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A collaborative standard-based mobile telemonitoring platform

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Abstract

Telemedicine is becoming an increasingly important approach to diagnostic, treat or prevent diseases. However, the usage of Information Communication Technologies in healthcare results in a considerable amount of data that must be efficiently and securely transmitted. Many manufacturers provide telemedicine platforms without regarding interoperability, mobility and collaboration. This paper describes a collaborative mobile telemonitoring platform that can use the IEEE 11073 and HL7 communication standards or adapt proprietary protocols. The proposed platform also covers the security and modularity aspects. Furthermore this work introduces an Android-based prototype implementation.

1 Introduction

Cardiovascular disease is one of the most common causes for deaths in Germany, representing 43% of the cases (status 2007). Statistically one out of two adults suffer from hypertonia (high blood pressure), more specifically, 44% of the female and 53% of the male population, in an age group from 18 to 79. [Jahnsen *et al*., 2008]

Hypertonia is economically one of the most important diseases in Germany, with a cost of about 8.6 billion euros in 2006 [Jahnsen *et al*., 2008].

In most cases the persons who are concerned, especially elder people, need to visit a physician, either in his or her office or in a medical center, to be examined. This scenario results in jammed anterooms and medical staff busy measuring blood pressure and the already limited healthcare resources cannot be deployed efficiently [Sufi *et al*., 2006].

In this context telemedicine is becoming a more and more important approach to this problem [Bärwolf *et al*., 2006]. By the interconnection of patients, physicians, medical centers and health insurance funds, virtual medical rounds are already reality [Bärwolf *et al*., 2006]. TEMPiS[1] is a telemedicine project started in 2005 that provides provision for apoplexy patients in Bavaria [Bärwolf *et al*., 2006].

[1] TEMPiS project, www.tempis.de
[2] I.E.M. GmbH, www.iem.de
[3] Health Level 7 Standard, www.hl7.de

Telemedicine can be used to diagnostic and treat diseases or even to prevent them [Lehmann, 2005]. A further benefit of telemedicine is distance overbridging for elderly and disabled people [Lehmann, 2005]. Besides, this approach gives them the opportunity to stay in their homes (Ambient Assisted Living) and be with their family [Sufi *et al*., 2006].

However the use of Information Communication Technologies in healthcare produces a huge amount of information that needs to be exchanged and accessed from many heterogeneous systems [Iroju and Soriyan, 2013]. The current market situation presents developers with a challenge: many healthcare device manufacturers offer complete systems (hardware and software) without considering the aspects of interoperability, since most of the available devices for vital parameter measurement use proprietary data formats and protocols [Ibánez *et al*., 2011]. As a consequence, interoperability between stakeholders (users, physicians, hospitals and other medical institutions) is barely possible.

An example is the telemonitoring system of the medical device manufacturer I.E.M. GmbH in Germany[2]. The company provides various monitoring devices, which transfer vital parameters using proprietary protocols via Bluetooth to a terminal. After that, the terminal sends the data within a SMS in PDU mode to a Short Message Service Center (SMSC). The SMSC transmits the short message to a national Remote Operating System (ROS), which forwards the information to the eHealth database server. Physicians are now able to fetch the data and manage it using the company's Hypertonia Management System (HMS Client-Server software) [I.E.M.]. Fig. 1 illustrates this data management concept.

This paper describes a model for a collaborative standard-based mobile telemonitoring platform to provide interoperability in information exchange in healthcare. Tough it is based on communication standards, the platform can also modularly adapt proprietary protocols to interconnect non-standard devices.

As a first step, a prototypic home based blood pressure monitoring scenario, from the admission of a new patient to

[2] I.E.M. GmbH, www.iem.de

data transmission, has been designed. The endpoint will be a hospital, which will store and analyze the measurements.

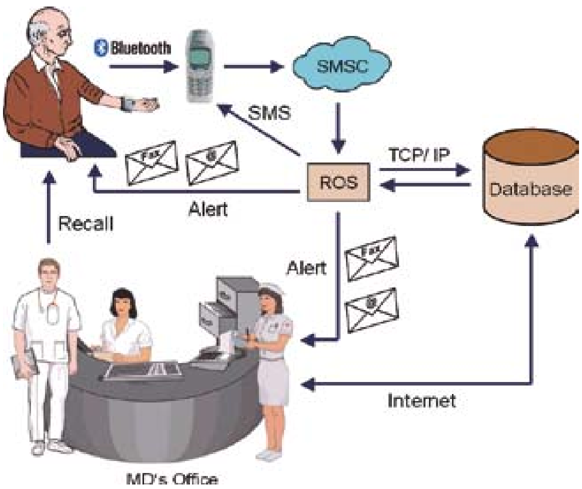

Figure 1: I.E.M. GmbH telemonitoring design [I.E.M.]

In this prototype, the mobile gateway will be a smartphone receiving measurements via Bluetooth in different data formats (proprietary or IEEE 11073) and forwarding them within an HL7[3] message to a server.

This paper is organized as follows: Section 2 describes the state of the art and introduces the technologies used for implementation. Section 3 presents the proposal for a mobile-based telemonitoring platform and its architecture. Section 4 gives a short description about the implemented features in the current version. The last section gives a conclusion of this work and some future outlook.

2 State of the art

This section presents similar telemedicine work followed by a short introduction to the technologies and standards used for this paper.

2.1 Related work

A similar approach to a mobile phone based telemonitoring platform is described in [Sufi *et al.*, 2006]. There, a telemonitoring system is presented, which uses mobiles for patients and healthcare service providers. The mobile devices run Java[TM] software and do the core communication. The system pursues a generic solution and provides different functions, like acquired biological signals submission, emergency notification, or a detection algorithm for abnormal situations. However there is no use of any healthcare communication standards as IEEE 11073 or HL7.

Another example is presented in [Ibánez *et al.*, 2011]. It suggests to put the measurement submission functions into a Residential Gateway. The data processing is unitized in OSGi[4] bundles. This system proposes a standardized telemonitoring system, which uses UPnP (Universal Plug & Play) standardized and non-standardized medical devices and the HL7 standard to transmit all gathered vital parameters. But this example does not cover any mobility or security aspects.

2.2 Technologies

This section describes the technologies used and required for implementation.

These technologies are the Android platform, the healthcare messaging standards IEEE 11073 and HL7, and the I.E.M. proprietary protocol and OSGi.

2.2.1 Android

In November 2007 Google announced the first version of an Android SDK. This was the first time when developers could implement Android applications and test them in an emulator. [Künneth, 2012]

Since then the Android platform is constantly improving and has the largest share of smartphone operating systems in the US [Llamas *et al.*, 2013].

Android applications are run on a virtual machine called Dalvik, which was designed for mobile devices and is different than typical Java runtime environments [Künneth, 2012]. Dalvik is register-based and has its own bytecode format and instruction set [Künneth, 2012]. Therefore all compiled Java bytecode must be transformed into Dalvik Executables (.dex) [Künneth, 2012].

2.2.2 Health Level 7

HL7 is a widely used standard for data exchange in clinical domains [Martín *et al.*]. In this work HL7 version 2.5.1 is used for exchanging blood pressure measurements and patient information.

An HL7 message, which is the basic data unit, is hierarchically structured and consists of segments, fields and components [Lu *et al.*, 2010]. Further, an HL7 message is generated after a specific event occurs. An event means that there is some new data available which needs to be transmitted amongst different systems [Lu *et al.*, 2010]. Another important HL7 feature is that the exchange of information needs to be done asynchronously. Following this, all relevant HL7 elements are introduced…

- Segments: A segment (see Fig. 2) is a group of fields segregated by a “<cr>”. Every segment begins with a three-character code, which identifies the segment: MSH (Message Header), PID (Patient Identification) or OBX (Observation Result). [Lu *et al.*, 2010]

```
PID|||2||Kolesnik^Maksim||1987-11-20|M
PV1||I||L|MK12910742021987
```

Figure 2:HL7 PID and PV1 Segments

[3] Health Level 7 Standard, www.hl7.de

[4] OSGi Alliance, www.osgi.org

- Fields: Fields are strings, which represent the content of a message. The strings within a field are called components. Each field has its specific order and can be optional or obligatory. These attributes can be found in the HL7 specification tables. Fields are separated by an arbitrary character (defined in MSH Segment). But the HL7 authority recommends to use "|" for field separation. Figure 3 illustrates the date of birth and patients name fields.

```
PID|||2||Kolesnik^Maksim||1987-11-20|M
```

Figure 3: HL7 Fields

- Components: As mentioned above, components are strings representing the data within a field. There can be zero or more components within a field. Its order can also be taken from the specification. Fig. 3 illustrates the patient's name field consisting of two components (first name and last name).

2.2.3 IEEE 11073

The goal of the ISO/IEEE 11073 standard is to enable interoperability and interconnection between medical devices [Martín *et al*.]. Therefore it provides a set of different device specializations for any kind of medical devices like 11073-10407 for blood pressure monitors. However there are hardly monitoring devices implementing the standard *[Ibánez et al*., 2011].

2.2.4 I.E.M. blood pressure monitor protocol

The Android application discussed in chapter 4 has the ability to process blood pressure measurements gathered by the Stabil-O-Graph (see Fig. 4) blood pressure monitor. The device was manufactured by I.E.M. GmbH and uses a proprietary protocol to exchange information.

Figure 4: Stabil-O-Graph blood pressure monitor

After a successful measurement the following parameters are transmitted: Systolic value, Diastolic value, Heart rate, time of acquisition, time when the measurement was transmitted and the serial number of the device.

2.2.5 OSGi

OSGi is a component-oriented framework for networked devices. Deploying the framework gives the ability to manage the lifecycle of a software component (bundle) (install, uninstall, start, stop) remotely. [OSGi Alliance, 2007]

There are a few different OSGi frameworks available. For this work Apache Felix[5] OSGi will be used.

There are a few steps that need to be done before Felix can be started in Android, as Android does not run a standard Java Virtual Machine but a special Virtual Machine called Dalvik [6]. Dalvik cannot deal with Java Bytecode but with a special format called DEX [Apache, 2009] so any classes within a Jar bundle need first to be formatted into DEX files.

3 Design of the mobile telemonitoring platform

The goal of this work is to design a telemonitoring system where the central component is a smartphone gateway. The advantages of such a system are wireless data transmission, mobility and interoperability due to the fact that we can implement the wireless-based proprietary protocols and healthcare standards introduced in section 2.2.

3.1 Architecture

The architecture shown in Fig. 5 uses a mobile gateway, which will permanently receive measurements, save them temporarily and send an HL7 message to any given health data server within a medical center. The measurements can come from telemonitoring devices compliant with the IEEE 11073-X protocols, but also from devices with proprietary protocols and from other type of home-located or personal devices like biometric or AAL sensors.

Using mobile devices gives also the patient more mobility and freedom as both the monitoring device and the gateway can be carried anywhere. Many modern smartphones can transmit the collected measurements both via WiFi or via cellular networks. This is an important feature if a patient, for example, needs to be monitored around the clock (mobile ECG).

A major issue, especially for elderly patients, is to reach a good acceptance of the platform by considering several aspects of usability. In this scenario, a tablet that provides a user-friendlier graphical interface could also replace the smartphone.

Implementing well-known healthcare standards makes this telemonitoring system very flexible and interoperable since any wireless medical device can be used. It is also possible to transmit the information to any medical facility if their systems are able to manage Health Level 7 Messages.

Once the data has been stored persistently, physicians or care service staff can access and evaluate the measurements.

[5] Apache Felix OSGi Framework, http://felix.apache.org
[6] Dalvik Technical Information, http://source.android.com/devices/tech/dalvik

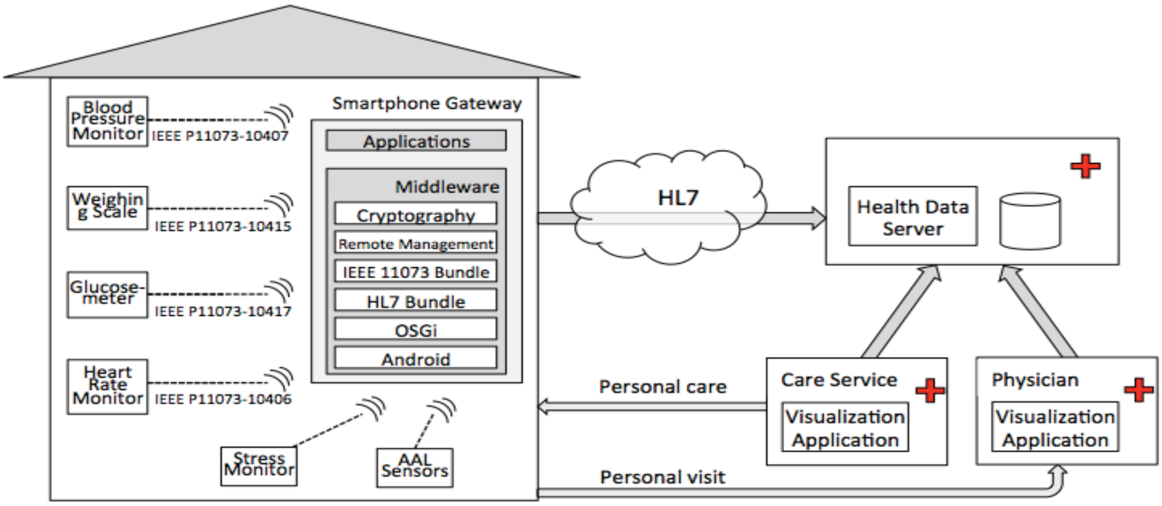

Figure 5: Telemonitoring platform design

Therefore, a mobile visualization application will be developed. This ensures the permanent access to health information for medical staff either at the patients home or at the physician's office.

3.2 Security

The collected patient information is very sensible and needs to be protected. It is very important that a patient or its address cannot be identified by the collected data [Fong *et al.*, 2011].

In general, security is characterized by the following concepts:

- Integrity: The information should stay in its original form.
- Privacy: Only authorized personal can access the data.
- Confidentiality: All critical information must be handled with confidence.
- Availability: The system must be available all the time.

Hence we need to apply security at patients home (Bluetooth data transfer, secret PIN usage for device pairing process), cryptography and certificates for secure information exchange from gateway to health data server and within medical centers (unauthorized access, health data manipulation).

Furthermore, we need to deal with problems like loss of mobile devices containing critical information, electricity failures or fire [Fong *et al.*, 2011].

4 Current Status

In the context of a Bachelor Thesis a first version of a prototype has been implemented. Figure 6 shows the available features. This system provides a module for parsing proprietary protocols developed by I.E.M. GmbH. The current version implements only the Stabil-O-Graph protocol.

For this implementation we decided to use an Android smartphone running API level 14 (Ice Cream Sandwich) and above. This requirement must be fulfilled since older Android APIs do not implement the IEEE 11073 Bluetooth Profile[7], which will be used in an advanced version of the application. During the implementation process a Samsung GT-N7100 Smartphone was used (1.6GHz Quad-Core Processor, 2GByte RAM). Another benefit of using Android is that it is based on the widely used programming language Java and therefore it is possible to deploy OSGi bundles.

The following sections describe the workflow from the addition of a new patient to the transmission of blood pressure measurements to a file server.

4.1 Application Features

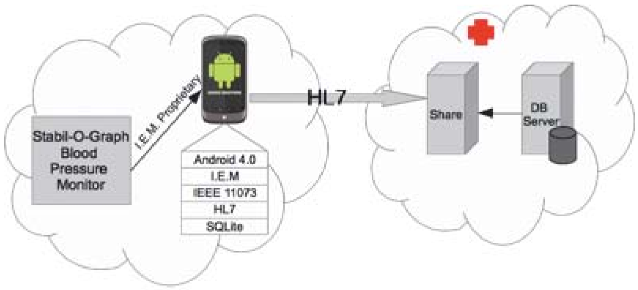

Figure 6: Prototypic Android monitoring application

Before starting the monitoring process, a new patient needs to be acquired (see Fig. 7).

[7] Android BluetoothHealth profile, developer.android.com /reference/android/bluetooth/BluetoothHealth.html

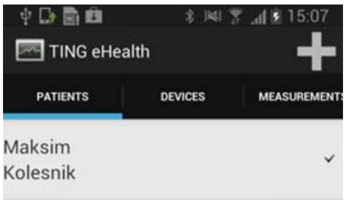

Figure 7: Selected patient

In order to generate an HL7 PID segment, the following information is needed: first and last name, date of birth and gender. The next step is to assign monitoring device. This can be done by selecting them from a list of all paired and available devices. Another click on the device will start an Android Service[8] (see Fig. 8).

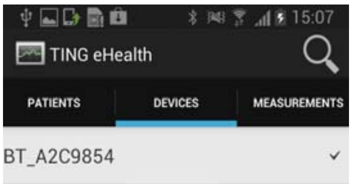

Figure 8: Selected devices

The service now runs in the background and waits until a new measurement is available. After the measurement has been successfully received, it will be temporarily stored in an SQLite database (see Fig. 9). Otherwise the data would be lost if no connection with the file server could be established. The last step is to generate an HL7 message (see Fig. 10), containing all measurements and patient information, and upload it to a file server.

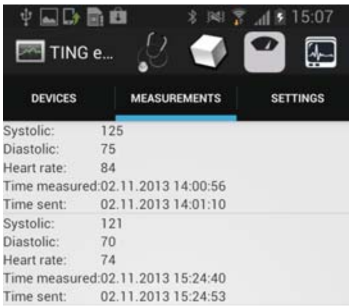

Figure 9: Received measurements

```
MSH|^~\&|AndroidMonitor|Reutlingen-University|SomeShareServer|
SomeHospital|2013-11-06 21:58:43.958||ORU^R01^ORU_R01|||2.5.1|||||
DEU|UNICODE UTF-8
PID|||2||Kolesnik^Maksim||1987-11-20|M
PV1||I||L|MK12910742021987
OBX|1|CE|8480-6^Intravascular systolic^LOINC||111|8480-6^mm
HG^LOINC|||||||2013-11-06 21:59:11||||61102X4K
OBX|2|CE|8462-4^Intravascular diastolic^LOINC||68|8462-4^mm
HG^LOINC|||||||2013-11-06 21:59:11||||61102X4K
OBX|3|CE|8867-4^Heart rate^LOINC||58|8867-4^/min^LOINC|||||||
2013-11-06 21:59:11||||61102X4K
```

Figure 10: Generated HL7 Message

[8] Android Started Service, http://developer.android.com/guide/components/services.html

5 Conclusion and future work

A mobile-based telemonitoring platform concept and a prototypic implementation have been introduced. To face the interoperability problem, the platform complies with the presented well-known healthcare standards IEEE 11073 and Health Level 7. The system is also able to deal with proprietary protocols developed by I.E.M GmbH and receive measurements from all their monitoring devices. Google's mobile operating system Android was equipped with Bluetooth Profile in the version 4.0 and is a good choice for an interoperable gateway because it supports both the needed wireless communications and the modular execution environment OSGi.

In future work the functionality of the application will be extended. At this point only a parser for the Stabil-O-Graph blood pressure monitor has been developed. Beyond that, some security techniques like cryptography and certificates must be implemented. But there are also a lot of non-technological issues that must be researched in future. Aspects like acceptance or usability are very important for both sides of the target audience, namely patients and physicians.

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