Integrating Context Information in a Mobile Environment using the eSana Framework

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Abstract: Mobile devices are becoming ubiquitous in everyday's life, their popularity and place independence are reasons for using these devices 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 certain situations. 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 extension to this framework that includes the use of contextual information to improve eSana. The use case "Find nearby pharmacy" will illustrate a simple application that uses context information to guide the patient to the best pharmacy within his range. A second use case will enrich the existing idea of transmitting physiological parameters with context information.

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 using them in the electronic health sector.

A number of researchers have worked on the idea of assigning mobile devices to patients. Furthermore, the survey presented in [WHO06] interprets the high demand of non-OECD countries for telemedicine and the use of a remote medical expertise to improve the available health care resources in less developed areas. When the mobile device is used to transmit physiological parameters, it is possible to distinguish between the following three domains:

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

The HealthPal medical assistant in [KS06] is an example of the first domain. The dialogue-based monitoring system aims at supporting elderly people in their preferred environment. Another example is proposed in [KLWK06], where the presented system provides help for younger people that are suffering from overweight.

An example of the second domain was done within the MOEBIUS project (Mobile extranet-based integrated user services) who integrated doctors and patients by submitting different physiological parameters [FRG+06]. [LKHK05] describes the usage of mobile devices in order to assist young cancer patients and concludes that the usage of such a system has a number of advantages: higher compliance of appointments with alerting functionality, higher data quality, less work on part of the doctor to prepare the documentation, less errors in the documentation.

An architectural and conceptual overview of an application of the third domain is described in [JH05]. 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 collecting real-time electrocardiogram signals including basic arrhythmia detection with automatic alerting to a call center is illustrated in [LML+04]. Their system architecture uses readily available commercial off-the-shelf components. Finally, [HNW+06] describes SAPHIRE, a monitoring and decision support environment that generates alerts if the patient's state become critical, in an assisted home-based scenario.

The existing eSana framework concentrates on the transimission of discrete physiological parameters (second domain).

This paper is structured as follows: The next section provides a short introduction into the eSana framework. After that, the term context and its integration in the eSana framework is presented. Section 3 illustrates two use cases that can be realized with eSana. Finally, section 4 gives a discussion and an outlook.

2 The eSana Framework

The approach used in the eSana framework as illustrated in figure 1 has been described in more detail in [SIM+06] and [SIM05]. The main goals of applications using this framework are as follows:

- Location and time-independent communication between doctor and patient.
- Integration of the patient into the disease management and documentation process (patient empowerment, see level-of-care pyramid in [RD04]).

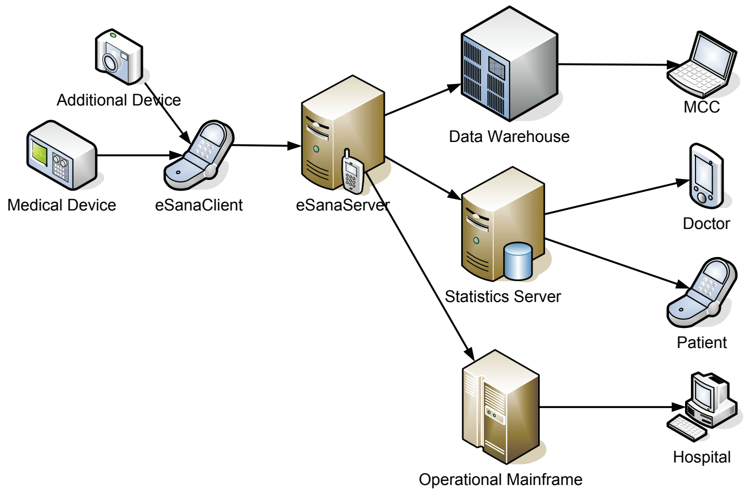

Figure 1: Overview of the eSana approach

2.1 Information flow

The eSana framework considers the needs of several actors, e.g. patient, doctors, nurses, health care administrators, by enabling various scenarios. One scenario is the transmission of physiological parameters. Several medical devices used at the home of a patient transmit their values to his or her personal mobile device (typically a cellphone) using a Wireless Personal Area Network such as Bluetooth. The mobile device acts as a Mobile Base Unit (MBU) and interfaces to the Internet after transformating the information. Additionally, the application on the MBU allows to query further discrete information from the patient (e.g. whether or not the user already had lunch). A screenshot of a diabetes patient's user interface utilized for transmitting glucose values is shown in figure 2. This additional information can be defined by the supporting doctor in order to personalize the whole application to the medical condition of the patient. Internally, the user interface is automatically generated by XML documents that are updated regularly, if necessary.

Once the patient decides to send the data, a Web Service is invoked on the eSanaServer. This server transforms the information and dispatches it to a number of interested subscribers (in this case, a statistical service that can be accessed by the patient's doctor). Other scenarios include the additional subscription of an alerting service for diabetes patients that analyzes the data and warns the doctor immediately, if the values exceed a defined threshold. In order to comply to the mobility needs of the doctor, both the statistical server and the alerting service allow access from a mobile device.

Figure 2: eSana user interface example

2.2 Security Considerations

Security is a fundamental issue for the exchange of medical data. [TTSO06] evaluates various security related issues experienced in the HYGEIAnet project. The work of [MSK06] applies general principles and solutions of mobile security onto mobile health applications. Finally, [MDP04] describes 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 ensure a stronger authenticity.

An approach to privacy in personalized ubiquitous systems is presented in [SSA06], where secure logs are a base for evidence creation.

3 Context in the eSana Framework

This section describes the concept of context applied to healthcare scenarios and illustrates them by presenting two context-based use cases within the eSana framework:

- The use case “Pharmacy finder” is situated in the first domain, as described in the introduction. It allows the user to retrieve information, pharmacies in this case, by using context information to optimize the result set.
- A second use case extends the original intention of the eSana framework, namely transmitting physiological parameters, by additional context information that can be defined by a doctor.

3.1 Introduction to Context

As illustrated in [Dey01], various people have used different definitions of the term context. In this paper we refer to the provided definition of [Dey01] himself, which suits our presented application scenarios well. [Dey01] describes context 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.

The work of [AM00] defines the minimal set of necessary context using the "five W's": *Who*, *What*, *Where*, *When*, *Why*. In table 1 we illustrate existing aspects of this context information and point to existing work in literature where it has been applied, if possible by means of a healthcare scenario.

Several papers discuss the use of context information in a health care scenario. The work of [BSC+04] describes a vision of a "smart hospital" and proposes an architecture to address the most important issues of this vision. The CASCOM project includes several aspects of pervasive eHealth applications. It is based on an intelligent P2P infrastructure and considers secure composition plannig ([LCB+06]) and performance considerations when communicating in a mobile wireless network ([HvPSS06]).

The work of [Che04] describes the use of OWL based context ontologies for pervasive computing environments. Additionally, the proposal in [PVdBW+04] offers a starting point for context ontologies for ambient intelligence which we will use as a base for our own in the following sections.

3.2 Pharmacy finder

Within this use case, the existing eSana suite is extended by a "Pharmacy finder" application that allows the patient to retrieve a list of pharmacies based on his geographical location, preferences and the current time. Figure 3 illustrates the ontology of the context transmitted for this application.

The application takes the following contextual information into consideration:

Location Location aware mobile devices have become accessible in the last few years. Typically, they include a GPS module that is able to track the current location. This information can be retrieved using the JSR 179 standard (Location API for J2ME). Other approaches often require the involvement of the mobile infrastructure operators and are not discussed here.

Time The current system time is part of the context. The nature of the application makes it necessary to consider different time zones. It is assumed that the user updates the time of his mobile device if necessary; another approach would be to calculate the time zone of the user using the geographical location.

Reason The user should define the reason why he would like to visit a pharmacy. This information cannot be deduced from any context information, therefore it must be

W	Aspect	Examples
Who	Profile	The current user of the system is typically known to the application. This information is part of the context information and can be used to generate personalised recommendations based on the actual or other users past decisions. [YZZ+06] describes a hybrid approach, including content-based recommendation methods, for context-aware mobile media recommendations. Such an approach can be used to match the user preferences against an available set of possibilities.
What	Activity	Determining the current activity of the user using available contextual information is the focus of many Customer Supported Cooperative Work (CSCW) approaches. Both [TFG06] and [SH06] discuss context-aware and activity-based applications in hospitals. The work of [CRS+04] introduces the concept of computer-supported coordinated care (CSCC) in a care network for elders. Additionally, [KCL06] describes how to determine the current activity in order to help elderly seniors.
Where	Position	*Semantical*: A semantical position (e.g. University of Fribourg, second floor) can be useful in closed environments like hospitals. Appropriate technologies are WLAN positioning or beacons. [SH06] utilize a mobile electronic patient record to improve information access in a hospital ward. The Pinpoint approach described in [Rot02] uses semantic servers to translate numerical positions (e.g. GPS coordinates) into a semantic location information. The work of [PWG06] presents the Multiple Camera Indoor Surveillance project used to identify and track people and summarize their activities. *Numerical*: Numerical values are the traditional representation of a geographical position. Typically, a GPS device is used to track the location of a patient when a certain event (e.g. transmission of critical data) occurs. Such a combination has been explored in [LML+04].
When	Time	The current time can be a powerful context information especially if it is used in combination with other data. In a simple case, an application could use a timestamp to tag all actions of a user for later evaluation. The use of time in a CSCW scenario at a surgical department is described in [Bar00].
Why	Reason	The motivation of the current user can be quite difficult to establish. In a healthcare scenario, however, measuring the current state of the user (heart rate, temperature) can give a good indication about the affective state of the person.

Table 1: Context information

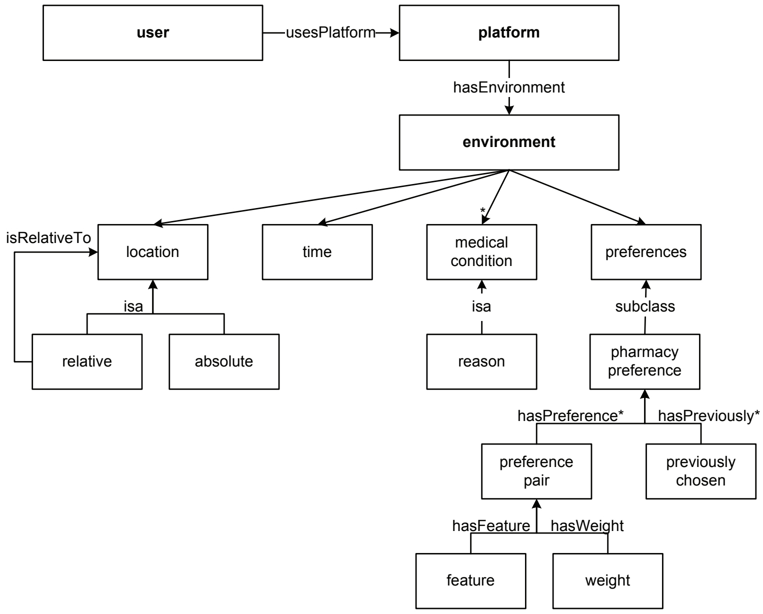

Figure 3: Pharmacy finder Context Ontology

entered manually by the user. It is assumed, however, that the reason correlates with the medical condition for which he uses the eSana framework application, hence the proposed reason codes will mirror this fact. Internally, the user codes are represented as a small subset of ICD-10 codes in order to rely on an existing classification. This information is optional.

Preferences It is possible to configure a list of personal preferences. These may include considerations as language preferences (e.g. 'Prefer pharmacies with employees that have German or French language skills'). Furthermore, a list of already visited pharmacies on other occasions is also part of the pharmacy preference context information.

Similar to the existing eSana applications, a form is presented to the patient before submitting the request. All available context information is shown within this form. It is not a prerequisite that the medical device can collect all contextual information. If there is no location module available (e.g. GPS), the system will ask the user to specify his location manually. It is also possible to change the personal preferences prior to submitting the request.

The user can start the application by selecting the "Pharmacy finder" part of the eSana suite. Depending on what context devices are available, the user is presented with a user interface that allows him to enter the missing values (e.g. the location, if no GPS module is available). Furthermore, he can change the existing preferences in order to refine the description of his current situation.

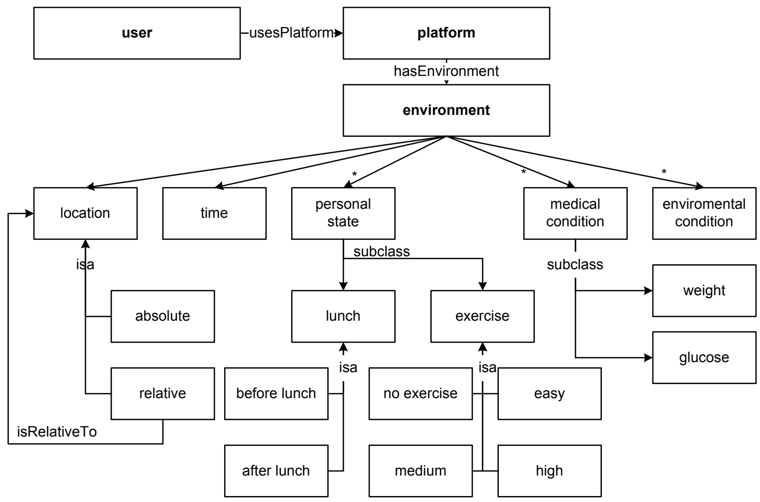

Figure 4: Example Context Ontology for transmitting blood values

3.3 Context in the transmission of physiological parameters

Originally, the eSana framework was developed to allow the configuration of applications that transmit physiological data (e.g. glucose values) to a server where they are dispatched and send further to subscribers [SIM$^+$06]. An extension to this use case is the implicit inclusion of context information. This information could support a medical expert when analyzing the physiological parameters of a patient.

Currently, the user interface is defined by a medical expert to personalize the needed parameters from a patient. This means, that the doctor defines the context ontology himself (relying on already prepared templates). A possible example for the diabetes case is illustrated in figure 4. An extension to this mechanism links the information to a list of available devices and fills out the form automatically. If a device is not available, the user interface may request the information explicitely from the patient. This is established at runtime so that the user interface adapts itself immediately to different situations (e.g. the patient measures his glucose values during his holidays, where no BAN-enabled balance is available). The user interface shows explicit information that has to be entered manually on top of the screen. Contextual information can always be overwritten by the user.

3.4 Changes in the architecture of the mobile device

The component diagram in figure 5 reflects the architectural changes needed to consider context information on the mobile application. Components and artifacts in italic represent new or extended components.

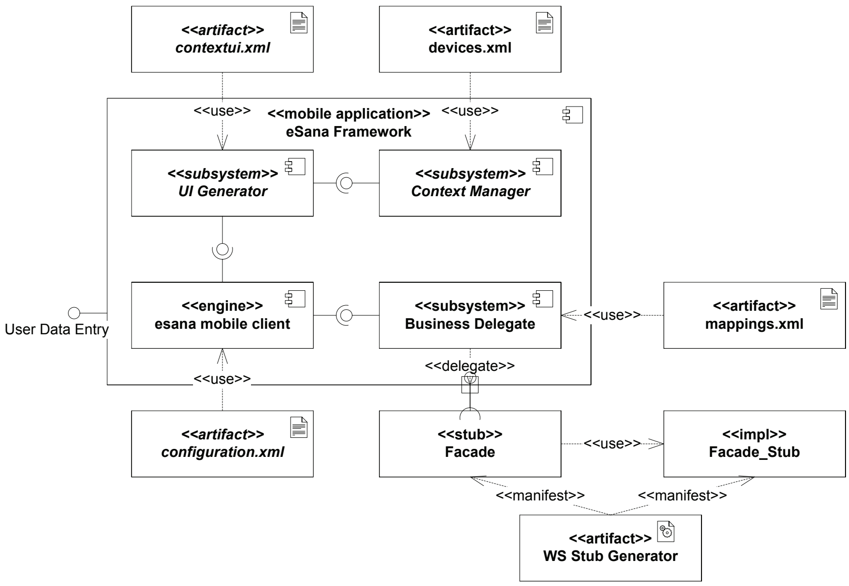

Figure 5: Component diagram

- The *UI Generator* must be extended in order to be able to receive contextual information from the *Context Manager*. The UI adapts itself to incoming data so that the user will only have to enter information that is not available in the current environment.
- The artefact that contains the definition of the UI must be syntactically extended in order for the *UI Generator* to map UI elements to device information.
- The application wide configuration artifact has to be enlarged to reflect global behaviours (e.g. timeouts) for the devices that supply data.

4 Conclusion and Outlook

This article described an extension to the existing eSana framework that considers contextual information from the environment in two different use cases. Necessary changes to the existing architecture have been evaluated.

In the future, we would like to evaluate how contextual data can be interpreted (e.g. by a medical expert). This includes the visualization of the information on a statistical application that evaluates the collected data but also possible mechanisms that would allow an alerting service to act on certain physiological information considering the context.

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