The eSana Framework: Mobile Services in eHealth using SOA

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Abstract: *A large number of people already own a mobile phone. In the eHealth area, the usage of this mobile device is becoming more and more popular. Patients can install small applications on their devices that help or guide them in certain situations. Additionally, the mobile devices can be used to transmit all kind of physiological parameters electronically. These parameters are stored on a special server. This paper presents the eSana framework that was developed as an integrated system to connect patients to medical experts. Its focus is the presentation of a generalized data gathering mechanism to collect physiological parameters from a patient and to attach a number of subscribers that offer a service based on this data. A sequence diagram will be presented in order to illustrate the different interactions between the various participants of the system and the service-oriented approach that allows adding new service providers to the whole system.*

Keywords: eHealth, eSana, mobile services, medical devices, framework, SOA

1. Mobile devices in eHealth

Current statistics show that more than 80% of the European population own a mobile phone. The increasing features of these devices are reasons for using them in the electronic health sector. A promising area is the automated collection of physiological parameters like blood glucose using mobile phones combined with a measuring device. These parameters can be transmitted to a medical expert afterwards.

A number of researchers have worked on the idea of assigning mobile devices to patients. Typically, one can 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 when certain physiological parameters are bad.

The work of (Heuwinkel, 2005) is an example for the first domain. Her system provides help for younger people that are suffering from overweight. During the day, the mobile device guides the patient. The system proposes the overweight person what and when to eat.

The second domain was done in the MOEBIUS project (Mobile extranet-based integrated user services) (Reichlin, 2003, Eikemeier et al., 2001) who integrated doctors and patients by submitting different physiological parameters. Another project was WellMate™ (Brännback & Söderlund, 1999), done in cooperation with Nokia. The idea of WellMate™ was to collect blood glucose values from diabetes patients. These values were transmitted to a service provider using SMS. In a project from the University of Munich (Wolf et al. 2004) a device for measuring the lung functionality was developed. This device is connected to a mobile telephone and sends the values to a server. Vitaphone (Vitaphone, 2005) is a German company that distributes a mobile phone to be used for personal emergency calls. Additionally, the phone can record ECG's and send them to a server using the GSM network. Finally, (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, less work on part of the doctor to prepare the documentation, less errors in the documentation.

The third domain is done in the work of (Panzarasa et al., 2004). They propose a system where patients can access their own physiological parameters and send them to Medical Communication Centers (MCC). The evaluation is done at a MCC. (Jung & Hinze, 2005) have done a similar work.

The aim of this paper is to present eSana, a framework developed as a mobile integrated solution for the communication between patients and medical experts. eSana redefines the communication between a customer/patient and a medical expert by the consequential use of mobile devices for the customer/patient part. Furthermore, eSana supports the patient when physiological parameters need to be transmitted regularly.

This paper concentrates on the transmission of physiological parameters and their evaluation (second domain, described in section 2). The integration of the other domains is described later on in the outlook in section 3.

2. The eSana Framework

The eSana Framework offers application developers a solid base in order to create their applications (Stormer et al., 2005). Although many applications are possible, this paper describes the evaluation of physiological parameters as described above. This scenario is used to get medical data from mobile patients (e.g. patients with chronic diseases as diabetes) and transmit them directly to a server; this data is afterwards offered in some way to a set of subscribed recipients that can build their own services with it. The data may be used for different means, as illustrated in Figure 1.

The main goals of offering an application described in the figure 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 the level-of-care pyramid in (Rittweger & Daugs, 2004)).

The framework is based on a service oriented architecture paradigm (Hofmann, 2003, Erl, 2005, Hohpe & Woolf 2005). This approach has a number of advantages:

- Process integrity: Control remains with the caller of the service.
- Improved information logistics: Better support of an underlying process model.
- Flexible application integration: Clear separation of concerns.
- Investment security: Relying in standards minimizes the risk of having to replace existing solutions. Moreover, Web-Service-Wrappers may be used to integrate with existing legacy applications.
- Higher visibility of functionality: Due to clearly defined and exposed interfaces.
- Efficient implementation: Due to a great number of supporting tools.

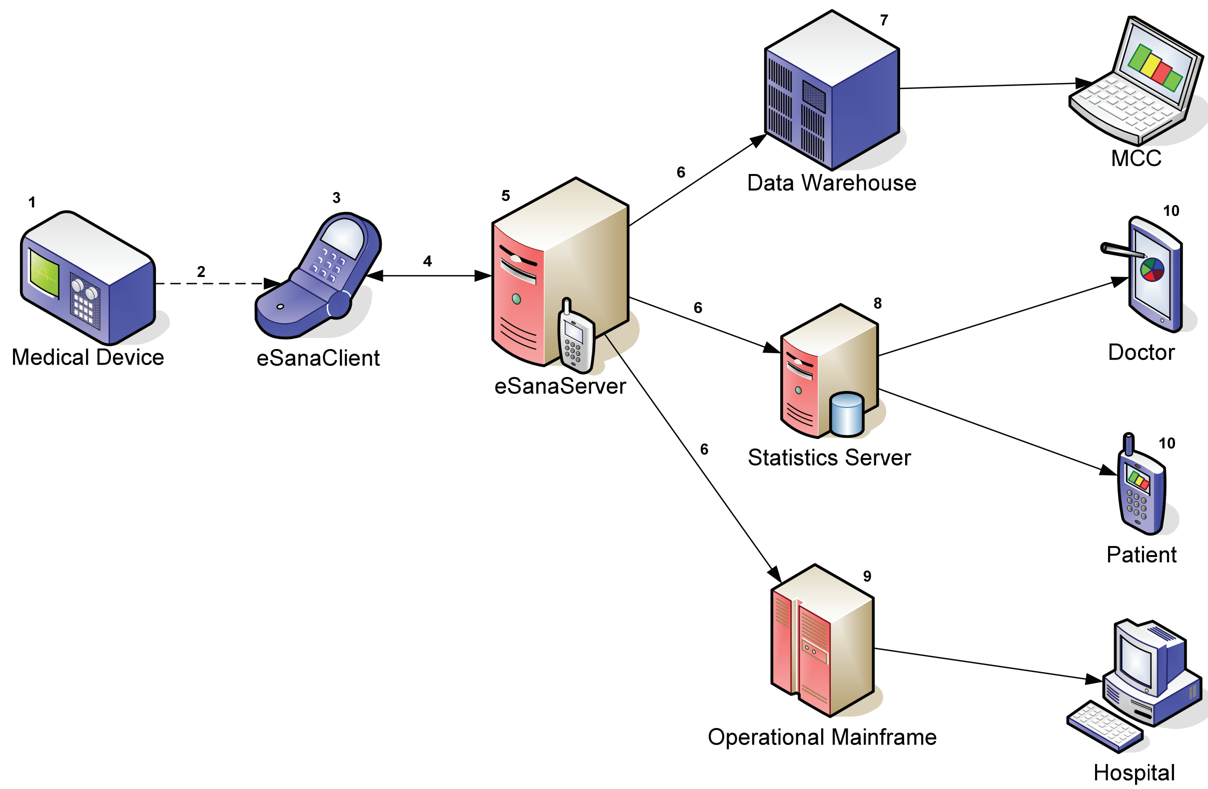

Figure 1: Overview of the eSana approach (the numbered items correspond to the subsections)

2.1. Medical Device

The process may start with one or more medical devices at the patient's home. Typical devices are blood glucose measuring and blood pressure devices as described in (Stormer et al. 2005). The patient uses them and they interface with the eSanaClient.

2.2. Personal Area Network Communication between medical device and the eSanaClient

The communication between the medical and the mobile device is typically done within a Wireless Personal Area Network (WPAN) or a Body Area Network (BAN); however, it is not a mandatory element of the system, as all data can also be entered manually into the mobile device. The connection between the two devices does however simplify the process of the data gathering for the patient and should be implemented, if possible.

Most medical devices today do not offer WPAN connectivity such as Bluetooth (Roth, 2002); some do, however, offer a serial interface which in turn can be linked with a Serial-to-Bluetooth converter. Therefore, the communication between the mobile device running the eSanaClient and the medical device(s) may be based on the Bluetooth protocol, which is implemented in most mobile phones and PDA's today (e.g. using the Java API for Bluetooth).

It is also possible to use other communication protocols (e.g. IrDA or a normal, cable-based serial connection) or to enter the data manually into a user interface offered by the application on the mobile device.

The format of the data differs between each medical device. The eSanaClient uses an XML configuration document. This configuration stores the necessary information to handle incoming data correctly. One example is the conversion of comma separated values (CSV) coming from a medical device to an XML syntax that can be processed. Furthermore, it is possible that the medical device must be initialized prior to sending the current measurements. The eSanaClient handles this task transparently.

2.3. Mobile Device running the eSanaClient

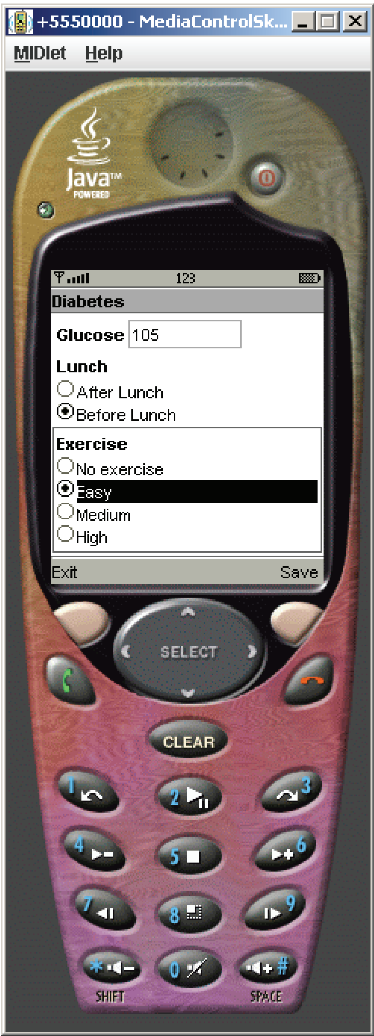

Figure 2: Example user interface on the eSanaClient

The physical device is typically a mobile phone or a PDA that runs Java ME applications. The client offers the automatic reading of parameters from medical devices and also an engine that generates a user interface for the patient. Such a user interface is formally described in an XML-based configuration file.

This approach allows the personalization of the applications for the patient. Typically it is a medical expert (e.g. doctor) who defines what parameters the patient should provide. Such parameters are dependent on the medical condition of the patient. Figure 2 illustrates such a form.

The generation of the user interface in XML allows it to offer easy tools for the decision maker about what parameters to gather. Such a description may look as follows (corresponds to the form in Figure 2):

```
<form id="frmDiabetes" title="Diabetes">
       <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>
       <commands
handler="ch.unifr.esana.forms.ThreadedCommandHandler">
              <command
                     id="cmdSave"
       action="ch.unifr.esana.forms.action.SaveToWebserviceCommand"
                     title="Save" type="ITEM"
                     priority="10" />
              <command
                     id="cmdExit"
                     action=" ch.unifr.esana.forms.action.ExitCommand"
                     title="Exit" type="EXIT"
                     priority="100" />
       </commands>
</form>
```

The configuration is loaded upon start-up from the server, if there is a new version for this patient (see Figure 3). This ensures a fast reaction-time if the medical expert decides that additional data is necessary (e.g. weight information).

An application provider may easily extend his target information by implementing new commands such as the saving process or even offer a wizard-like user interface where the patient moves from form to form. He can also extend the user interface elements by implementing custom ones (e.g. table layout). However, the framework implements and offers many of the most-needed actions and elements, which can simply be put together.

2.4 Communication between the eSanaClient and the eSanaServer

The communication, like reading the most current configuration or submitting the entered parameters, between the eSanaClient and the eSanaServer is done using Web Services with SOAP over HTTP. Newer mobile devices now ship with a Java ME package that implements the JSR172 specification (JCP, 2006); calling the web service on the server is therefore very simple and application providers may build their dedicated versions of commands that call other web services.

One reason for using such a high-level approach is to be able to implement specific eSanaClient versions on other mobile devices, such as PDA's or Smart Phones running Windows Mobile without having to implement an entirely new communication module. Furthermore, web services are widely accepted and standardized as a mean to loosely couple different components of a system over a network.

If necessary, it is possible to implement new transmission methods like sending an SMS to the server; this approach, however, does not allow for a synchronous response and works only with small amounts of data.

If the eSanaServer or the network is not available, the message is stored temporarily and sent at a later time. This implies a storage mechanism on the mobile device. Fortunately, most devices offer such storage options. For security reasons, this is the only time where messages are held locally.

Due to the sensitive nature of the data, the whole communication is encrypted, so that intermediaries may not read it. This can be done using a secure channel (e.g. https) and by encrypting the information on application-level (e.g. using X.509 certificates). The latter approach is used to authenticate the sender (patient in this case) to the recipient (eSanaServer). Section 2.12 describes the security specifications for such a system in more detail.

2.5 eSanaServer

The eSanaServer handles most administrative tasks for the eSanaClient; it offers a simple façade that is exposed as a web service. Important administrative tasks are the treatment of the authentication and of the personalization configurations for the eSanaClient. The former task is typically externalized in order to use a global health provider authentication interface.

The most important task, however, is the reception of submitted parameters from a given client; the server uses a subscriber model to allow external services to declare their interest in certain information from a given person. After such a single registration process the eSanaServer knows where to send the received data to. There is no upper bound for the number of recipients.

The façade is logically separated from the dispatching process; dispatching runs asynchronously and, depending on the registration process, temporarily stores the medical parameters if the recipient is not available. Such a push-approach is interesting for the subscribed services, as they receive the information as soon as it is available; the sporadic nature of the parameter submissions also makes it difficult do define a periodic pulling.

2.6 Communication between the eSanaServer and the subscribed services

The arcs on Figure 1 illustrate some possible services attached to the eSanaServer. The communication between them can be implemented again in form of web services, in order to enforce the SOA paradigm. The subscribed services must expose a defined interface and communicate it during registration. This interface is then called and the data is transmitted. During the subscription process it is possible to specify that the data should be sent in an anonymized form. Depending on the recipient (service), this might be a legally necessary method in order to receive the data.

As the transmission operates only between servers, the implementation of other transmission protocols is possible. The interactions between the services and the eSanaServer correspond to the Publish-Subscribe Channel Pattern as described in (Hohpe & Woolf, 2005).

The next subsections describe only possible services that are attached to the eSanaServer; the architecture allows several more.

2.7 Data Warehouse Service

This service receives the data and loads them into a data warehouse. Such a service is interesting for MCC's that want to analyze overall tendencies and effects of certain influences in order to improve their advice. It might also be interesting for governmental statistical ministries to be able to evaluate the public health. Such an approach using the eSana framework is described in (Ionas et al., 2006).

2.8 Statistics Server

The statistics server receives data from the eSanaServer and stores them in order to offer statistical information to both a patient (the same that has submitted the data) and/or his medical expert. Depending on the requested statistic, a chart is generated and sent to the clients. Clients may be again mobile devices (as illustrated) or web browsers that access a web server.

If serving a mobile phone as client, the readability of the generated charts becomes a concern. In order to optimize this, the client must provide the statistics server with as much information about his environment as possible, so that the maximum available quality is reached. Again, to comply with the overall design principles, a web service façade is offered to the clients.

The storage of the information might be a security concern; therefore only accredited providers should offer such a service to the public. The authentication of the user (patient or doctor) works analogous to the method described in section 2.5.

2.9 Operational Mainframe

This service can be used in a different scenario and is used to illustrate the various application domains of the eSana framework: Instead of having a patient entering medical data at home, the whole process is located in a hospital. Nurses check the vital information of their in-house patients (or a subset thereof) and enter them in a PDA. The patient identification can be read by scanning his bracelet with the PDA (same procedure as described in sections 2.1 and 2.2). This information is stored in the local medical information system using a conversion interface; such an interface may be implemented by the vendor or other third-party providers. Once the data is stored in the IS it is available for all necessary participants (e.g. doctors).

One possible problem of this approach is that wireless devices are often not allowed in hospitals. However, more and more hospitals start to offer WLAN environments that may be used as networks to submit the data.

Such an environment is normally closed and does not send any data over a public network. It is possible, however, to send data, or part of it, to a Statistics server, as described in section 2.8. Such a scenario makes sense if the patient is only in the hospital for an analysis (e.g. more detailed analysis of blood parameters in a diabetes situation; something which can be done less often than a glucose test). Allowing for such an approach would offer the medical expert of the patient (who is most likely not the same as the one performing the test in the hospital) with this data, which he may use for his future advice to the patient.

Another idea is to use such a closed environment in a Home Healthcare scenario, as described in (Archer, 2005). The nurses will visit the patients' homes and submit their physiological information into a hospital information system for further evaluation by a doctor. Although using a public network to submit the data, it is only used within a specific context.

2.10 Evaluation of historical data using mobile devices

Statistical information can be evaluated by either a doctor or a patient using again a mobile device. From the perspective of a patient, the same application as entering the data (see section 2.2) is used. The evaluation of the data on a mobile device may pose some problems in terms of readability. A typical patient, however, will need only the most basic charts about his historical data.

On the other hand, the doctor of the patient will use the same data to analyze the situation in a different fashion. The charts will typically be considerably more complex and maybe also allow some interaction. Therefore this process requests a more sophisticated mobile device, like a PDA or even a Notebook.

2.11 Top-Level Interactions between the different participants

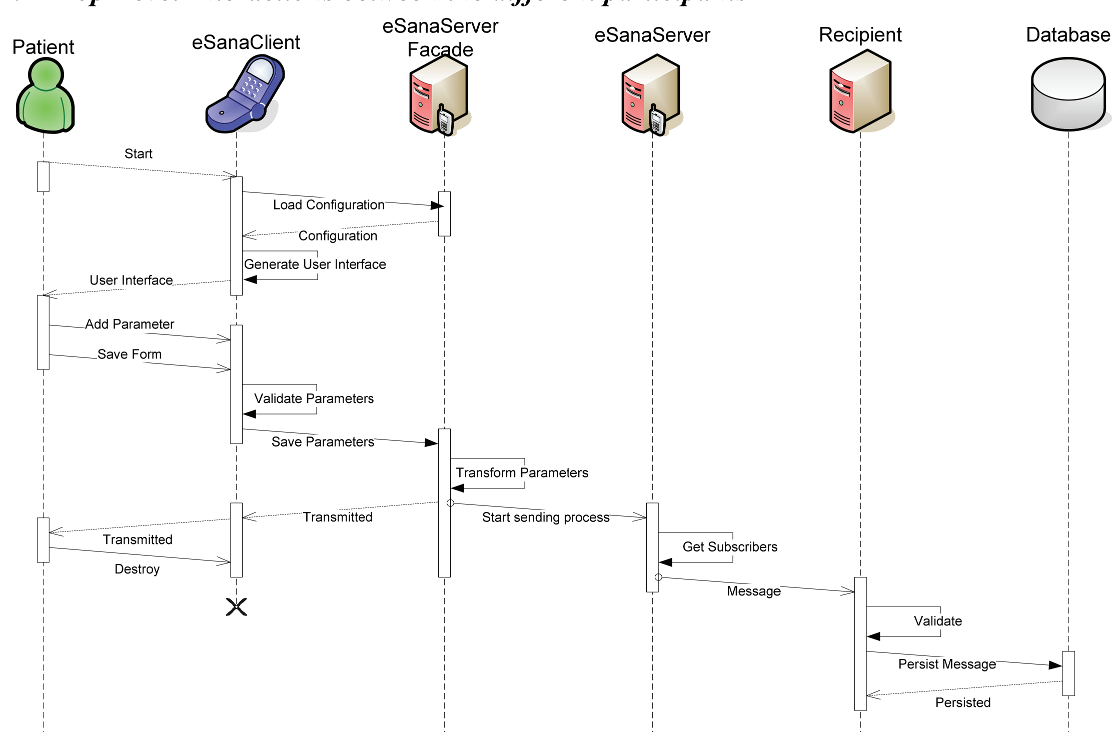

Figure 3: Example Sequence Diagram of a possible application

Figure 3 illustrates the interactions between the parties involved in the eSana architecture in form of a sequence diagram. On the right side of the eSanaServer life line, a service called "Recipient" is attached. This service is only very basic and basically simply stores the received data into a database.

2.12 Security Considerations

Security is a fundamental issue for the exchange of medical data. (Marti et al., 2004) describes in a similar setting its security specifications 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 the mobile device (arc 2).
- HTTPS with user and server X.509 certificates between mobile device and server (arc 4) and also between servers on different system (arc 6).
- HTTPS between the service providers and the end users (element 10). Whether user X.509 certificates will be used, depends on the service offered. Typically an application communicating with a medical expert will ensure the authenticity of the client stronger.

Moreover, the content of the transmission itself is encrypted asymmetrically. The eSanaServer described in section 2.5 should not have access to the sensitive information pieces about a patient, but only be able to route the encrypted content to the subscribed services. Merely the services will then be able to decrypt the actual content.

3. Conclusion and Outlook

This paper describes the eSana framework that allows integrating a number of mobile medical applications by relying on a service oriented paradigm. As a use case, a data gathering approach is illustrated to show how data may flow from a patient using an eSanaClient over an eSanaServer to an arbitrary number of recipients that may offer services of any kind.

The data gathering process is decoupled from the usage of this data. This allows various participants to play an active role in the whole system (e.g. by providing a specialized service) without having to reinvent the wheel for each application.

The described use case is located in the second domain as laid out in the introduction. The other domains can also easily be integrated into the whole framework; the following sections outline how the first and third domain may be used.

3.1. First domain: Provide information to the patient

As can be seen in Figure 1 the arcs go from left to right, i.e. the data is sent to services over the eSanaServer and nothing comes back. In order to provide information, however, there could be services that generate information and send them to the eSanaServer. The latter collects, tags them and sends the correct information to the corresponding patients upon start-up (pull) or using another method (e.g. push via SMS).

The mechanism to pull the data upon start-up is already designed in the framework, as illustrated in Figure 3. As well as to load the newest configuration, a set of messages can be downloaded. The readability of text on a mobile device like a phone is limited, so the text may only contain a reference to the Web or a short summary of the message.

The provisioning of such a message into the system is done by message providers; a message provider may be the doctor of a patient who might send a message to his patient based on the evaluation of his medical data (e.g. “Please contact my secretary on 012/3456789 to fix an appointment, I need to talk about your actual weight”). Other providers are possible that send general information about certain conditions and where subscribed patients will receive sporadic or periodic information to their mobile phones.

3.2. Third domain: Alert patients on certain physiological parameters

The integration of this domain is even easier; an alerting mechanism is simply a service that subscribes to certain data to the eSanaServer. Once the data is received, the parameters are evaluated based on certain, parameterized by the doctor, rules. The doctor may therefore define for example: “If the glucose values of patient X of the last 5 days jumps more than 4 units, alert me via SMS and E-Mail.”

Several alerting services may be defined; one such system might be used for patients to be alerted regularly about certain events (e.g. measuring weight once a week), although this could also be done with normal calendar functionality. Such a calendar and reminder functionality is described in (Leimeister et al., 2005) in the context of reminding patients to take what medicaments.

3.3. Use of SOA paradigms

Apart from the advantages described in section 2, particularly the use of Web Services on a mobile device offers a number of benefits:

- Migration of processes to a powerful machine allows complex analysis’s to be executed from a mobile device, without having to work with constrained memory and processor resources (e.g. statistical evaluation of own medical data as illustrated in Figure 1).
- Centralized updating of business logic without the disadvantage of less optimal user interfaces (as on WAP or XHTML browsers on a mobile device).

On the other hand, there is a trade-off between the advantages mentioned and the communication overhead. Mobile devices do not offer the same bandwidth as desktops; therefore this may be a delaying factor, also depending on the size of data that the physiological parameters (in our example) produce. (Arshad et al., 2003) reduce the size of the transmitted data by employing compression.

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