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Abstract

Mobile devices are becoming ubiquitous in every day's life; their time and place independence are reasons for using them in different areas. One such area is electronic health, where patients can install small applications on their mobile devices that help or guide them in the management of their disease. The eSana framework offers a set of tools and approaches that allow the transmission of discrete physiological values electronically in order to evaluate them by medical experts.

This paper presents an application scenario in the field of dermatology. It illustrates the information flow between patient and dermatologist including all transformation services. One speciality is the combination of binary image data and structured information about a given condition sent over a mobile network. The main goal is to show a set of necessary components in order to support the relationship between patients and their dermatologists by using medical standards.

Keywords: eHealth, mHealth, mobile services, dermatology, eSana framework, information flow

1 Mobile devices in eHealth

A very large percentage of the European population owns a mobile phone. Their ubiquity, connectivity and increasing features are reasons for their usage in the electronic health sector.

Assigning mobile devices (e.g. mobile phones, PDA's) to patients has been researched in a number of papers; some of these will be presented in the following sections. A survey presented in (WHO, 2006) interprets the high demand of non-OECD countries for telemedicine and the use of a remote medical expertise toimprove the available health care resources in less developed areas.

When a mobile device is used to transmit physiological parameters, it is possible to discriminate between the following three domains:

- Mobile devices are used to help the patient by providing information.
- Mobile devices are used to transmit physiological parameters.
- Mobile devices are used to alert patients or medical professionals when certain physiological parameters become critical.

Providing information to patients

The HealthPal medical assistant in (Komninos and Stamou 2006) is an example of the first domain. This dialogue based monitoring system aims at supporting elderly people in their preferred environment.

Another example is proposed in (Königsmann et al. 2006), where the presented system provides help for younger people that suffer from overweight. It includes motivational support and alerts and connects the single patient with a group of patients that suffer of the same problems. Furthermore, a traffic light system divides nutrition into three classes in an unobtrusive way.

Transmission of physiological parameters

An example of the second domain was introduced with the MOEBIUS project (Mobile extranet based integrated user services) who integrated doctors and patients by submitting different physiological parameters (Fischer et al. 2006).

(Leimeister et al. 2005) describe the usage of mobile devices in order to assist young cancer patients and conclude that the usage of such a system has a number of advantages:

- Higher compliance of appointments with alerting functionality.
- Higher data quality as compared to a paper-based version.
- Less work on part of the doctor to prepare the documentation.
- Fewer errors in the documentation.
- Parents are relieved of the daily burden of planning and controlling the daily activities of their children.

Alert of patients or medical professionals with critical values

An architectural and conceptual overview of an application of the third domain is described in (Jung and Hinze 2005). Their work focuses mainly around the actors patient, doctor and nurse. The use cases for a mobile alerting system are built around them.

Another example is SAPHIRE, described in (Hein et al. 2006), a monitoring and decision support environment that generates alerts if the patient’s state becomes critical, in an assisted home-based scenario. It bases on guidelines that are able to evaluate the incoming data and deduce critical states. The communication with a clinic is solved using a secure VPN connection; potential updates to the guidelines are automatically downloaded upon start-up of the application and are thus always up to date.

2 The eSana Framework

The eSana framework is being developed at the University of Fribourg in Switzerland and offers a platform to developers of medical applications. It consists of an architecture that simplifies repetitive tasks while remaining flexible for application-specific extensions. It has been described in more detail in (Savini et al. 2006).

The main goals of applications using this framework are as follows:

- Location and time-independent communication between patients and their doctors.
- Integration of the patient into the disease management and documentation process.

The eSana framework (see Figure 1) runs the eSana server and on a mobile device (e.g. mobile phone or PDA) using the Java Micro Edition (JME) platform (Schmatz 2004); other mobile platforms like the .NET Compact Framework or XHTML-based approaches are envisaged but no implementation efforts have been made with these technologies at the time of writing. Various medical devices may be attached wirelessly to the mobile client and send medical data or information about the environment (e.g. location, room temperature…). The application offers a user interface to the patient and sends the gathered data after submission to the eSana server.

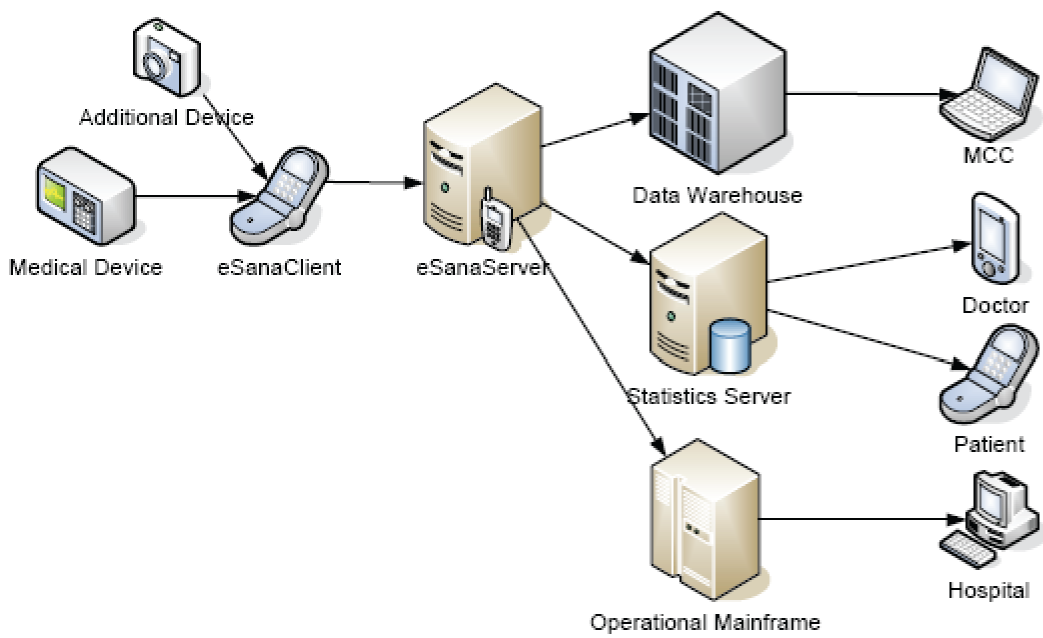

Figure 1: eSana Overview.

The eSana server is based on a hub and spoke architecture and relays received data to a set of subscribers after a transformation process. Such a transformation may include the anonymisation of the data, so that the subscriber does not know to which patient it belongs. This makes sense if the data is used to create impersonal statistics. Anonymisation includes the removal of all information that may be used to deduce the identity of a patient, such as the name and location.

The subscribers are not part of the eSana framework; they transform the data depending on their purpose and may offer a user interface to their users in order to view/analyze the data. The interaction back to the patient is done using a façade that allows the sending of structured messages.

The main component on the client side is the *eSana mobile client* that uses a configuration file upon start-up of the application. Also upon start-up, the mobile client connects with the server and downloads updated and personalized artefacts, such as a new user interface or unread messages from the eSana server.

This means that the medical professional can update the user interface of the mobile device at any time during the observation process, if he needs additional information. Thus, the patient is always working with the most up-to-date user interface and enters the information his medical professional needs at the moment.

The user interface on the mobile device is defined as an XML artefact and is generated upon launch. It allows several data types; for the dermatology use case, a new data type *image* is needed in order to allow the access to the built-in camera of the mobile phone using the Mobile Media API (JSR-135).

Context information

Context is defined in (Dey 2001) as any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application. (Abowd and Mynatt 2000) define the minimal set of necessary context using the “five W’s”: *Who, What, Where, When, Why*. An overview of the application of context in eHealth projects is given in (Savini et al. 2007a).

In a smart home or smart hospital scenario many devices are available in the environment of the patient that send data regularly or explicitly (e.g. thermometers, GPS devices, balances …). This information may be used for several reasons:

- There is a specific interest for the medical professional to evaluate this information in order to get concrete values about surrounding influences.
- Many devices, such as balances, are able to give much more information than is normally visible on their user interfaces. Other information (e.g. distribution of fat in the body) is also awkward and error prone to retype on a mobile device. If such information is electronically available in the current environment, the user does not have to type it.

Information coming from the context may influence the user interface presented to the user. Such an interaction for the eSana framework has been described in more detail in (Savini et al. 2007b).

Communication with eSana Server

The mobile device communicates with the eSana Server using web services as described in (Savini et al. 2006). This is done using the JME Web Services

Specification API (JSR-172) or the kSoap API. The advantages include a higher reusability of the server-side façade using standards which facilitates the implementation of the mobile application on different platforms (e.g. Windows Mobile, Google Android, JME…).

A drawback of this approach is the verbosity of the SOAP messages (Erl 2005, chapter 5.4) sent between client and server that can only partly be reduced using compression techniques.

Security Considerations

Security is a fundamental issue for the exchange of medical data. (Tsiknakis et al. 2006) evaluate various security related issues experienced in the HYGEIAnet project. All aspects of security in ubiquitous computing applications, including RFID tags, are summarized in (Weippl et al. 2006). They identify the following three main problem areas: protection precautions, confidentiality, and integrity. Furthermore, also availability, authenticity and anonymity are discussed. Finally, (Marti et al. 2004) describe the security specification for the MobiHealth project. It can be summarized by using the following technologies mapped onto our own approach:

- Use of Bluetooth security between the medical and mobile devices.
- HTTPS with client and server X.509 certificates between mobile devices and the server and also between servers and different systems.
- HTTPS between the service providers and the end users. The usage of client X.509 certificates depends on the offered service. Typically, an application communicating with a medical expert will require a stronger authenticity.

3 Dermatology application context

Dermatology is defined as the diagnosis, care and prevention of diseases of the skin, the mucous membranes close to the skin and of the hair and the nails (SGDV 2008). The diseases can be categorized in many ways: tumours, allergic diseases, pathogenous diseases, acne, pigmentary abnormalities… An extensive list can be found in (Bahmer et al. 2005). Several diseases are chronic and require supervision.

Figure 2: Examples of skin diseases (from left to right: scar tissue, lichen, hyperkeratosis).

Analysis of skin diseases often includes some kind of image of the region in conjunction with a set of attributes describing various parameters.

Motivation and Application Scenarios

(Braun et al. 2005) describe a feasibility study conducted at the University Hospital in Geneva, Switzerland, where mobile phones with integrated cameras were used to take images of leg ulcers sent to dermatologists for evaluation. It concludes that the agreement between the remote and face-to-face evaluations was very good and that 82% of the participants felt comfortable making a diagnosis based on the pictures.

The study was conducted using the first generation of mobile phones with integrated cameras. Meanwhile, most mobile phones have integrated cameras that are much more sophisticated.

Application scenarios considered for the presented architecture are:

- **Long-term care**: The patient has venous ulcers (*Ulcus cruris*) and is treated at home by caregivers. Whenever the nurse is not sure about the further procedure, he is able to send the images with additional information about the current condition of the patient to a dermatologist and receive indications about the procedure to follow (e.g. medication).
- **One-time support**: An elderly patient lives at home and is visited regularly by out-patient nurses. On a normal visit they are confronted with a burn or a sudden rash on the patient and are not sure whether this condition needs further treatment. The nurse takes an image of the patient and sends it to a dermatologist requesting evaluation. The dermatologist may decide that it makes sense to bring the patient to a hospital for further analysis.
- **Precautionary support**: A patient with many freckles would like to know from time to time whether the bigger and maybe not round freckles are dangerous (melanoma). He sends images about the doubtful freckles and has more security whether his condition needs further treatment.
- **Second opinion**: A doctor that makes house visits is not sure in a case about a specific condition and takes images of the patient. He sends them to a dermatologist who in turn indicates his colleague about the further procedure.
- **Acne**: Younger patients with a lot of acne take, after a first consultation, regular photos of their condition and send it to their dermatologists. The dermatologist is kept up-to-date and can judge based on the images and additional information, whether the therapy is successful. They may also contact the patient in order to fix a new appointment or indicate him to alter or stop his medication.

Actors

The following actors have been defined for the dermatology application context:

- **Patient:** He needs to transmit images bundled with additional information (e.g. itchiness, dampness) about his current condition to his dermatologist.

He owns a suitable mobile device and has received an introduction on how to use the built-in camera to shoot correct images of the area of interest.

- **Dermatologist:** He would like to receive regular or sporadic updates of the situation from the patient. Receiving information more often than would be possible with personal visits may lead to a reduced number of necessary personal appointments and, in some cases, a better understanding of the condition of the patient, as temporary or sudden changes in the condition can be identified immediately.
- **Caregiver:** Caregivers use the application in certain scenarios (see section 0) to get a specialists' opinion about the procedure to follow. Typically, they use higher end mobile devices like PDA's and have received a more in-depth training for the application. Therefore, they act as proxies for their patients. This actor has been used in the scenario described in (Braun et al. 2005).

4 eHealth Information Flow

The information in Figure 3 flow bases on the eSana framework:

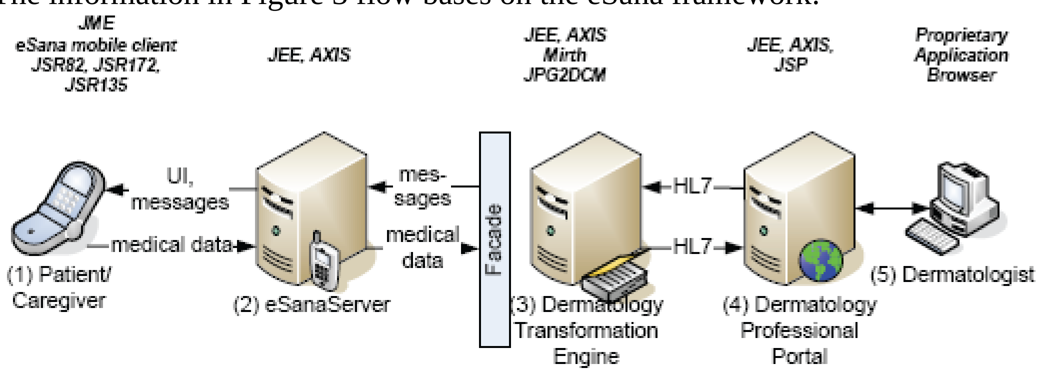

Figure 3: Simplified Dermatology use case information flow.

(1) The patient takes an image of his condition and adds some information (e.g. surface of the skin is wet).

(2) When he submits his information the eSana server receives it and checks where to send it to. In this case, only one recipient is defined. The data is sent using a session façade (Marinescu 2002).

(3) The dermatology transformation engine receives the data over the façade and applies a transformation process that converts the proprietary XML structure into HL7, the image (typically JPG) into DICOM and embeds the latter into the former. Afterwards, the HL7 message is sent to the portal.

(4) The portal receives the package consisting of information and image and offers a set of services to the end users.

(5) The dermatologists may receive the information from the patient in a number of ways, e.g. using a web based portal to view and analyze the images.

Furthermore, a channel back to the patient allows the dermatologist to send electronic messages to the patient. The next sections describe these steps in more detail using the information flow from patient to dermatologist as example.
The mobile device runs a JME application. Upon start-up, the most up-to-date version of the user interface is downloaded and the user is presented with a form where he has to enter some data (see Figure 4). In dermatology this information may include:

- Duration/Type of the disease distribution
- Current medication
- Pain: No, Yes, Since when, where
- Wound: Itches, stings …
- Blood heat: No, Yes, Since when, augmenting, decreasing


```
<textField id="dGlucose" title="Glucose" default="" maxsize="7"
constraint="DECIMAL" />

<choiceGroup id="cgLunch" title="Lunch" type="EXCLUSIVE">
        <choice id="AFTERLUNCH">After Lunch</choice>
        <choice id="BEFORELUNCH">Before Lunch</choice>
</choiceGroup>

<choiceGroup id="cgExercise" title="Exercise" type="EXCLUSIVE">
        <choice id="NONE">No exercise</choice>
        <choice id="EASY">Easy</choice>
        <choice id="MEDIUM">Medium</choice>
        <choice id="HIGH">High</choice>
</choiceGroup>
```

Figure 4: User Interface artefact extract on the mobile device.

eSana Server

The eSana server receives submitted information from the mobile device of the patient by offering a web service interface. This interface calls the necessary business logic that checks which subscribers use this information and sends it to them. In this application scenario, there is only one recipient (the Dermatology Transformation Engine).

The communication between the eSana Server and the recipients is signed and encrypted asymmetrically. This guarantees that the recipient knows that the information comes from the eSana server and nobody can read the messages between these two systems.

In this application context, no transformation process such as anonymisation is used on the eSana server, as the recipient needs to know to which patient the information belongs in order to apply its access control lists.

The communication between the two servers is done using a façade that implements a defined eSana interface. This ensures extensibility, as future services may implement the same interface and receive the same information, if they are registered as recipients in the eSana server.

Dermatology Transformation Engine

This section describes the transformation engine server, which receives the information of the patient in an eSana proprietary format and transforms it into a medical standard using freely available software. These two elements are described in more detail.

HL7

Health Level 7 (HL7) is a well established message-based interface standard addressing ontological compatibility for the exchange, management and integration of electronic information in the healthcare domain (HL7 Inc. 2007).

HL7 version 2.5.1 defines messages as the smallest atomic unit of data exchanged between systems. A message has a type that defines its purpose. It consists of a set of segments in a defined sequence. A segment starts with a three-letter literal value to identify it. A segment is a logical group of data fields. Data fields have a predefined position in their associated segments (HL7 Inc. 2007 ch. 2, p. 6). By default, HL7 version 2.5.1 messages are encoded in plain ASCII (HL7 Inc. 2007, ch. 1, p. 9).

Mirth Integration Engine

Mirth is an open source HL7 integration engine that handles routing, filtering and transformation of messages. It supports a variety of message standards and transport protocols. A Mirth server hosts a set of integration interfaces which are referred to as channels. A channel consists of four steps: the source connector that receives the message by either listening on a port or reading from a file or database, the filtering and validation step, the transformation step where a set of transformation rules can be applied to the message and the destination connector that transfers the message to one or more destinations (Mirthproject, 2008).

Process

The Dermatology Transformation Engine hosts a channel which offers a web service. The web service is called by the façade. It does the following: Accepting an XML artefact that contains the skin attributes, the patient recorded and one or more JPG images the patient took of the relevant skin areas. The images are encoded in Base64. After applying a set of filtering and validation rules, the message is passed to the transformation module, where the following transformation steps are executed:

- Mirth creates a HL7 version 2.x message of the type *Unsolicited Observation Message* (ORU_R01) (HL7 Inc. 2007, ch. 7, p. 12). It contains the following segments: The message header (MSH), the patient identification (PID), the observation request (OBR) and the observation result (OBX). It was decided to use HL7 version 2.x in this application context for the communication with other healthcare providers. Version 2.5.1 is an ANSI standard and widely adopted (HL7 Inc. 2007).
- Patient related data is mapped to fields in the PID segment, e.g. the patient's name is mapped to the fifth field, the patient's sex to eighth, etc., as defined in the HL7 version 2.5.1 standard (HL7 Inc. 2007, ch. 3, p. 72).

- The skin attributes described by the patient are added to the thirteenth field of the OBR segment called Relevant Clinical Information; see (HL7 Inc. 2007, ch. 7, p. 32).
- Mirth calls a built-in function to decode the Base64 encoded image and stores it as a temporary file on the file system.
- Mirth then executes the tool *jpg2dicom* (part of the dcm4che project, see (Dcm4che 2008)) with the temporary JPG generated in the previous step and a temporary file for the DICOM output as arguments.
- Mirth calls a built-in function that encodes the temporary DICOM file in ase64 and inserts it into the fifth field of the OBX segment along with the type of data and subtype of the encapsulated data and the used encoding. The format of the data inserted is described in the second field of the OBX segment. For this channel, it is *Encapsulated Data* (ED). Sending the DICOM image as *Encapsulated Data* in an OBX segment is only one possibility offered by HL7 (HL7 Inc. 2007, ch. 7, p. 42). An alternative is to use a *Reference Pointer* (HL7 Inc. 2007, ch. 2, p. 163) (also in the OBX segment). The image would then be stored on another system and only the pointer to that image is stored in the HL7 message (HL7 Inc. 2007, ch. 2, p. 208). For this prototype, the former approach was chosen for reasons of simplicity.

As illustrated in Figure 3, the HL7 message is then sent by the destination connector to the Dermatology Professional Portal.

Dermatology Professional Portal

After receiving the HL7 message with the embedded DICOM image, this server offers a set of services to the end users (in this case the dermatologists). The following scenarios can be implemented:

Generation of an e-mail

The HL7 message can be attached to an e-mail; this e-mail is encrypted asymmetrically. Afterwards it is sent via a public network (Internet) to the dermatologist's inbox.

The dermatologist decrypts and opens the message. The message body consists of some general information (patient name, timestamp, etc.) and an attachment containing the HL7 message. Opening the attachment will start his patient information system software that will import the data including the image into the patients' medical record.

Web Frontend

The dermatologist opens a portal URL in his web browser and logs into the system. He is presented with a view listing all HL7 messages of all his patients and can browse through them. It is also possible to download the messages onto his local machine and to process the HL7 messages manually.

Web Services
The portal server offers a set of web services that can be accessed by existing patient management software. This possibility offers a transparent access to the dermatologists as they continue to work with their existing software.

Secure FTP access
The generated HL7 messages are stored on a secure FTP server that can be accessed by the dermatologist. This variant appears very basic but offers a lot of flexibility to IT-savvy users.

Dermatologist

As described before, the dermatologist has many ways of working with the information received. Depending on the chosen approach, the interaction with the patient can happen in several ways:

Generation of e-mail
When the dermatologist receives an e-mail containing the HL7 message, he may be able to send a new e-mail to the patient indicating the procedure to follow in textual form. The drawback of this approach is that the message back happens recorded by the patient is sent using the eSana framework, whereas the communication between the dermatologist and patient occurs differently.

Web Frontend and Web Services
In the case of a web frontend, the dermatologist enters a message in the portal application. This message is encoded in HL7 and sent to the dermatology transformation engine which transforms it into an XML message suited for the eSana server. Upon request (i.e. at start-up of the application) of the mobile device, this message is downloaded and displayed to the user.

In the case of web services with a tighter integration into existing patient management software, the message can be inserted directly into the application, which generates a HL7 message. This message is relayed to the transformation engine which in turn transforms it into an eSana suited XML format.

Both these approaches have the advantage of having the history of the interaction all in one place.

Secure FTP access
If the dermatologist accesses the HL7 messages directly using FTP, no communication back to the patient is possible, except using a dedicated messaging portal or e-mail.

5 Lessons learned

In this paper we have described a collaboration approach between patients and dermatologists. This approach uses the eSana framework to connect a mobile application to a dedicated dermatology transformation engine. The engine transforms the proprietary structures of the framework into the medical standards HL7 and DICOM in order to integrate with existing software and tools.

The use of medical standards needs to be tested with the software used by the dermatologists, as the HL7 standard is not always unambiguous in the handling of attached files or images as used in this paper.

Classified by actor, the advantages of using such a system are:

- **Patient**: The patient is able to transfer his current medical condition immediately to the dermatologist. Depending on the access scenario chosen, this condition is transferred automatically into his medical record. As soon as the dermatologist reviews the condition, the patient receives an immediate answer about the further procedure.
- **Dermatologist**: He is able to receive the current medical condition of a patient without the need of a visit. This can be especially helpful in urgent or unclear situations or when the condition has to be supervised over a longer period of time.
- **Caregiver**: The caregiver is able to improve the assessment of the current situation by getting the judgement from an experienced dermatologist; this will improve the quality of care of his patient and decrease the number of misjudgements.

For the implementation of a final product, some questions remain:

- How is the IT literacy and infrastructure of dermatologists and their patients?
- What are the preferred access scenarios of dermatologists to view the information about their patients?
- How do dermatologists prefer to communicate with their patients?
- What application scenarios are thought to make sense in a first rollout of such an application?
- What hindrances do dermatologists see for the rollout of such an application?

The questions above are addressed in a survey with Swiss dermatologists in March 2008 conducted by the University of Fribourg and the Swiss Association of Dermatologists (SGDV). We hope to be able to outline a concrete application scenario with the results based on the eSana framework and the preliminary work described in this paper.

Furthermore, the eSana framework is being extended to address the new features necessary for such an application. This includes in particular the capture of images on the mobile device using the built-in camera and the handling of this new data type in the server applications and façades.

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