want to get all data or only aggregated data in terms of a status report (surgery possible / not possible). In addition, the mHealth application detects emergency situations (e.g. very high blood sugar levels) and alerts the hospital if necessary. The surgical management can check at any time whether the surgery will be possible, a change in behavior of the patient is necessary or an adaptation of the surgical plan is required.

Even at the stage of rehabilitation the Web Service on the patient's smartphone can provide on-demand information about the patient compliance (e.g., lack of physical exercise), allowing the timely intervention of the treating physicians.

4.2 Scenario 2: Regular Data Measurement by Patients

In the second scenario we imagine a 33 years old male patient diagnosed of having a genetic disease that disallows his body to effectively fight against blood lipids. Therefore, he is likely to have an increased risk of an attack. In order to lower this risk, besides a special medication, the patient is asked to have 24 hours blood pressure measurements at least once a year. A couple of years ago, this was more or less unhappy day every year, in which the patient had to wear a heavy blood pressure monitor over a whole day. Lately, his doctor told the patient that with new upcoming technology in the mHealth sector, the process for 24 hours blood pressure monitoring could be eased a lot.

By connecting a small and light blood pressure sensor to his smartphone, the patient is easily able to collect the necessary data in a convenient way. Furthermore, by collecting additional data from the mobile device of the patient, e.g., the current geolocation and/or the acceleration at which the patient is currently moving, the gathered data could be contextualized in order to ease the task for later analysis.

Happy to know about these new possibilities, the patient is willing to take his next 24 hours blood pressure measurements with this new technology. Two weeks after the measurement was done, the patient has a new appointment with his doctor in which the data from the measurement should be discussed. During this discussion, the doctor recognizes a tremendous increase in the blood pressure at 17:03 at the day of the measurement. First, neither the patient nor the doctor could explain this increase, but by looking at the contextual data gathered along the blood pressure values, the reason for the increase of the blood pressure became clear. By analyzing the geoposition of the patient and his acceleration at the time of the increasing blood pressure, it turned out that the patient was watching his famous soccer team playing against another local team. Knowing this, the patient remembers that at this exact time, the opponents of his famous team managed to shoot a goal. Being upset about this event clearly explains the increase in the patients' blood pressure values.

Again here in this scenario, beside the two major advantages of on the one hand privacy of the data (the data remains with the patient and is not stored centrally) and the just in time provision of the interesting data to the right person (in this case the doctor) could easily be seen. Furthermore, advantages of using modern mobile devices in mHealth scenarios, like the rich source for the contextualization of the patient are also obvious.

5 IMPLEMANTATION OF AN EXAMPLE SCENARIO

The prototype consists of two parts namely Web Services (i.e., running on a mobile device) and a web based client (i.e., running in a browser).

The following paragraphs describe the detail about these aforementioned components of the prototype followed by the interaction among the components.

5.1 Mobile Application

Android based mobiles are selected for the implementation of the concept as according to the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker's 2013 report, android based mobiles are the market leaders. An Android based application is developed to collect the various sensors data.

There are two categories of sensors, the ones integrated in a mobile phone and others which are externally linked via well-known communication technologies (e.g., Bluetooth, Wi-Fi).

In this particular implementation, the location of

a patient is determined by an integrated global positioning system (GPS), and the speed of movement is measured by a built-in accelerometer, which measures the force of acceleration caused by the gravity or weight to determine the speed. The standard Android library is used to retrieve the sensors data.

Besides the integrated sensors, to measure the heart-rate and, to measure the instant speed of a patient, a Zephyr sensor (Zephyr HxM BT – Heart Rate Monitor) is used. The sensor is mounted to a smart fabric based strap, which must be worn around the chest. The data is periodically collected via Bluetooth. The HxM sensor provides a Bluetooth API to collect the data in a specific message format.

After the collection of the data from all those aforementioned sensors, the data is saved by the application shown in Figure 1 to a SQLite database.
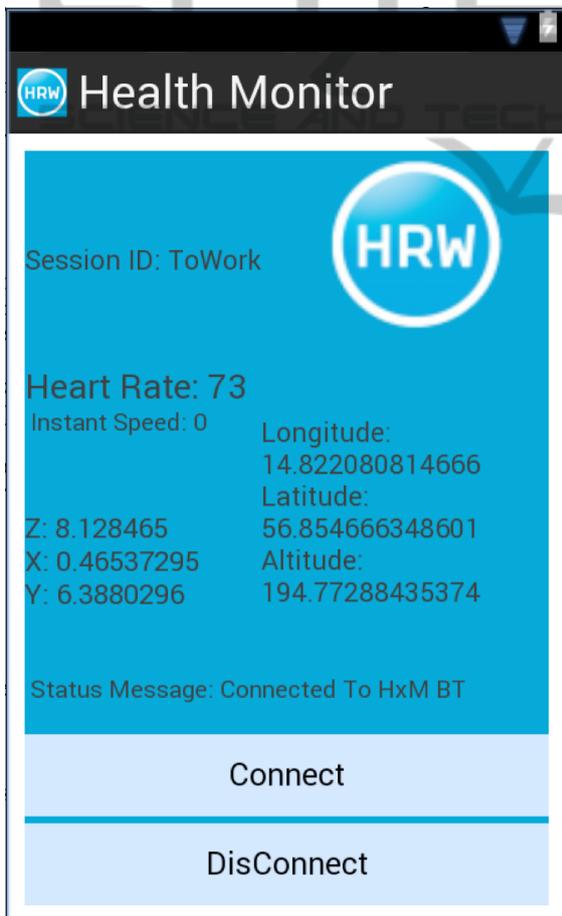

Figure 1: A screenshot of the app collecting data from an mHealth session.

A SQLite database runs without a server, which makes it a suitable choice for the energy limited mobile devices. Nevertheless, SQLite data is very

application related and dependent, once an application is uninstalled then the data will no longer be available. The database contains two tables "sessions" and "sensorsData".

Besides retrieval and storage of the sensors data, another part of the application handles the incoming request as a mobile Web Service. It fulfills the authentic incoming request by sending the stored data on the device to the client.

5.2 Web Client

The client runs in a browser and can be invoked from everywhere. Most of the functionality is implemented in JavaScript and HTML5. Nevertheless, due to the same origin restriction, some façade, according to the façade/proxy design pattern (Gamma, et al., 1995) services needed to be implemented on the server side. For this implementation we have chosen PHP.

After a successful authentication (e.g., as a doctor), the web application sends a Web Service request to the mobile device of the patient in order to receive a list of all available sessions. By choosing a certain session, another Web Service request is send to the mobile device that receives the data gathered during this session. This data could then be visualized in a tabular format or as a representation in a Google Map, where, e.g., the data is located at the correct geoposition and different parts of the data could be visualized according to the geoposition at which they appeared. An example of the visual representation on the client side in a Google Map could be seen in Figure 2.
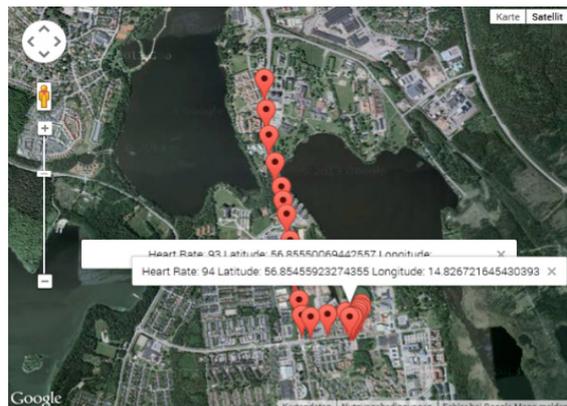

Figure 2: Visual representation of gathered health data in a Google Map.

5.3 How All Work Together

The functionality of the prototype is described from

the two different perspectives namely a user (e.g., a patient), and a user of the collected data such as a general physician, a family member or patient himself.

From the mobile-health-moniters' user (e.g., a patient) perspective, a user starts the application which collects the sensors information on his/her mobile device. Before starting a new session to record the sensors data, a user must wear a HxM chest strap with mounted heart-beat sensor to collect the real heart-beat of a user, otherwise a default value (i.e., which is "0" in this case) will be stored. Once the session is started, every few seconds the new values from the location sensor, 3-axis accelerometer and HxM are retrieved and stored in the "sensorsData table in the "mhealth" database. Let's assume, a user started a session during the workout, once the workout is over, the user decides to discontinue the session and clicks the disconnect button, once the session is disconnected a new entry in the "sessions" table will be stored with start-time and end-time of the session.

When a concerned person (e.g., a personal doctor, a family member, a care take, or the user/patient him-/herself), let's assume, a house-doctor wants to know about the patient who is using the mobile-health-monitoring app. The house-doctor will enter the web-link in a browser to invoke the mobile Web Service running on the mobile device. Before accessing the patients' data, the house-doctor must identify him-/herself with credentials through a username and a password. After the house-doctor is identified, all the stored sessions on the patients' mobile device are retrieved via the mobile Web Serivce. Now, the house-doctor can select any session to analyse the measured data.

6 CONCLUSIONS AND FUTURE WORK

Wrapping up, this paper provides a discussion about the usage of standardized Web Services on mobile devices like smartphones in the context of mHealth scenarios. We provided some example scenarios, a discussion about the current state of the art and also about benefits and drawbacks of the presented approach. Last but not least, a web-based implementation of one of the example scenarios was presented.

Nevertheless, beside the obvious benefits of such an approach, there are also some topics that need to be considered much more intensively in future research.

One of the major things to have in mind, is the security of the data on the phone of a patient. More likely, data security (especially data privacy) could be much easier realized for a central database (i.e., administrated by IT specialists). On the other hand, data security is anyway a topic that users of smart devices have to deal with and there are already quite powerful technologies available that increase the level of security for mobile data. Here, an important task for future research efforts will be to integrate such technologies in the described scenarios.

Another aspect comes into play if we consider that the different kinds of data possibly gathered by mobile devices need to be arranged and visualized in a way that allows doctors to easily interpret this data. Since doctors are usually not specialists in data analysis, additional efforts need to be considered for the presentation and analysis of the data.

Last but not least, the reliability of the medical data gathered by not necessarily medical devices is an issue that needs to be tackled.

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