A Ubiquitous Personal Health Record (uPHR) Framework

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Abstract - Personal Health Record (PHRs) represents the entities in a medical community and is readily used by the medical community to store and share individual medical data in an electronic format. The PHR consists of the individuals' electronic medical record provided by health care practitioners as well as personal information entered in by the individual. PHRs currently exist within various domains and health information systems. Currently there are several medical sensor devices, standards, and health record formats, which have been integrated with PHR without emphasis to standard. Thus, in this paper we proses a framework, where it emphasizes the implementation of standards for data acquisition, storage and transmission in order to maximize the compatibility among disparate components, e.g. various PHR systems. Data from mobile biosensors is collected on a smartphone using the IEEE 11073 standard where possible; the data can be stored in a PHR on the phone (using standard formats) or can be converted in real-time into more useful information in the PHR, which is based on the International Classification for Primary Care (ICPC2e). The phone PHR data or information can be uploaded to a central online database server using both the WiFi or GSM transmission protocol and the Continuity of Care Record message format (CCR, ASTM E2369). In other words, our goal is to integrate remote monitoring from wearable medical sensor devices to PHR system accessible from anywhere, anytime.

Index Terms - Ubiquitous, Personal Health Records, IEEE 11073 Standards, Biosensors, Context Awareness, Mobile Application

1. Introduction

Currently there are several medical sensor devices, standards, and health record formats, which is confusing. Also, monitoring of physiological events in healthcare facilities has limitations: 1) failure to sample rare events; 2) failure to measure physiological responses during normal periods of activity, rest, and sleep; 3) brief periods of monitoring cannot capture rhythmic variations in physiological signals.

But the use of biosensors outside of healthcare facilities is growing and is useful[1]. To routinely implement systems including biosensors, standards should be a necessity. There are several standards organizations which have created numerous applicable or partially applicable standards. However, actual implementation is lagging behind. Numerous publications have described implementations of systems with mobile or static biosensors for personal use, home use, wellness monitoring, etc., but few of them have mentioned standards for data acquisition, storage or transmission.

Some examples can illustrate the point.
- AlarmNet[2,3] in Virginia, USA, is an example for assisted living and residential monitoring. AlarmNet integrates environmental, physiologic, and activity sensors in a scalable architecture. Standards: not mentioned
- Berkely Tricorder[4] is a wearable health monitoring device capable of measuring a subject's electrocardiogram (ECG), electromyography (EMG), blood oxygenation, respiration (via bioimpedence), and motion. Standards: not mentioned
- CodeBlue[5] is a wireless infrastructure intended for deployment in emergency medical care, integrating low-power, wireless vital sign sensors, PDAs, and PC-class systems. Standards: not mentioned
- Stream query processing for healthcare bio-sensor applications, provides an overview on a DSMS (D.. S.. M.. S..) prototype called T2[6]. T2 has been applied to monitoring and analyzing electrocardiogram (ECG) data streams, arriving via wireless networks from mobile subjects wearing ECG sensors. Standards: not mentioned.
- Intelligent Mobile Health Monitoring System (IMHMS) provides medical feedback to patients through mobile devices based on biomedical and environmental data collected by sensors. It comprises a Wearable Body Sensor Network, Patient's Personal Home Server and Intelligent Medical Server. Standards: not mentioned
- MobiHealth project [7,8,9] built a system for [10,11,12] monitoring crucial health signals through tiny medical sensors and transmitting them to healthcare professionals through powerful and cheaply available wireless systems. Standards: not mentioned
- OpenHealth[13], is a research project for development solutions of eHealth inside of mobile environments, this solutions are based on the management wireless biomedical devices in Body Area Networks (BAN) under the IEEE standards and Open Mobile Terminal Platform. This project implements the main components of the ISO/IEEE 11073-20601 standard; Domain Information Model; Service Model and Communication Model, with the goal of to transform the information in a interoperable format than permit the information exchange and communication between Agents and Manager.

All these projects are focused on addressing remote healthcare monitoring, but only OpenHealth clearly implements standards (IEEE 11073). Hence there is still room for more development on existing related frameworks like Openhealth and Open Health Framework (OHF) (Which the goal of the OHF is to extend the Eclipse Platform to create an open-source framework for building interoperable, extensible healthcare systems e.g electronic health records (EHR).

There for in this paper, we proposed a framework base on standards-compliant and customization of different devices and sensors to be integrated with mobile PHR systems.

2. Overview of uPHR Architecture

Fig 1 is our proposed uPHR architecture based on the literature reviews. It consist of a Medical Device (MD) e.g wearable sensors including built in phone camera sensor, that collect data from user/patient via Bluetooth health device profile (HDP) and sends the patient's biomedical parameters, to a Host System (HS) that stores the collected information. The HS may be a Hospital Information System or a PHR, among others. However, since there are usually several MDs in a relatively small area, our architectures include a third element, namely the Concentrator Device (CD), a device (e.g. smartphone, personal computer, personal health appliance, tablet) which gathers the information from the different MDs and forwards it to the HS. A Telehealth Service Center (TSC) can be the interface to the main HS, e.g. a Web site for an online database. The HS may share medical information with others (Third-Party Host Systems –TPHS, or Consultation System -CS).
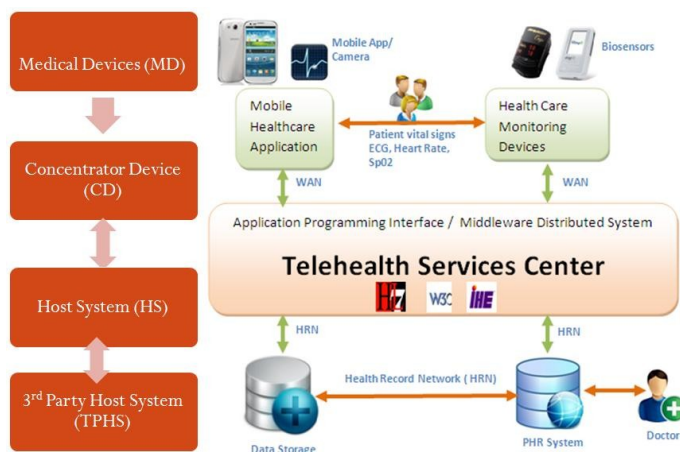

Fig 1: Overview of uPHR ARCHITECTURE

In overview interoperability is both a prerequisite and an enabler for versatile, integrated, efficient and useful communication between MDs and HSs in the context of comprehensive and high quality uPHR services. Standardization of this communication flow is a crucial factor in achieving interoperability. Various standards, protocols and integration initiatives aimed at promoting the creation of end-to-end standard-based interoperable uPHR services have emerged in recent years, including standards for medical device interoperability (MDI) (i.e. MD-CD interface), standards for the interoperable exchange of EHRs (i.e. HS-TPHS interface), integration initiatives for the coordinated use of these standards (i.e. CD-TSC-HS or CD-HS interfaces).

A. Medical Device Interoperability (MD-CD interface)

In this section we highlight and reference inclusion of MDI in fig. 1 as follows;
- Point-of-Care Connectivity [14]
- Medical Information Bus (MIB) also called IEEE P11073 [15].
- INTERMED (ENV13735) [16]
- Vital Signs Information Representation (VSIR), usually called VITAL (ENV13734) [17]
- ISO/IEEE11073 Point-of-Care (X73PoC) [18,19]
- Medical Device – Integrated Clinical Environment Manager (MD-ICEMAN) [20]

These attempts were not really adopted, but they helped to establish the base in the medical device interoperability arena. Finally, the ISO/IEEE11073 Personal Health Devices standard (X73PHD)[21,22] emerged in 2008. The X73 standards, where originally intended for bedside monitoring in hospital environments, to wearable, multi-sensor monitoring systems designed for home healthcare.

Standards also govern communications among EHRs and PHRs. Message format standards include
- ISO/EN13606 standard[23] represents the information in an EHR in an XML format.
- Health Level 7 (HL7)[24], version 2.x (the most widely used) represents information in a simple text structure of segments and fields.
- Continuity of Care Record (CCR - ASTM E2369-05).

B. Exchange of Electronic Health Records (HS-TPHS interface)

An EHR concept defined as a systematic collection of electronic health information about individual patients or populations; Although, Personal Health Records (PHRs) have been steadily growing as an addition to EHRs. The key distinction between a PHR and an EHR is that the individual who is the subject of the record is the key stakeholder determining content and possessing rights over that content. An example of PHR is Google Health, which has recently given up on the same endeavor for some reasons.

C. Integration initiatives (at the CD-TSC-HS interfaces)

Several Referring again to Fig 1, which standards are appropriate for which sections? Several major players in the field - IHE[25,] Continua [26,27], HITSP [28] and Microsoft [29] – have joined to suggest the following:
- MD-CD. This interface uses X73PHD.
- CD-TSC. This interface uses X73PHD nomenclature, Web Services Interoperability (WS-I)[30] as transport technology and the IHE Device to Enterprise Communication profile (DEC, also called Patient Care Devices-01, PCD-01[31]), using HL7 v2.6 for messaging purposes.
- TSC-HS. This interface uses the IHE Cross-Enterprise Document Reliable Interchange (XDR) profile[32] as a means of establishing communication. Data encoding is based on the HL7 Personal Health Monitoring (PHM) Report document format[33], which in turn is based on the HL7 Clinical Document

Architecture (CDA)[33].

The question remains, which of the above can be applied or would be appropriate for a PHR system using cellphones or smartphones both as data collection (CD) devices and as PHR (HS) holders?

3. A Proposed uPHR Framework Based on x73phd

A detailed description of the X73PHD standard can be found in[22]. Thus, in this section an extended description of the structure and the key elements in the process of communication between agents/MDs and managers/CDs is presented from fig 1 based on X73PHD. The X73PHD standard defines the reference model according to a well-defined object-oriented paradigm that guarantees extensibility and reusability through three different models e.g Domain Information Model (DIM), Service Model and Communication Model.

Illustrated in Fig 2 below is our block diagram representation of our uPHR framework, elaborating more technical components/detailed as not shown in Fig 1 (uPHR model architecture above). The framework consists of a server and multiple small, inexpensive battery-powered devices that lack much in the way of displays and other user interfaces, including built-in smartphone camera (sensor). Our framework consists of a mobile healthcare device/application and one or more body sensor e.g finger Pulse Oximeter and body sensor nodes. As shown in Fig.1, there are two categories of device specializations: x.73 (10404) sensors may include Heart Rate and SpO2, while x.73 (10406) may include ECG to measure serious heart conditions (vital signs). At the moment the X73PHD has not defined any device specialization for built-in smartphone camera for monitoring heart rate. Hence we propose device specialization for the Built-in smartphone camera sensor as our contribution.
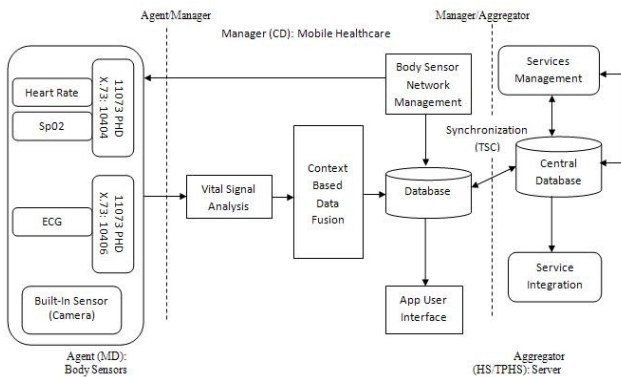

Fig 2: Proposed uPHR Framework

Biosensors involved here, perform data collection, preprocessing, and wireless transmission to the Mobile Healthcare. We use smart phone application as Manager, including its built-in camera sensor. It receives data from sensor nodes via Bluetooth, with option to do the same from the built-in camera and communicates with the server through readily available communication network in rural areas such as 3G, GPRS & WiFi. In collecting data from biosensors, we contribute our architecture by applying/implementing a solution for the first problems mentioned in the Introduction – lack of standards. Here are some biosensors that our application prototype will support;

- Nonin Onyx II 9560 Pulse Oximeter.
- CardioCare ECG monitor
- Built Smartphone Camera Sensor

Two categories of sensor data are processed in the Mobile Healthcare by two modules: vital signal processing and context data from the phone capabilities such as recording geographic location e.g GPS. For example, ECG data will be processed to reduce the noise and reform the baseline from disturbances, and then to identify and locate the QRS complex, and finally locate the ST segment. By these highlighted processes, heart rate and ECG waveform morphological changes will be evaluated respectively. Furthermore we intend to employ heart rate variably (HRV) mobile-based analysis, as previous research applied ICT driven framework at computer-based level of analyzing HRV. Meanwhile, activity types are classified and activity intensity is calculated using accelerometer data. Context-based fusion of ECG processing results and activity information will be able to estimate heart status. This brings us to another problem – deriving information from the sensor device. Our solution is to store ECG data in standard formats such as HL7 aECG[32] or SCM-ECG[32]. Again, relatively few of the devices on the market seem to use either of these. But one can bypass these standards with a decision to not store the raw data, as it would take alot of space and would not be comprehensible to a normal PHR user. Instead, the relevant information can be derived from the data and stored.

The "Nonin" sensor can provide heart rate (as intensity changes), changing over time, and SpO2, also changing with time.

The phone camera can provide heart rate as light intensity changes over time following the sequence of data flow as below; Select Quadrants of Video, Split the pixels to Red-Green-Blue (RGB), Compute Red Intensity of Frames, Raw Intensity, Smooth data moving average filter, Split data into windows of time or reduce window size when no proper data, then finally count peaks from one window slice.

Because heart rate changes with time, activity level, stress level, etc., it is more useful to derive the parameters listed above to describe the rate and its variation. Other parameters such as SpO2 are often presented as simple numbers and do not require further processing.

There is a local database in the smartphone /sdcard and a central database in the server (HS). The local database/cache stores the sensor data and processing results. Abnormalities detected will be accompanied by original ECG waveform, activity information, and time stamp. The local database also stores personal profile of the individual, the system parameters of sensor nodes, and the settings of the smartphone app, for example, warning threshold, warning event definition, etc.

There is a body sensor network management module in the manager (CD), which is a simple version of a middleware to monitor the status of the sensor nodes (shown in Fig. 2). The parameters of those sensor nodes, including sampling rate and communication protocol parameters in the local database/cache, are updated regularly through Bluetooth communication. The sensor nodes will be reset if there is any parameter change in the local database. That change may be the result of interactive function of "setting" by the user or database synchronization with the central database. On other hand, the event of battery level changes will drive the local database/cache update, and consequently the central database update as well. When the battery level reaches the threshold, a warning message will be sent to the user. Warning on the event of abnormalities is triggered the same way. There is a database entry defining a warning event. The parameters include the name of the abnormality, the function that detects the event, the threshold, the action, the destinations of the message to be sent, and the message and data items to be sent, etc. When the abnormality is detected, or the output of the detection function reaches the threshold, the event is triggered.

4. Conclusion

We started by emphasizing the need for Framework" to adopt PHR integration, including biosensors and built-in phone camera, which can be used in remote monitoring. At the same time we emphasized the need for interoperability in the paradigm of applying Information Technology to Health assistive technology and finally adopt international standards for data acquisition, storage and transmission, in order to be compatible with existing (or future) health infrastructure. Our emphasis is on mobile health and mobile biosensors, and after reviewing various standards we have found the IEEE 11073 PHD standard to be the most appropriate for data acquisition, although to implement it we must still customize connections to individual sensor devices. Our decision to derive useful and comprehensible (to the normal user) parameter values from raw sensor data streams allows us to avoid the problems of storage and transmission of large quantities of data, especially important in developing countries. Our phone-based PHR uses the ICPC2e standard for its vocabulary, and the CCR standard for communications with central, online PHR databases and systems. Thus, we hope to help people in rural, less developed regions benefit from health monitoring with biosensor systems which are available and affordable.

References and Notes

[1]   P. Binkley, W. Frontera, D. Standaert, et al. predicting the potential of wearable technology: Physicians share their vision of future clinical applications of wearable technology [J]. IEEE Engineering in Medicine and Biology Magazine, (2003), 22(3): 23 – 27.

[2]   J. Stankovic, G. Virone, et al. Context-aware wireless sensor networks for assisted living and residential monitoring [J]. IEEE Network, (2008), 22(4): 26 – 33.

[3]   L. Tarricone, M. Zappatore, et al. A framework for context-aware home-health monitoring [J]. International Journal of Autonomous and Adaptive Communications Systems, (2010), 3(1): 75– 91.

[4]   R. Naima, J. Canny. The Berkeley tricorder: Ambulatory health monitoring[C].Proceedings of the 6th International Workshop on Wearable and Implantable Body Sensor Networks. Los Alamitos: IEEE Computer Society, (2009): 53 – 58.

[5]   D. Malan, TRF. Fulford-Jones, M. Welsh, S. Moulton: CodeBlue: An Ad Hoc Sensor Network Infrastructure for Emergency Medical Care. Proceedings of the MobiSys 2004 Workshop on Applications of Mobile Embedded Systems (WAMES 2004) (2004), 12-14.

[6]   H. Agrawal, M. Cochinwala, et al. Stream Query Processing for Healthcare Biosensor Applications . International Conference on Data Engineering - ICDE , pp. 791-794, (2004).

[7]   M. Fraser. Biosensors: Making sense of them. Medical Device Technology, 5(8):38-41, Feb (1994).

[8]   S. K. S. Gupta, S. Lalwani, Y. Prakash, E. Elsharawy, and L. Schwiebert. Towards a propagation model for wireless biomedical applications. IEEE International Conference on Communications (ICC), 3:1993-1997, May (2003).

[9]   S. P. J. Higson, S. M. Reddy, and P. M. Vadgama. Enzyme and other biosensors: Evolution of a technology. Engineering Science and Education Journal, pages 41-48, Feb (1994).

[10]   R. Lappalainen, T. Tuomisto, T. Koobi, V. Pentikainen, M. Tuomisto, and V. Turjanmaa. Terva: wellness monitoring system. Engineering in Medicine and Biology Society, 20th Annual International Conference of the IEEE, 4(29):1988-1991, Oct (1998).

[11]   C. Otto, and E. Jovanov. Wireless sensor networks for personal health monitoring: Issues and an implementation. Computer Communications (Special issue: Wireless Sensor Networks: Performance, Reliability, Security, and Beyond), Elsevier, 29(13-14):2521-2533, Oct (2006).

[12]   M. van Gils, T. Tuomisto, R. Lappalainen, and I. Korhonen. Wireless wellness monitor for personal weight management. Information Technology Applications in Biomedicine, IEEE EMBS International Conference, pages 83-88, Nov (2000).

[13]   http://openhealth.morfeo-project.org/, Last accessed: July, (2012).

[14]   POCT1-A2, Vol. 26 No. 28, Replaces POCT1-A, Vol. 21 No. 24, Point-of-Care Connectivity; Approved, Standard—Second Edition, Clinical and Laboratory Standards Institute, CLSI (2006).

[15]   MIB, "Medical Information Bus. Standard for Medical Device Communications. Framework and Overview," ANSI/IEEE Standard 1073.(1996).

[16]   INTERMED, "Health informatics – interoperability of patient connected medical devices," CEN/TC251- ENV13735. (1999).

[17]   VITAL, "Health informatics – Vital signs information representation," CEN/TC251 - ENV13734. (1999).

[18]   ISO/IEEE11073, "Health informatics. Point-of-care medical device communication (x73-PoC). Part 1.MD Data Language (MDDL)." http://www.ieee11073.org/ First Edition : (2004).

[19]   ISO/IEEE11073, "Health informatics. Point-of-care medical device communication (x73-PoC). Part 2. MD Application Profiles (MDAP)." http://www.ieee11073.org/ First Edition : (2004).

[20]   ISO/IEEE11073, "Health informatics. Point-of-care medical device communication (x73-PoC). Part 3. Transport and Physical Layers." http://www.ieee11073.org/ First Edition : (2004).

[21]   R. M. Hofmann, "Modeling medical devices for plug-and-play interoperability," MSc, Dept. of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, (2007).

[22]   ISO/IEEE11073-00103, "Health informatics. Personal Health Devices communication (x73-PHD). Technical report - Overview."

[23]   ISO/IEEE11073-104zz, "Health informatics. Personal Health Devices communication (x73-PHD). Device specializations."

[24]   ISO/IEEE11073-20601TM-2008, "Health informatics. Personal Health Devices communication (x73-PHD). Application profile-Optimized exchange protocol."

[25]   ISO/EN13606 CEN/TC251, "Electronic Healthcare Record (EHR) Communication. Standard Parts 1-5," (2004) (1st Ed.).

[26] HL7. Health Level Seven. Devices Special Interest Group. Available:http://www.hl7.org/Special/committees/healthcaredevices/index.cfm. Last accessed: March, (2011).

[27] Device to Enterprise Communication (DEC) Profile PCD-01. IHE-PCD Technical Committee. Available: http://wiki.ihe.net/index.php?title=PCD_Profile_DEC_Overview. Last accessed: March, (2011).

[28] F. Wartena, et al., "Continua: The Impact of a Personal Telehealth Ecosystem," in International Conference on eHealth, Telemedicine, and Social Medicine (eTELEMED), pp. 13-8, (2009).

[29] R. Carroll. "Continua: An Interoperable Personal Healthcare Ecosystem." pp. 90-4, (2007). Available: http://doi.ieeecomputersociety.org/10.1109/MPRV.(2007).72

[30] RMON IS-77, "Remote Monitoring Interoperability Specification," RMON IS 77 20081218 V1.0.

[31] Microsoft Health Solutions Group. HealthVault. Available: http://www.healthvault.com/. Last accessed: March, (2011).

[32] HL7. Personal Healthcare Monitoring (PHM) Reports. Available: http://www.hl7.org/special/Committees/projman/searchableProjectIndex.cfm?action=edit&ProjectNumber=209.Last accessed: March, (2011).

[33] HL7. Clinical Document Architecture (CDA). Available: http://www.hl7.org/implement/standards/cda.cfm. Last accessed: March,(2012).