

Towards e-Health Device Interoperability: The Spanish Experience in the Telemedicine Research Network

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Abstract—The expansion of e-Health solutions is hindered by the high costs and low flexibility of home and mobile telemonitoring systems. This situation may be improved by the use of standards to design open, plug-and-play and interoperable devices. This work describes the joint efforts of three research groups in Spain towards the interoperability of their telemonitoring solutions based on the ISO11073 / IEEE1073 family of standards.

I. INTRODUCTION

HOME telemonitoring has experienced an important growth in the past years, and nowadays it has proved its efficiency as a follow-up option in scenarios such as chronic disease management, home hospitalization, follow-up after ambulatory surgery and elderly patients' care. Mobile telehealth solutions are expanding the limits of telemonitoring, allowing patient follow up while they carry out the activities of their daily living [1]-[3].

The main barriers for a wider adoption of home telemonitoring are: 1) difficulty to integrate telemonitoring in routine patient management workflow 2) poor usability and 3) high costs. The reasons for high costs are mainly acquisition cost (devices are costly) and maintenance costs, usually pushed up by the need for visits to the home for installing / reconfiguring and replacing the devices [4].

We claim that interoperability can be the keystone for breaking these barriers as it can decrease costs, increase system usability and facilitate the integration of telemonitoring information in the Electronic Healthcare Record (EHR).

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We foresee a picture where devices such as a wireless pulse-oximeter or sphygmomanometer can easily be added to and removed from a Personal Area Network (PAN) to configure a customized telemonitoring solution. This PAN is fully *plug-and-play* and there is no need for difficult configuration of devices or technical people troubleshooting installations at the home. Within this scenario the service managers have the chance to replace a medical device, which can be manufactured by different providers, without the need for fully replacing the whole telemonitoring solution. Medical devices can be used with different *gateways* (i.e. a Personal Digital Assistant (PDA) or a mobile phone), depending on network availability and costs at the patient location. In this ideal situation, both acquisition and maintenance costs can be reduced and usability of the system is noticeably increased. All information received from the patient is seamlessly integrated into his/her EHR, and handy to any authorized health professionals who may need it.

It is plain that this picture is far from today's state of affairs in telemonitoring, and the work towards this goal is full of difficulties [5]. In this context and inside the Spanish networked research project, "Telemedicine Network" [6], three research groups from different Universities have joined their efforts to develop an end-to-end modular and interoperable telemonitoring solution, based on standards and valid for both mobile and home telehealth.

II. METHODOLOGY AND EXPERIENCES

The main advantage of this collaborative research comes from the fact that all three groups had worked before in mobile telemonitoring, but followed different approaches. The goal of the joint research effort presented in this paper is to re-design these previous systems to achieve a common technical solution, as generic as possible and based on standards that can then be adapted (customized) to the use cases addressed by each group.

Figure 1 shows a summary of these three previous systems. Their main features are described later.

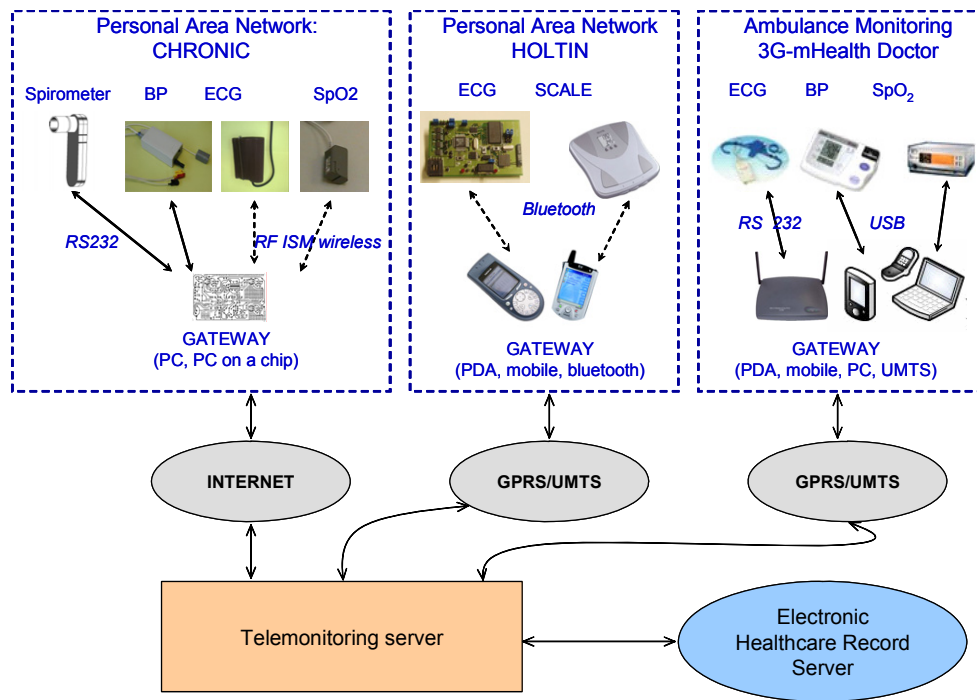


Fig. 1. Current experiences in home and mobile telemonitoring.

- Experience #1.** CHRONIC system [4] is used for disease management in chronic respiratory patients. It is a complete solution that includes call centre, applications for patient, case manager and specialist doctor as well as for professionals doing home visits. Its home telemonitoring system is based on a personal computer (PC) with the look of a videotape recorder that can be handled with a remote and a television as user interface. It is used to perform for spirometry (FVC, FEV1 and flow volume curve), one-lead electrocardiography (ECG), pulse-oximetry and blood pressure measurement. These devices are connected to the PC, which acts as a gateway, by cable or wireless communication, using the industrial scientific and medical band. System users are chronic obstructive respiratory disease patients during exacerbation episodes, who perform one telemonitoring session every day. Results are immediately transmitted to a management centre where they are available for case manager and specialist doctors.
- Experience #2.** HOLTIN [7] is a telecare system for a single patient with chronic cardiovascular disease that allows the patient to be completely mobile and carry on a normal life. The patient wears a light Intelligent Holter (HOLTIN) with low power consumption and automatic cardiac event detection that can acquire up to three ECG signal leads. When a cardiac event occurs, the data are sent from the Intelligent Holter to the patient's mobile phone through Bluetooth wireless technology. The phone, which runs an application, acts as a gateway and transmits the data to a telemonitoring server using a GPRS connection. The telemonitoring server allows visualization of the ECG signals and registers them following the SCP-ECG standard [8],[9]. On the other hand a home system for a single patient concerned with his weight which wants to be controlled by a health/diet professional has been designed.

The system includes a weighing scale based on Bluetooth and an access point as a gateway. This access point can be customized in other home telehealth scenarios for including other vital signs monitoring devices as well.

- Experience #3.** 3G-mHealth Doctor [10] is an enhanced mobile healthcare multi-collaborative system, operating over Third Generation (3G) mobile networks in different medical and critical emergency scenarios, supported by Universal Mobile Telecommunications System (UMTS). It is designed to facilitate communication between healthcare personnel with medical specialists in a remote hospital. The system architecture is based on advanced signaling protocols that allow multimedia multi-collaborative conferences in IPv4/IPv6 3G scenarios. The system offers real-time transmission of medical data (ECG, blood pressure, pulse-oximetry) and videoconference, together with other non real-time services. It has been optimized specifically to operate over 3G mobile networks using the most appropriate codecs.

From these previous experiences, our aim is to create an integrated telemonitoring platform. This integration effort should build on previous work devoted to interoperability in the medical device field. The ISO11073/IEEE1073 (known as X73) set of standards for Point of Care Medical Device Communication is the best-positioned international standard to provide interoperability with different sensors [11]. The X73 standard, currently in the development phase, is a single set of standards for complete connectivity among medical devices that contribute plug-and-play, transparency, and ease of use and configuration. X73 extends to the seven levels of the Open System Interface (OSI) protocol stack and absorbs EN 13734 (VITAL) [12] for the upper layers,

EN 13735 (INTERMED) [13] for the intermediate layers, and the older 1073 standards (1073.3 and 1073.4) for the lower layers. Thus, it gives a full solution from the cable itself and connector, to abstract representation of information and services. X73 distinguishes four main standards groups: transport (e.g., wireless or cabled), services of general application (e.g., for events or polling), device data (e.g., object-oriented model and representation terminology), and network communication standards (e.g., gateway between the representation of data and IEEE1073, DICOM, or HL7 messages). A review of the X73 family has been carried out by the three research groups in [14].

Although initially devoted to the Intensive Care Unit and Hospital field, these standards are being adapted for their use in out-of-hospital environments, such as home telemonitoring. In recent years, it is more common to find wireless, portable or wearable devices based on Bluetooth, Zigbee, or other RF technologies. X73 standardization on this equipment implies heavier communication protocols and higher energy consumption. Nowadays, there are several ISO/IEEE working groups devoted to this task and new documents will be produced in relation to wireless RF communications [15]. Likewise, inside this high level of international participation, our three research groups, supported by Convenor of the CEN TC251/WGIV, are working on a new X73-Use Cases proposal based on RF wireless protocols.

III. SYSTEM SPECIFICATION AND DESIGN

The goal of the system design is to provide a telehealth solution consisting of a set of wired or wireless sensors (ECG, spirometer, sphygmomanometer, pulse-oximeter, etc.) connected to a gateway acting as a Medical Device System (MDS) as defined by X73. Figure 2 shows this design with reference to the Domain Information Model (DIM) established by X73 [16]. We think of this MDS as a set of software modules that can be run on different physical gateways (cellular phone, PC, PDA), shaping a X73-compatible gateway, a common platform that can be personalized and used in each one of all the possible scenarios.

Our current challenge is to modify the existing independent telemonitoring solutions, Figure 1, and transform them into a fully standards-based prototype made of independent interoperable modules as depicted in Figure 3, and complement it with a module for storing information in the EHR also in a standard format.

This design will support a network of X73-compatible devices measuring vital signs from different patients in different locations. The user/provider is free to choose all the sensors and the gateway between all the X73 products that the market can offer at this time, and can also mix components from different manufacturers according to his preferences in make, quality, price, etc.

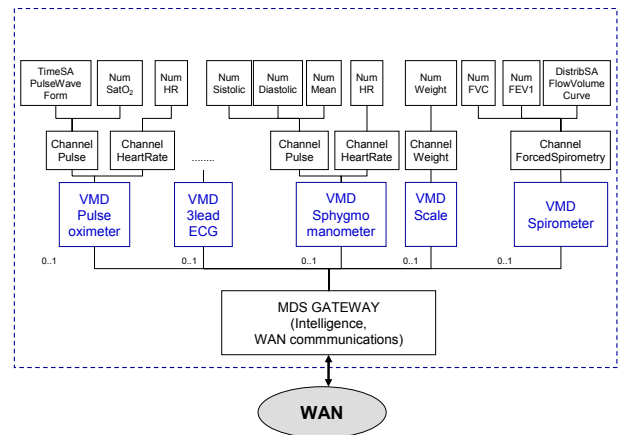


Fig. 2. Systems components as related to X73 Domain Information Model for the Medical Package.

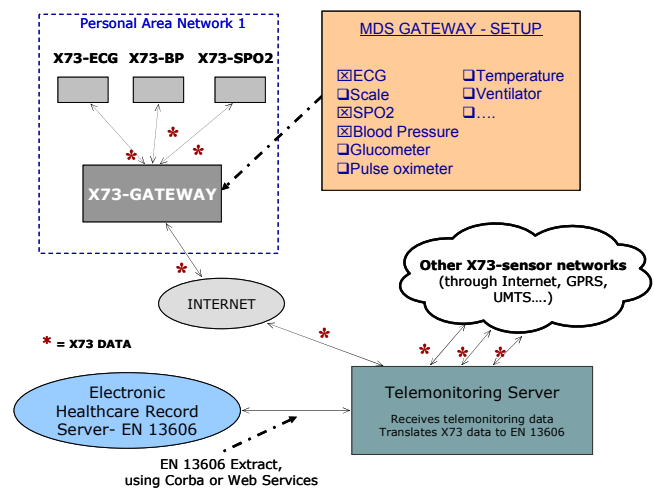


Fig. 3. X73 Standards- based prototype.

Devices must have full plug-and-play capabilities and be connected and configured with the lowest level of user intervention, even by users with now technical knowledge. The end user, without the support of a technician, should be also able to substitute or add a device in case of failure or due to a change in the follow-up design.

The service provided will be as follows: the data acquired from the different sensors will be transmitted to a X73-compatible access point or gateway; which will be configured and personalized for a given service as shown in Figure 3, by, for example, setting the type of X73-sensors and the transmission techniques used. The gateway will in turn store or resend the information to a telemonitoring server located at a distance (service provider).

The workplan to design this sensor network is based on sharing out the different layers (ISO-OSI) addressed by the X73 standard to progress in a faster way and to ensure layers are kept independent but interoperable. This layered design, starting from the upper layers, should follow:

- **Highest levels (related to 1073.1.x.x):** Use of the X73-nomenclature (generic and specific of each device), which is a set of codes to name the elements in the data model, and the syntax that maps the codes to machine-processable forms. Implement the model as described by the X73 standards.
- **Intermediate levels (related to 1073.2.x.x)** Use the protocols and services for communication following the standard for the exchanged messages, as well as the encoding rules and the Protocol Data Units (PDU).
- **Lowest levels (related to 1073.3.x.x and 1073.4.x.x).** At our present work, we find a problem with the lack of X73 standardization of wireless connectivity. We plan to fix it when required by using the lower layers of the wireless technology (Bluetooth, Zigbee, etc), then merging them as possible with the upper layers, which really follow the standard, waiting for the X73 to get updated to these technologies.

The telemonitoring server located at the remote site will collect data from the different sources and networks and store them. According to the objective of designing an end-to-end standards based solution, information will be translated to an extract following the EN-13606 standard for EHR communication. This will be done using an interoperable server developed by a partner in the Telemedicine network, Hospital Universitario Puerta de Hierro [17]. The server accepts EN-13606 extracts both through CORBA and Web Services connections. Currently, we are working in the definition of archetypes for telemonitoring information.

IV. CONCLUSION

The work towards interoperable telemonitoring devices based on standards is imperative to achieve mature e-health solutions that are not dependant on a single vendor. It is interesting to approach this work from the perspective of different research groups with disparate objectives, as interoperability problems arise faster than in proprietary developments. Ambient intelligence platforms involving health related data will also profit from the advances in this research.

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