Enhanced Solutions for Healthcare Telemonitoring in Smart Homes based on the ISO/IEEE11073 standard

I. Martínez*, M. Galarraga**, P. de Toledo***, J. Escayola*, L. Serrano**,
S. Jiménez-Fernández****, E. Viruete*, J. Fernández* and J. García*

* Aragon Institute for Engineering Research (I3A) - Univ. Zaragoza (UZ), c/ María de Luna, 3. 50018 - Zaragoza, Spain.

** Electronics Engineering Dept. - Public Univ. Navarre (UPNA), Campus de Arrosadía s/n. E - 31006 Pamplona, Spain.

*** Computer Science Dept. – Univ. Carlos III, Avda. Universidad, 28911 – Leganes (Madrid), Spain.

**** Bioengineering and Telemedicine Research Centre (GBT) – UPM, Ciudad Universitaria s/n - 28040 Madrid, Spain.

imr@unizar.es

Summary

This work describes a proposal of five new use cases for telemonitoring in smart homes developed by three research groups in Spain. This proposal arises from the fact that standards are needed for any healthcare telemonitoring solution pretending to be competitive in an open context, while the ISO/IEEE11073 (X73) standards are moving to include these scenarios. The use cases are compliant with the current status of X73 standards and include some appropriate necessary changes, due to patient mobility and home scenario characteristics. The aim of the proposal is to explore the advantages of standard compliant scenarios and to detect integration and implementation difficulties using these standards. In this way, the three research groups have started to implement some needed functionalities that can provide healthcare facilities in the patient preferred environment and added value to the platform where the different systems could communicate in a standard format. The main contributions presented for the proposed use cases are related to Internet Protocol connectivity and mobility management, wireless medical devices support, system supervision and user or patient-centered design.

I. Introduction

The ongoing increase of elderly people and chronic diseases in developed countries makes it necessary to extend patient follow-up from hospitals to home and mobile scenarios. Therefore, new solutions should be adopted to afford the need of remote healthcare and assisted living. In these e-Health scenarios new use cases emerge and they may require specific analysis. Moreover, recent advances on Information and Communication Technologies (ICTs) are bringing new opportunities in the field of personal health devices and services used for patient home telemonitoring. Currently, e-Health offers in this area a wide range of solutions built up with several medical device combinations for biomedical signals acquisition [1]. Body Area Network (BAN) and Personal Area Network (PAN) technologies are emerging as wireless communications advance providing the support for these scenarios. The need of different network technologies in this context and their transparent use by patients are necessary conditions for a successful implementation of telemonitoring services. This can be reached by means of Internet Protocol (IP) connectivity and mobility management [2]-[4].

Most of the previous e-Health solutions are based on proprietary protocols and systems, thus becoming unreliable for being used in a wider context. The problem of interoperability of smart health components constitutes the main obstacle in the development at large scale of home telemonitoring services. Hence, the use of standardization seems to be the only way to solve this problem [5]-[7]. The ISO/IEEE11073 (X73) is a family of standards for medical devices (MDs) interoperability considered as European standards via the TC251 of the European Committee for Standardization (CEN). X73 was formed by absorbing three previous standards: 1) a standard for Vital Signs Information Representation (ENV13734 or VITAL) for the upper layers [8], 2) a standard for Interoperability of Patient Connected Medical Device (ENV13735 or INTERMED) for the intermediate layers [9], and 3) a standard for the Medical Information Bus (MIB/IEEE1073) for the lower layers [10]. The X73 standards were initially designed to address Intensive Care Unit (ICU) scenarios [11] and thus, e-Health telemonitoring scenarios were not considered in the set of the X73.

In this paper X73 standards are adapted, with the appropriate necessary changes, to include e-Health telemonitoring in the context of patient home and mobility [12]. The new proposed use cases constitute the start point to the analysis of the needs in these scenarios, and also imply a contribution to the standards evolution with the acquired *know-how*. These use cases include mobile cardiac monitoring, home weight monitoring, chronic respiratory patient management, elderly patient follow-up and wellness monitoring. The effort of providing implementations for these proposed use cases is probably the best way for testing X73 standards and also to detect handicaps, difficulties and possible improvements in such a task. This work allows foreseeing some possible ideal-standard future scenarios far from today's state of the art in telemonitoring. Furthermore, these can be scenarios where the data can flow seamlessly from a sensor in the patient's home to a hospital, with the possibility of interaction with the patient's Electronic Healthcare Record (EHR). In summary, scenarios that bring up advantages in interoperability, network transparency, scalability, costs, comfort and system usability for the patients.

This paper also proposes a platform to integrate these new use cases with new functionalities and modules that may provide Plug-and-Play (P&P) capabilities. The experience of implementation is compliant with X73 and other standards (EN13606 or HL7). It permits to include (with minor modifications) items not yet supported by these standards, such as wireless communications, but being ready to adopt the upcoming changes for telemonitoring scenarios. The features of these use cases are detailed in Section II. A brief description of the proposal of the X73 integration platform for an enhanced P&P solution is covered in Section III. New functionalities and improvements based on the Ambient Intelligence (AmI) paradigm, and included in the integrated platform are described in Section IV. Finally, the main conclusions of the work are drawn in Section V.

II. PROPOSAL OF NEW USE CASES FOR HOME TELEMONITORING

As a first step to prove the suitability of applying the X73 standard to telemonitoring in ambient assisted living, it is crucial to clearly identify the addressed Use Cases (UCs), and their specific functional and technical requirements. Following the X73 perspective, the architecture of a homogeneous home/ambulatory system is defined in X73 according to a set of sensors (Virtual Medical Devices, VMD), a central device (Computer Engine, CE), and a Monitoring Server (MS), see Fig.1. From the previous experiences with patients, doctors and other healthcare professionals [13]-[15], the functional description of each UC are detailed as follows:

- *UC1 – Mobile cardiac monitoring*. This UC relates to the ambulatory follow-up of cardiac patients and involves monitoring of the patient's ECG signal for long periods of time to detect possible syncopes or cardiac events. The VMD should be a wearable Holter monitor [13] with the following features: measurement of one or more ECG leads with a sample rate of at least 200 samples/s, storage of ECG records for periods around 2 hours, out of storage memory or low battery warnings, automatic detection of cardiac events (such as tachycardia, bradycardia or asystolia), manual activation of event recording when the patient suffers specific symptoms, etc. Data gathered and main alarms triggered should be made available to the care team at a dedicated MS. Data can be handled in pull mode (healthcare professional queries for the data), while critical alarms should be made available in push mode (i.e. by messages to cell phone or pager). Summaries of these data should be sent to the patient's EHR for longer term storage and reference. A portable CE (i.e. mobile telephone) is needed, and it is mandatory to communicate with the VMD through a wireless connection (although wired connection is also possible) and with the MS through a wireless access network as well as to foster mobility.
- *UC2 – Home weight monitoring*. This UC aims to monitor cardiac arrest patients, whose weight variations usually imply exacerbations of their illness. Every time the patient follows the weighing protocol, the weight is transmitted to the CE through a wireless connection, and then to the MS over a wired network access. Once there, a specialist can access the MS to inspect the recorded data, in pull mode. The main feature to be taken into account by the patient is the battery status alarms.
- *UC3 – Chronic respiratory patient management*. The target group of this UC is patients with a chronic respiratory condition (typically COPD [14]) whose specialist's recommendations for self-monitoring during an exacerbation episode or for longer periods are: spirometry (main values and flow volume curve), oxygen saturation (pulse-oximeter), and answers to a symptoms questionnaire. In case the patient has a co-morbidity, typically coronary disease or diabetes, monitoring may as well include ECG, non-invasive blood pressure, and weight (cardiac) or blood glucose (diabetes) levels. The case manager provides the patient with the required VMDs and a wireless CE (i.e. a mobile phone) to allow ambulatory operation and patient comfort. Data transmission between CE and MS could be store-and-forward (not time-critical) and being sent within the same day. Case manager could check patient's status daily (pull mode) and receive alarms triggered by the system. The service is supervised by technical staff from the service provider which takes care of the equipment. Other features to take into account include warnings (via SMS, beeper call, e-mail, web page) about: measurements range in abnormal levels, system's malfunction (no batteries, device not connected or not working properly), absence of patient data after a pre-established period (in order to call to the case manager or social worker for a visit), etc.
- *UC4 – Elderly patient follow-up*. Non-intrusive but efficient follow up of elderly patients living on their own is one of the main uses of home telemonitoring. Similarly to UC3, in this UC vital signs are acquired once a day under patient supervision. Additionally, the physical activity of the user is estimated. The used VMD is a wearable wireless 3D accelerometer (allowing activity monitoring), which records patient movements during all day, detects falls, and provides a summary of activity level. Although the patient is continuously moving, similarly to UC1, as she/he is monitored only while being inside home, the CE is fixed and it communicates to MS through a wired access network.
- *UC5 – Wellness monitoring*. This UC relates to patients at home, concerned with their health, which monitor different parameters several times a day (in store-and-forward mode) and send the results to a MS [15]. This UC considers several measurements equipments as VMDs (blood-pressure, pulse-oximeter, even weight scale) and, due to the fixed characteristics of these measurements, the communications among VMDs, CE and MS are wired.

From these UC functional descriptions, the authors propose their translation into the implementation of an interoperable X73-based solution. This process implies: the inclusion of new sensors to be bound to an X73 CE following P&P basis, the revision of the wired/wireless communications (only IrDA and RS-232 physical interfaces are currently included in the standard description, as it will be discussed in Section IV), the adaptation of VMD working modes to the X73 application profiles (*baseline* for continuous monitoring like ECG or pulse rate, and *polling* for requested monitoring events like blood pressure, temperature or weight), etc. With this aim, the specific technical requirements for each UC and their X73-compliance (distinguishing between black and white dots) are summarized in Table II.

Moreover, the described telemonitoring process has been focused on the communications between VMDs, CE and MS to manage measurements, alarms, etc. However, an end-to-end solution might include the possibility of sending selected parts of the monitoring information to be stored in the EHR server, using EN13606 standards [16], as it is shown in Fig. 1.

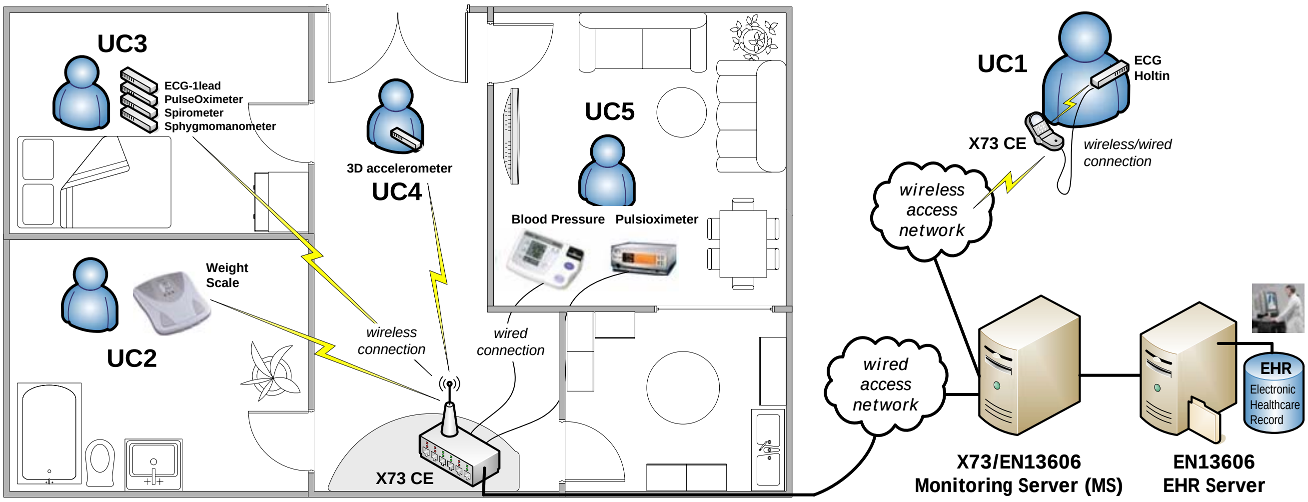

Fig. 1. UCs generic scheme integrated in a smart home context

TABLE I. SPECIFIC TECHNICAL REQUIREMENTS IN EACH UC
(● = currently non X73-compliant, ○ = X73-compliant)

	UC1	UC2	UC3	UC4	UC5
VMD – CE connection					
Wireless (Bluetooth, Zigbee)	●	●	●	●	
Wired (RS-232/USB)					○
CE – MS communication					
Wireless access (GPRS, UMTS, WiFi, WiMax)	●				
Wired access (xDSL, ISDN)		●	●	●	●
Other features					
X73 adapter over integrated PC			●		●
X73 adapter over μcontroller		●		●	
User warnings (via SMS, beeper call, e-mail, web page)	●		●		
Battery status control	○	○	○	○	
Malfunction warnings	○		○	○	○
P&P functionalities	○	○	○	○	○

III. X73 INTEGRATION. A P&P SOLUTION FOR MDS INTEROPERABILITY

The UCs previously presented aim to be implemented end-to-end, following the X73 standard [17], and being integrated into a homogeneous telemonitoring X73 platform [12], see Fig.1. The X73 standard covers all the levels in the communication process between VMD and CE. Thus, it enables a real modular integration and it constitutes a challenge for standard-based P&P solutions. The implementation experience presented in this paper follows these guidelines according to a structured design. The *top-down* process within the stack layers, see Fig. 2, is divided in three main steps:

- *Application layer*. X73 defines in its Part 1 the *Medical Device Data Language* (MDDL, as the X73 nomenclature for the *semantics* and *syntax* used in the fields of the Protocol Data Unit (PDU), usually with object oriented attributes). MDDL defines the *Domain Information Model* (DIM) including the Static Model (it is the object orient model for representing any VMD following the definitions standardized in the *Medical Data Information Base*, MDIB) and the Dynamic *Model* (it provides a communication model based on the ISO concept of agent-manager with a '*Device Communication Controller*' (DCC) and a '*Bedside Communication Controller*' (BCC), respectively). Moreover in this layer, X73 defines in its Part 2 the *Medical Device Application Profiles* (MDAP) for the X73 communication model. It is implemented by several protocols (Service Elements, SE): ACSE (for Association Control), CMDISE (for Common MD Information and basic services), and ROSE (for Remote Operations between call requests and responses). These protocols constitute a set of Basic and MD Encoding Rules (BER/MDER) whose messages have been coded in this implementation using Abstract Syntax Notation (ASN.1). The ASN.1 structures (defined by X73) are compiled by an *ad-hoc* developed translator (based on ANTLR 2.7 parser and ASN.1c 0.9.22 compiler) and written in C/C++ source code and Java utilities.
- *Presentation and session layers*. It is mainly a negotiation mechanism for the BER/MDER syntaxes used by higher layers: the *abstract syntax* (which set of messages are to be exchanged), and the *transfer syntax* (how the messages are encoded). It provides support to the ACSE through a simplified version without synchronization or dialogue control.
- *Transport and physical layers*. The implementation of these levels varies depending on which protocol and physical interfaces are used. The first prototype of this implementation is based on the only wired possibility (via RS-232) that X73 defines in its Part 3. The proposed platform is evolving to include other protocols (as TCP/IP) and interfaces (as USB, Bluetooth or ZigBee), as it is discussed in Section IV.

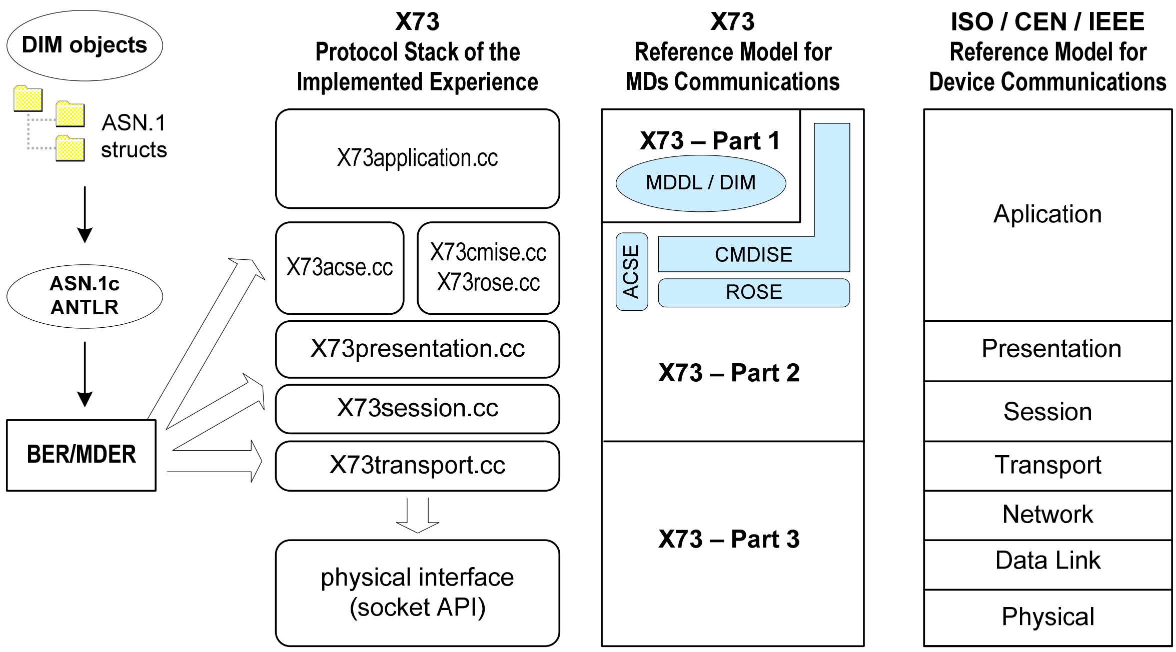

Fig. 2. X73 communication model and implemented protocol stack.

Currently there is an overwhelming majority of MDs that do not implement the X73 standard or that do not have an X73-compliant physical output which is strongly conditioned to the vendors and manufacturers. However, for a real X73 integration providing P&P solutions, the existence of native X73 MDs is necessary. Thus, in this development, proprietary devices with X73 adapters have been used. These adapters implement the proprietary interfaces that can only be modified by knowing the vendor programming codes on one side and the X73 standard (following the structured design previously detailed) on the other side. Therefore, the X73 adapter acts as agent (DCC) establishing the X73 communication with the X73 CE that acts as manager (BCC). This generic X73 communication is particularized to each X73 adapter (and its MD associated) by means of two configuration files: *settings* (with the proprietary technical characteristics, detailed in Table I) and *profiles* (with the functional requirements, detailed in the UCs presented in Section II). The original signal is acquired from MDs in the vendor format, translated to X73-compliant format by the X73 adapter, and sent as X73 data over the TCP/IP connection from the X73 CE, see Fig. 3. The MDs and X73 adapters considered in the proposed solution are:

- Intelligent Holter (HOLTIN) is a low voltage-low power customized wearable device supplied with a Li-Po rechargeable battery. An 8-bit microcontroller performs the main tasks (acquisition of ECG signal, detection and storage of cardiac events) and a Bluetooth chip enables the communication with the mobile phone (X73 CE in UC1) without X73 adapter. However, a native X73 implementation is a handicap that has to be addressed, due to the current X73 version does not include Bluetooth, and it also will require the standard to be lighter to avoid excessive power consumption.
- The TEFAL PP1015B0 is a battery-powered weight scale provided with a Liquid Crystal Display (LCD). This MD requires an *ad-hoc* adapter, integrated into Peripheral Interface Controller (PIC) in UC2, which taps data from the LCD via USB input interface, and manages the MD communication via a Bluetooth output module over a TCP/IP connection.
- The MEDLAB EG00302 is a pulse-oximeter that measures blood oxygen saturation (SpO_2), heart rate and plethysmographic waveform, and provides RS-232 input interface. To configure the MD, an attached microcontroller-based module supports a RadioFrequency (RF) output interface for UC3 and UC4.
- The OMRON 705IT measures asynchronously the blood-pressure and the pulse rate, with a 28 acquisitions memory, and provides a USB connection (that requires a RS-232 adapter for its fully X73-compliance in UC5).
- The DATEX-Ohmeda 3900 is a pulse-oximeter with a RS-232 serial-port output (the only wired interface included in X73 description) that measures blood oxygen saturation (SpO_2) and heart rate every 2s, and provides alarm support for UC5.

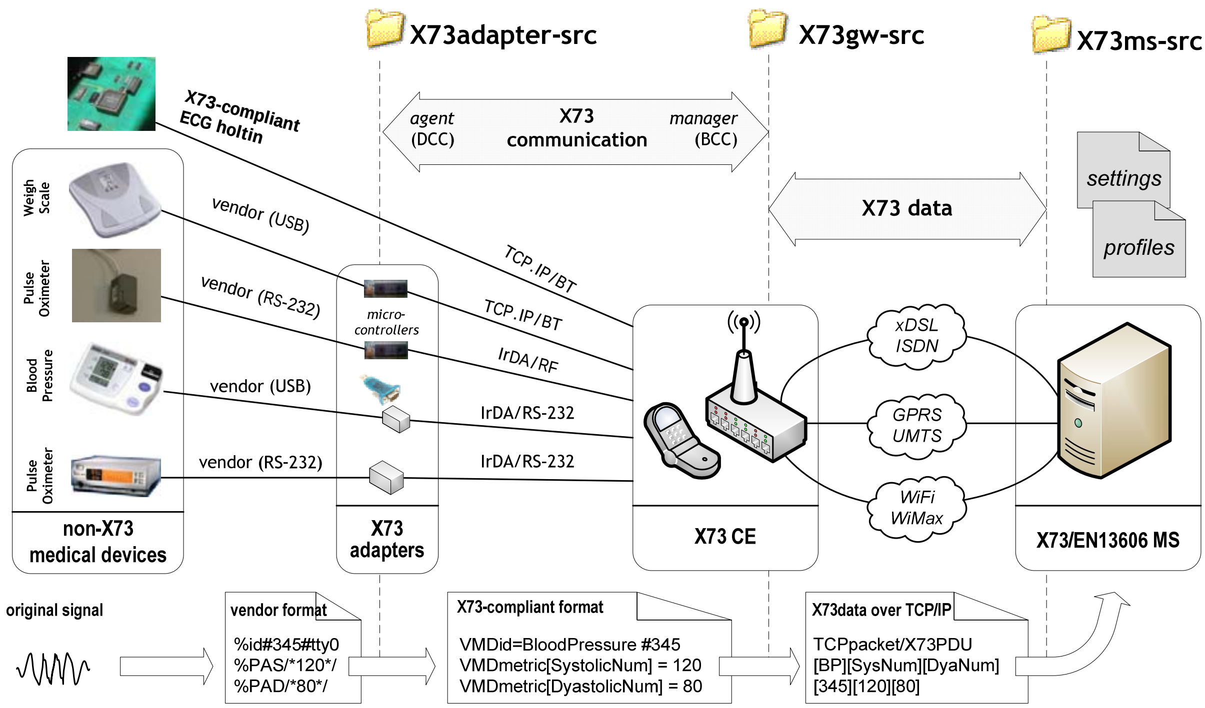

Fig. 3. MDs and X73 adapters considered in the proposed solution.

IV. X73 OPEN POINTS. NEW FUNCIONALITIES AND FUTURE TRENDS.

The proposed X73 integration platform contributes to a P&P solution taking advantage of the X73 features for MDs interoperability. These functions open a new wide range of possibilities although some of them cannot be implemented matching the specifications due to the standard's early development stage. Still, we describe some experiences in progress that might help addressing the future of X73's evolution and completion. Some of them are focused on improving the telemedicine service security and robustness while others are aimed to give support to new UCs like the mobile monitoring scenario. One of the main objectives in our research is to extend the use of X73 to ambient assisted living at home and outside, addressing the patient needs in their preferred environment, and taking advantages of the benefits of standardization. Thus, these new X73-based functionalities and improvements based on the Ambient Intelligent (AmI) paradigm are:

A. IP connectivity and mobility management.

In the previous discussions, X73 data from CE to MS are transmitted over IP networks. In this section, we deal with the possible future integration of X73 in systems provided with IP connectivity and mobility (especially useful for UCs based on wireless access network). Systems with different alternatives of IP connectivity are equipped with one or several IP network access technologies that can be used to maintain X73 data communications in spite of any possible changes in the available resources. In these systems, IP mobility is responsible for carrying out the change between technologies in a transparent way to upper architectural levels, which is often denoted as Media Independent Handover (MIH) [2].

In order to achieve this objective an *ad-hoc* algorithm, divided into three main blocks (see Fig.4), has been designed. The most relevant information exchanged between blocks is described as follows. When the X73 Application Interface (AI) block requests the establishment of a new communication to the Communication Management (CMg) block, it informs about the different required parameters: desired priority, communication traffic model, needed capacity, delay, *jitter*, etc. The CMg block, once the communication has been properly established, sends the confirmation feed-back, together with a communication identifier to AI. In parallel, the Connection Monitoring (CMo) block periodically sends the parameters of all the available connections to CMg: capacity, available bandwidth, delay, jitter, packet loss rate, etc. In this manner, CMg can release or assign and relocate (through the handover process) the different communications in the available connections depending on their priorities and their required Quality of Service (QoS) levels. This information is transmitted in the beginning of the process and every time a change is detected. As a feedback, CMg block informs to CMo about the assignment state of the parameters to the communications, so that the latter could calculate available bandwidth more easily. Although there are multiple proposals to carry out its implementation [3], [4], we would like to highlight those under study in the IEEE 802.21 working group [2].

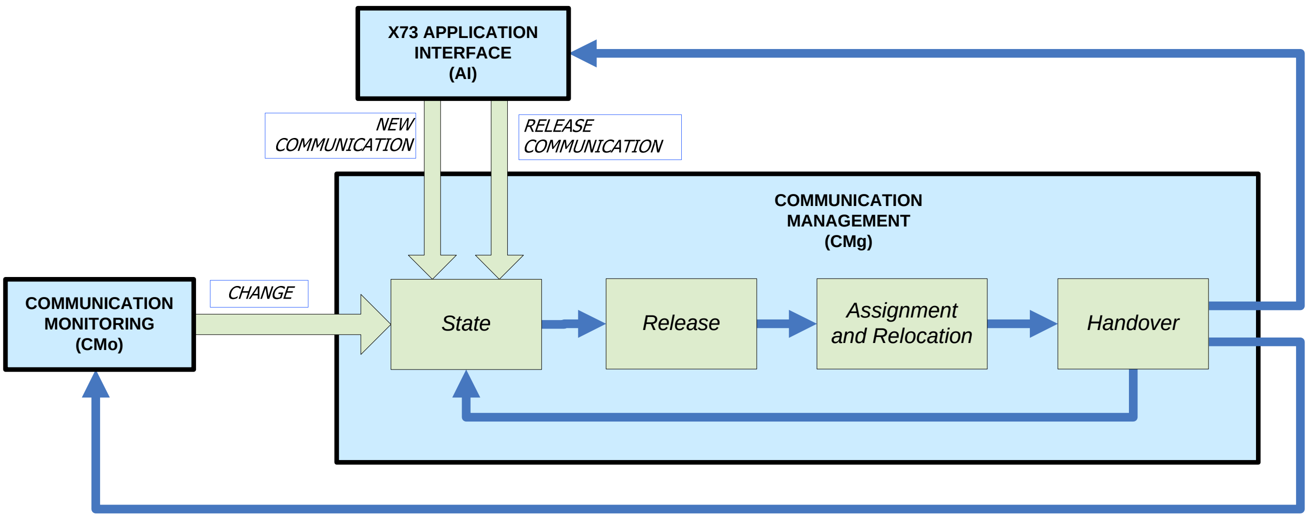

Fig. 4. IP connectivity and mobility algorithm.

B. Wireless MD support.

Initially oriented to an ICU scenario, cable-based connections like RS-232 and IrDA are the only transmissions modes supported by the X73 standard at the moment. The use of this type of connection makes it hard to connect a large number of devices to the gateway or a data logger due to likely limited physical connectors. The implementation of wireless transport support into X73, will not only make possible to increase the number of connected devices or users to the same gateway, but also to provide the mobility that is sometimes necessary depending on the scenario. Adding a new device to an existing BAN or PAN will have little or no setup due to the P&P feature. As a counterpart, problems regarding to the device's operating time arise, which leads to a revision of the X73 high level communication protocols due to particular electronic features as low voltage-low power sensors and processors included in wearable MDs. Most of the system's intelligence processing load should not then be implemented at the sensor's side. In general, avoiding long time communications and being efficient in terms of overhead, bandwidth and CPU use are the main goals in these protocol improvements [18]. These goals are driving a deep review of the X73 standards, envisioning a new profile for Personal Health Devices (PHD) communications [19]. In our system a Bluetooth transport module is being implemented on the X73 adapters because of its protocol stack fits in X73 model with some minor modifications, as it is shown in Fig. 5.

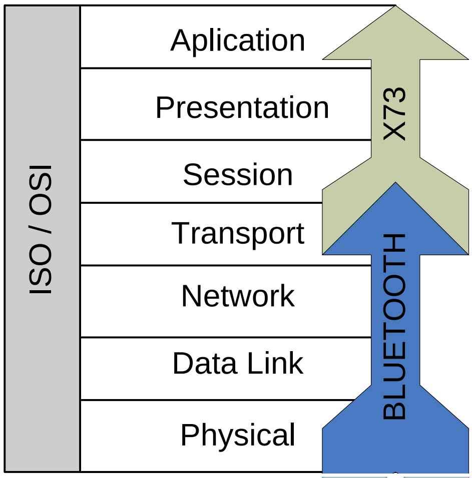

Fig. 5. Vertical depiction of the layered device architecture relative to the ISO/OSI model.

C. System supervision.

The success of home healthcare services depends mainly on the system's control module performance that is located at the gateway. The X73 standard supports a complete alarm reporting list regarding technical or measurement quality problems (see Table II). In our implementations some additional technical and human situations may have to be reported to the MS where a healthcare professional is supervising the system. For instance, any missing or exceeding device in the UC can be easily detected by comparing the established P&P connections table to the required list. In a similar way, absences of patient response or unexpected device behavior are more examples of alarms to be reported that, in some cases, can be communicated to the patient directly from the gateway.

TABLE II. AN EXAMPLE OF TECHNICAL AND MEASUREMENT QUALITY ALARMS DEFINED BY THE X73 STANDARD FOR A BLOOD-PRESSURE METER

Name	Code	Description/ Definition
High limit alert	450	A metric exceeds a given threshold
Sensor disconnected	308	Sensor disconnected or fault
Battery low or dead	194	Battery discharged or defective
Inop	550	e.g. device inoperable

D. User-centered design.

Patient interaction has been proven to be helpful in order to make her/him percept the system as a really useful health service and not just a highly complex computerized setup. In order to achieve that interaction, personalized graphical and sensorial interface are implemented in the gateway, which depends on the patient handicap, and is based on a simple keyboard, voice commands recognition, external display, loudspeakers, etc. Likewise the system ensures that the measurement data are within reasonable range, performing an alarm managing as described before and helping to use the devices (e.g. guiding the patient in her/his sampling procedure and providing the device's location around the house when needed). This guiding information called *profile,* is gathered from the remote secure server through an up-to-date EHR of the patient which is stored in the respective database. Considering that the patient treatment will likely vary in time, a remote profile configuration update module is implemented so it is not necessary to visit the patient's system by a health professional with each update.

V. CONCLUSIONS

The work towards interoperable telemonitoring devices based on standards is mandatory to achieve mature e-Health systems that are not dependent on a single vendor. It is interesting to approach this work from the perspective of different research groups, as interoperability problems arise faster than in proprietary developments. New use cases (including cardiac, weight, chronic respiratory, wellness and elderly patient monitoring) have been considered in the context of patient mobility and smart home environments. Moreover, the necessary changes in the standard (new physical interfaces and internetworking support, lighter protocol versions that will lead to lower battery consumption, fewer network resources, etc.) have been proposed in order to extend X73 to new wireless technologies and personal health devices.

Solutions for healthcare telemonitoring in enhanced intelligent platforms X73-based will also provide new functionalities. This work has presented some of these possibilities including: IP connectivity and mobility management, wireless transmission and wearable medical devices support, system supervision (hardware malfunction or patient status alarms), and user centered design. It is clear that the absence of standardized P&P solutions for medical devices is an unacceptable barrier to spread-use of telemedicine, e-care and e-Health.

ACKNOWLEDGMENT

The authors wish to thank Mr. Melvin Reynolds, convenor of the CEN TC251 WGIV, for his key suggestions to this research. We also appreciate the contribution of the Research Groups of the Spanish Telemedicine Research Network to the excellent results of the entire project carried out during the last four years. This research work has been partially supported by projects TSI2005-07068-C02-01 and TSI2004-04940-C02-01 from *Ministerio de Educación y Ciencia* (CICYT) and European Regional Development Fund (FEDER), Pulsers II IP IST-27142 from VI Framework, a personal grant to Miguel Galarraga from *Departamento de Salud* (Navarra Regional Government) and FPU grant AP-2004-3568 to Eduardo Viruete from *Secretaría de Estado de Ciencia y Universidad* (Spanish Government).

REFERENCES

[1] R. Wooton, J. Craig, "Introduction to Telemedicine", ISBN-10: 1853156779, *Rittenhouse Book Distributors*, 2nd Edition, 2006

[2] IEEE 802.21 Working Group, http://www.ieee802.org/21. Last access: 26/4/2007.

[3] N. Nasser, A. Hasswa, H. Hassanein, "Handoffs in Fourth Generation Heterogeneous Networks," *IEEE Communications Magazine*, pp. 96-103, 2006.

[4] D. Le, X. Fu, D. Hogrefe, "A Review of Mobility Support Paradigms for the Internet," *IEEE Communications Surveys & Tutorials*, pp. 38-51, 2006.

[5] P. de Toledo, M. Galarraga, I. Martinez, L. Serrano, J. Fernández, F. del Pozo, "Towards e-Health Device Interoperability: The Spanish Experience in the Telemedicine Research Network," *Int Conf IEEE Eng in Medicine and Biology Society* (EMBS), pp. 3258-61, 2006

[6] J. Yao, R. Schmitz, S. Warren, "A Wearable Point-of-Care System for Home Use That Incorporates Plug-and-Play and Wireless Standards," *IEEE Trans Inf Technol Biomed*, 9(3):363-371, 2005.

[7] S. Warren, J. Yao, R. Schmitz and J. Lebak, "Reconfigurable point-of-care systems designed with interoperability standards," *Int Conf IEEE Eng in Medicine and Biology Society* (EMBS), vol. 26, pp. 3270-3273, 2004.

[8] IEEE13734 - CEN/TC251. VITAL Health informatics - Vital signs information representation," http://www.medicaltech.org. Last access: 26/04/07.

[9] ENV13735 - CEN/TC251. INTERMED. Health informatics - interoperability of patient connected medical devices," http://www.medicaltech.orgh. Last access: 26/04/07.

[10] R. J. Kennelly and R. M. Gardner, "Perspectives on development of IEEE 1073: the Medical Information Bus (MIB) standard," ***Int. J. Clin. Monit. Comput.*** vol. 14, pp. 143-149, 1997.

[11] M. Galarraga, L. Serrano, I. Martinez and P. de Toledo, "Standards for medical device communication: X73 PoC-MDC," *Medical and Care Compunetics 3. IOS Press - Studies in Health Technology and Informatics.* (ISSN: 978-1-58603-630-0), vol. 121, pp. 242-256, 2005.

[12] I. Martínez, J. Fernández, M. Galarraga, L. Serrano, P. de Toledo and J. García, "Implementation of an End-to-End Standards-based Patient Monitoring Solution," *IEE Proc Communications - Special Issue on Telemedicine and e-Health Communication Systems,* accepted for publication, 2007.

[13] S. Led, L. Serrano, M. Galarraga. "Intelligent Holter: a new wearable device for ECG," *European Medical and Biological Engineering Conference EMBEC*, Prague, 2005 [HOLTIN project, in collaboration with Cardiology Dept. of Negrín Univ. Hospital, Canary Islands].

[14] P. De Toledo *et al*., "A telemedicine experience for chronic care in COPD,", *IEEE Trans Inf Techn Biomed*, Vol. 10, Issue 3, pp 567-573, 2006.

[15] E. Viruete, C. Hernández, I. Martínez, A. Alesanco, J. Fernández, J. García, J. Ruiz and A. Valdovinos, "New telemonitoring medical services," *National Journal of the Health Informatics Spanish Society SEIS I+D*, vol. 52, pp. 31-38, 2005.

[16] A. Muñoz, R. Somolinos, M. Pascual, J. A. Fragua, M. A. Gonzalez, J. L. Monteagudo and C. H. Salvador, "Proof-of-concept Design and Development of an EN13606-based Electronic Healthcare Record Service," *J Am Med Inform Assoc*, vol. 14, pp. 118-129, 2007.

[17] IEEE1073. Health informatics. Point-of-care medical device communication. Standard for Medical Device Communications [Overview and Framework] [Part 1. Medical Device Data Language (MDDL)] [Part 2. Medical Medical Device Application Profiles (MDAP)] [Part 3. Transport and physical layers]. http://www.ieee1073.org. Last access: 26/04/07.

[18] J. Yao and S. Warren, "Applying the ISO/IEEE 11073 standards to wearable home health monitoring systems," *Journal of Clinical Monitoring and Computing*, vol. 19, pp. 427-436, 2005.

[19] Personal Health Devices (PHD). IEEE Standards Association webpage: http://standards.ieee.org/. Last access: 26/04/07