

Towards Plug-and-Play Interoperability for Wireless Personal Telehealth Systems

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Abstract— This survey paper serves as an introduction to the challenges and needs related to wireless personal telehealth systems and provides an overview of ongoing activities in industry and various communication standards, aiming to enable plug-and-play interoperability. Specifically, we address a recently founded industry consortium, the Continua Health Alliance, and ongoing standardization efforts within the family of ISO 11073/IEEE 1073 standards, the Bluetooth SIG, and the ZigBee Alliance.

Keywords— Personal Telehealth, Wireless Communication, Interoperability, Standardization, Continua Health Alliance

I. INTRODUCTION

In 2004 the costs for healthcare in the United States have increased above 16 percent of the gross national product (GNP) [1]. This correlates with the fact of an aging population and an increasing number of chronically ill people. While in 2000, the proportion of the population in the United States aged ≥ 65 was 12.4 percent, this is expected to increase to 19.6 percent in the year 2030 [2]. Considering diabetes as an example, the proportion of persons of age ≥ 65 with a chronic diabetes condition is approximately one in five (18.7%) [2]. Even assuming that this ratio remains constant in the future and does not get worse, the expected overall increase in percentage of persons with chronic diabetes conditions due to the aging of society is alarming. This development is not restricted to the US but it is a worldwide problem that particularly developed countries are facing. Hence, a major challenge in healthcare is to improve the quality of care for an increasing number of patients using limited financial and human resources.

Personal telehealth systems, including remote patient monitoring and management, are increasingly recognized as having the potential to help overcoming that challenge. Per definition, in a personal telehealth system the caregiver is geographically separated from the care consumer with the care plan being individually tailored to the patient's needs. This patient-centered concept of bringing the care from the hospital or the doctors office to the patient at home results in cost-reduction and improved quality of care. Being able to more frequently observe the patient's state of health by performing remote measurements of the patient's vital signs enables optimizing the patient's medication and treatment.

This results in longer independent living for older patients and lower mortality rates. Through increased frequency of daily automated, but personalized, patient intervention, the care providers can manage a broader range of chronic disease patients, improving efficiency. However, the biggest opportunity for reduction in costs is not in lower costs for nurse visits but rather in a reduced need for high-cost chronic care and hospitalization.

In addition to the care being provided in a remote and personalized way, an important factor for enabling the success of future telehealth systems is to make the last hop to the patient wireless. By introducing wireless technology cumbersome cables can be eliminated, enabling greater physical mobility and making the system more unobtrusive and ubiquitous for the patient. For the wireless link at the patient side the technologies being considered range from enabling a simple cable-replacement to allowing real networking of vital sign measurement devices, as for example in the context of body sensor networks (BSN).

An example for a sophisticated system solution incorporating the aspects mentioned above is Motiva [3], a TV-based remote patient monitoring platform from Philips. The platform comprises daily, personalized patient interactions, delivered via broadband connection to the home television. Patients receive reminders and messages, educational videos, and feedback on their vital signs comprising weight, blood pressure, and blood glucose levels, based on a tailored care plan defined by their caregiver at enrollment.

However, besides the benefits of wireless personal telehealth systems mentioned above, there exist also several challenges and issues still unresolved or with tentative answers so far. Just to name some examples: An inherent problem of telehealth is the lack of context information of the raw medical data that is transmitted to the remote caregiver, not knowing for example the patient's posture or current activity level when measuring blood pressure. In contrast to lack of information, the amount of data being transmitted has to be carefully chosen in order to prevent cognitive overload of caregivers or providers. Besides having an overall safe system, it should be reliable. This is especially an issue if wireless connections are employed, as these are prone to interference and variations in quality of the propagation channel. Furthermore, the system should be secure in terms of being protected against unwanted access, and assure privacy of the patient's data. From a legal per-

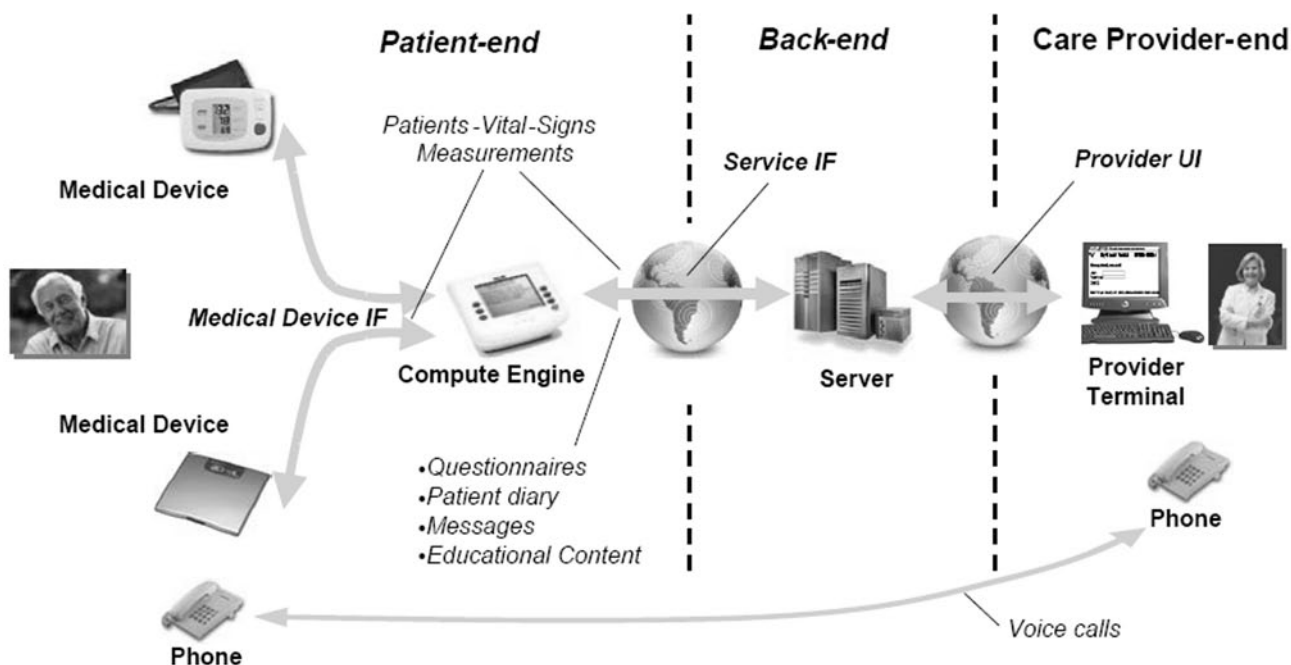


Figure 1: Model of a typical personal telehealth system for chronic disease management

spective there is the question of liability for remote health systems. Another important topic relates to the business aspects for the system implementers: Who are the payers of telehealth systems and what are the strategies for reimbursement? Besides health insurance companies, a new class of payers might be the patients themselves, who actively manage their health by consuming health care rather than being provided with it.

All these issues have to be considered in designing solutions to the overall complex problem of personal telehealth care. However, a lot of isolated and proprietary solutions exist today. Indeed there is an enormous conglomeration of personal health devices and services lacking interoperability, and hence preventing that the issues mentioned above are solved in a unified and standardized way. Thus, it is exactly the approach of enabling plug-and-play interoperability and connectivity within the context of wireless personal telehealth, which is necessary for the success of future telehealth systems.

In the remainder of this paper we elaborate in more detail the problem of interoperability in the personal telehealth domain (Section II) and give an overview of current ongoing standardization activities. After presenting an overview of a recently formed industry consortium addressing the overall problem of interoperability in Section III, we address current standardization activities regarding interoperability

on upper-layers and the application layer of the OSI stack in Section IV and V, respectively. Finally concluding remarks are given in Section VI.

II. THE INTEROPERABILITY PROBLEM

An example of a personal telehealth system for chronic disease management is shown in Figure 1. Typically it consists of three parts. A patient-end with personal health devices in the patient's home or on the patient's body, a back-end part for storing the data and a care provider-end, where the personal health consultant has access to the patient's data.

The devices at home are medical devices (e.g. blood pressure meters, weight scales, pulse rate meters, or thermometers) for measuring the patient's vital signs and usually some kind of compute engine (e.g. a PC or a mobile phone) for gathering the data and providing a user interface for the patient. The back-end part contains a server component, which is connected via a network, e.g. the Internet, to the patient-end part. Similarly, at the care provider-end access to the patient's data on the server is enabled via some network, which could also be e.g. the Internet.

Obviously there is a need for intercommunication among the various components within the system. Focusing on the patient-end part there are several alternative wireless tech-

nologies, as e.g. IEEE 802.15.1 (Bluetooth), IEEE 802.15.4, or IEEE 802.11 (WLAN), to establish a wireless link between medical devices and compute engines. Indeed this has been accomplished with a number of personal health devices. However, the standardization process with regard to medical device interoperability lacks behind technical possibilities. Virtually all of these solutions are specialized applications with proprietary interfaces unique to the two devices being linked. That means if for example the blood pressure meter from company X can communicate with the same companies compute engine, almost certainly a blood pressure meter from vendor Y can not interoperate with the compute engine from company X . Ensuring compliance on the physical layer between two devices does not ensure interoperability, as there are many different way to transmit the same information over a physical layer interface. In order to ensure plug-and-play interoperability between multi-vendor devices, the devices must be able to *understand* the format and the content of the messages they communicate to each other.

Hence, on the patient-end side the problem of device interoperability has to be solved on three principle levels: On lower-layers a standardized transport technology enabling basic connectivity has to be developed. On upper-layers application profiles have to be developed, which define what capabilities of the transport technology have to be used to best support the application requirements. Finally on application level standardized data models and formats have to be developed, which represent an abstract unique mapping of the real world entities. While a significant amount of problems on the lower layers has been solved already and mature standards are available, more work at levels closer to the application is needed. For a discussion of medical device interoperability refer also to [4].

Concerning the back-end part at some point in the system the data has to be translated into HL7 (Health Level 7) [5], which is usually employed by archival repositories.

III. THE CONTINUA HEALTH ALLIANCE

In June 2006, 22 industry-leading technology and health companies joined forces and formed an open nonprofit industry alliance [6]. Since its inception the alliance has grown continuously, now comprising 36 promoter companies (see Figure 2 for an overview of the Continua promoters), and another 32 contributor companies.

According to its mission “*establish an ecosystem of interoperable personal health systems that empower people & organizations to better manage their health and wellness*” the alliance plans to select connectivity standards and set out guidelines for interoperability. The objective is not to



Figure 2: The 36 promoter companies of the Continua Health Alliance [6] in November 2006.

develop new standards, but to leverage existing ones as much as possible, and to close recognized interoperability gaps by means of interoperability guidelines.

Regarding the architectural structure of personal telehealth systems as indicated in Figure 1, Continua addresses the whole range from the medical device at the patient’s home to the back-end services by defining interoperable interfaces. Currently, several wired and wireless standards are under investigation for selection to establish connectivity at the various interfaces. For the connection of medical devices to the system these include Bluetooth, USB, ZigBee, Wi-Fi, amongst others. For connections regarding the in-home network the list includes wireless and wired Ethernet, and power line communications. Last but not least, regarding the connectivity from the patient’s home to the back-end services some candidates amongst others are Cable, DSL, Cellular (e.g. GPRS or CDMA), WiMax, and POTS¹. For a very good online resource of wireless technologies please refer to [7].

Besides technical aspects, an objective of the alliance is to establish a certification program with a consumer recognizable logo for the devices. Furthermore, the alliance plans to collaborate with government regulatory agencies regarding consistent policies for the use of hi-tech personal health devices at home, and to develop new ways for reimbursement of personal health systems. These different areas of

¹ Plain Old Telephone Service

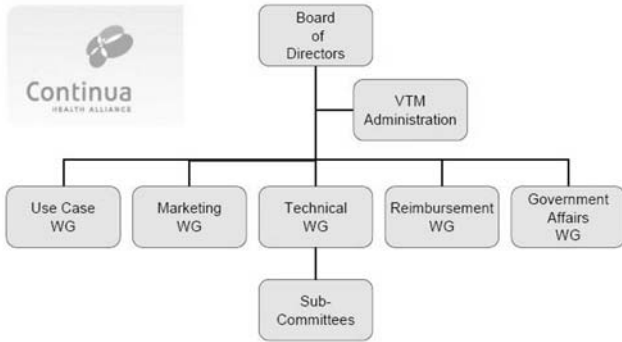


Figure 3: The Continua Health Alliance organizational structure.

involvement are also reflected by the organizational structure of the alliance, as shown in Figure 3.

Regarding the scope of application domains addressed, Continua does not focus exclusively on the chronic disease management domain, but also extends to elderly monitoring, i.e. monitoring the health and healthcare needs of aging people, and proactive health and fitness.

According to the timeline of Continua [8] the first version of the certification program development is expected to be completed at the end of 2007, such that the first certified products might enter the market in 2008. While the first version products are expected to cover the most basic devices and use cases in the envisioned application domains, extended versions are planned in the following years.

IV. DATA MODELS AND FORMATS

As pointed out in Section II, to solve the interoperability problem on application level it is necessary that devices speak a common language by means of a common nomenclature, data types, message syntax, and encoding rules. Many national and international organizations work on standards that enable upper-layer medical information exchange. The most important standards include DICOM [9], HL7 [5], and the ISO 11073/IEEE 1073 [10] family of standards - often also referred to as *Medical Information Bus* (MIB) or x73 standards. DICOM is rather a standard for transmitting medical imaging data, including also handling, storing and printing, and HL7 is a comprehensive set of standards for the exchange of healthcare information between computer applications. Whereas the ISO 11073/IEEE 1073 standard is a family of standards intended to enable medical devices to interconnect and interoperate with other medical devices. See Table 1 for an overview of some important parts of the x73 standard.

The standard is based on an object-oriented system management paradigm. An object oriented data model, the do-

main information model (DIM), defined in ISO 1173-10201, is used to specify objects, attributes, attribute groups, event reports, and communication services, that may be used to communicate device data and to configure medical devices and functionalities. The standardized nomenclature (ISO 11073-10101) comprises a set of numeric codes that identify every item that is communicated between systems. Related to the general domain information model, there exist device specializations for several medical devices (see Table 1), which provide guidelines for how the DIM should be constrained for application to specific devices. Application profiles according to the 2yzzz-series provide specific sets of restrictions for the use of the object model and service model tailored for a class of communication needs. They are independent of specific device types or specific lower communication layers. For example, the Polling Mode application profile (ISO 11073-20201) defines a context free polling mode to access the device medical data and is especially intended for small-scale devices. For an overview of the x73 documents and the x73 concepts for medical device communication refer also to [11].

The x73 standards for point-of-care medical device communication are mainly designed for acute monitoring and treatment applications in a particular diagnostic, bed or treatment area in the hospital domain [11]. Besides general requirements like patient and user safety of medical devices, minimal user interaction and unambiguous association, the key objectives for clinical domain applications addressed by the standard are real-time plug-and-play interoperability and frequent network reconfiguration. According to the employment of bedside devices some attention has also been paid to the reduction of implementation complexity and computational burden at the devices. For example, the message overhead is moderate and the encoding and parsing of protocol data units (PDUs) is very efficient due to the concept of *canned* messages (message templates can be filled in memory in which only the actual updated values must be copied [11]).

However, these design objectives align only partly with the requirements for personal telehealth systems, where especially sensor and battery powered devices demand for very low computational complexity and low power consumption. For wireless devices the latter requirement not only implies to minimize transmit power, but also to reduce transmission time by means of minimizing protocol overhead. On the other hand, in personal telehealthcare the network configuration and user association is rather static than dynamic and there is no distinct requirement for real-time streaming and real-time alarms today, as the setting is usually not acute.

In view of the rising activities in the personal telehealth care domain and as a consequence of the diverging require-

Table 1: The ISO 11073-xyzz series of standards (status: s = published standard, d = draft, new = new project authorization request).

OSI Layer	Part	Title / Content	Stat.
	00000	Health Informatics – Point-of-care medical device communication – Framework and overview	D
	00103	Health Informatics – Personal health device communication – Technical report – Overview	new
7	1yyzz	Data & Information Definitions	
	10101	Health Informatics – Point-of-care medical device communication – Nomenclature	S
	10201	... - Domain information model (DIM)	S
	10300	... - Device specialization – Framework and overview	D
	10301	... - Infusion device	D
	10302	... - Vital signs monitor	D
	10303	... - Ventialtor	D
	10304	... - Pulse oximeter	D
	10305	... - Defibrillator	D
	10306	... - ECG monitoring	D
	10307	... - Blood pressure	D
	10308	... - Temperature	D
	10309	... - Airway meter	D
	10310	... - Cardiac output	D
	10311	... - Airway gas analyzer	D
	10312	... - Hemodynamic calculator	D
	10313	... - Pulmonary calculator	D
	10314	... - Respirator	D
	10315	... - Weighting scale	D
	10316	... - Dialysis device	D
	10400	Health Informatics – Personal health device communication – Device specialization – Common framework	new
	10404	... - Pulse oximeter	new
	10406	... - Heart rate monitor	new
	10407	... - Blood pressure monitor	new
	10408	... - Thermometer	new
	10415	... - Weighting scale	new
	10417	... - Glucose meter	new
7-5	2yyzz	Application profiles	
	20101	Health Informatics – Point-of-care medical device communication – Application profiles – Base standard	S
	20102	... - MIB elements	D
	20201	... - Polling mode profile	D
	20202	... - Baseline profile	D
	20601	Health Informatics – Personal health device communication – Application profile – Optimized exchange protocol	new
4-1	3yyzz	Transport and physical profiles	
1	4yyzz	Physical layer interface	
3	5yyzz	Internetworking support	
4	6yyzz	Application gateways	
	9yyzz	Related concepts	

ments mentioned above several new project authorization requests have been submitted recently to the IEEE standards association and the new ISO/IEEE 11073 *Personal Health Data* (PHD) working group has been established. The standards that this group is going to specify are the parts indi-

cated as “new” in Table 1. They include specializations of 6 personal health devices and a new application profile aimed to address the needs and requirements of personal health devices mentioned above. Related to this activity it is also likely that the DIM will be extended to include additional items being unique to the personal health domain as e.g. patient context information describing the posture of a patient when measuring blood pressure. It is also expected, that the list of devices in the 104zz-series is further extended in future.

It should be noted that the issue of upper layer interoperability as addressed by the x73 standards is an integral part of the agenda of the Continua alliance, which makes the results of the new ISO/IEEE 11073 PHD working group likely to be adopted later on by Continua.

V. WIRELESS TRANSPORTS

Among the many wireless short-range communication standard activities worldwide, the IEEE 802.11 (WLAN) and the IEEE 802.15 (WPAN) family of standards have the largest impact on wireless today. Although providing lower data rates than IEEE 802.11, it is mainly the IEEE 802.15 family that fits best the requirements of small-scale personal health devices in terms of low power consumption and low complexity. After the activities in IEEE 802.15.3 (high-rate WPAN) have been abandoned the two major WPAN technologies today are IEEE 802.15.1 (better known as Bluetooth² [12]) and IEEE 802.15.4 [13] in combination with ZigBee [14] building on top of it, with IEEE 802.15.4 defining only the physical and MAC layer of the OSI stack. Operating in the license-free worldwide 2.4GHz ISM (Industrial, Scientific and Medical) band, IEEE 802.15.4 operates additionally in two less-crowded sub-GHz bands. See Table 2 for more details and an overview of other important system parameters of Bluetooth and ZigBee³.

Let us briefly compare both technologies regarding personal telehealth applications, which are mainly characterized by episodic measurements. The data rate of ZigBee with a maximum rate of 250 Kbit/s is less than the theoretical maximum rate of 3 Mbit/s for Bluetooth, however still fulfilling the requirements of virtually all personal telehealth applications.

Both technologies use spread-spectrum (SS) techniques for increased interference robustness. Due to the direct-sequence approach of ZigBee in one of 16 non-overlapping channels it is possible to run non-interfering networks si-

² The IEEE adopted the V1.1 version of the Bluetooth specification.

³ From now we refer to the combination of IEEE 802.15.4 and ZigBee simply as ZigBee.

Table 2: Some Bluetooth and ZigBee System parameters

	Bluetooth	ZigBee
Frequency Band	2.4 GHz	2.4 GHz (868 / 915 MHz bands)
Channel access	Slotted TDMA (FHSS)	CSMA/CA (DSSS)
# simultaneous networks	~ 10 (PER > 10 %)	16
Data Rate Per Channel	1-3 Mbit/s (theoretical)	250 kbit/s
Network Topology	Star	Star, P2P, Cluster Tree, Mesh
Multihop Capability	No	Yes
Network Size	8	65,535
Power consumption	low	very low

multaneously. According to the frequency-hopping (FH) approach comprising all of the 79 channels this is not strictly possible with Bluetooth as indicated in the table.

Although the transceiver physical characteristics are very similar in terms of transmit power, the power consumption for ZigBee is considered to be less than for Bluetooth in personal telehealth applications. This is mainly due to the FHSS approach of Bluetooth, where synchronization to the FH-sequence of the master (e.g. the compute engine) is required by a medical device. When entering a power saving mode either a timer running is required to stay in sync or synchronization is required when reconnecting to the network which can take in average little less than one second. However, for both methods the resulting additional power consumption, and hence the effect on battery lifetime, is significant if frequent episodic measurements are employed. In contrast, ZigBee devices do not require synchronization with the network as they use a carrier sense multiple access (CSMA) approach.

Another main difference of both technologies is the supported network topology. While Bluetooth can be considered mainly as a single-hop wireless cable-replacement technology ZigBee supports a variety of different network technologies including most general mesh networking with multi-hop routing. A good comparison of both technologies is also given in [15], though with the focus on body-worn sensor networks. To summarize, due to their different technological characteristics it is expected that ZigBee and Bluetooth will take on complementary roles in the broad domain of personal telehealth.

An important advantage of Bluetooth, which makes it a prime candidate for wireless telehealth applications today, is its standard maturity and availability for end user products. The latest version of Bluetooth [12] is version 2.0 with the next release being expected early 2007. Furthermore, end of

2006 the Bluetooth SIG claimed that already more than 1 billion Bluetooth devices have been shipped so far.

However, both Bluetooth and ZigBee basically cover only the lower OSI layers up to the transport layer. In order to establish interoperability from the physical layer to the application layer for personal health devices, they can be used as a transport under the data model and format specified in the upper layers by x73. There are in principle two different ways to achieve this. Either certain transport profiles for the various wireless transport technologies are defined in the 11073-3yzz series of standards, or certain application profiles are defined on top of the wireless transports. The latter option is currently pursued for Bluetooth. In May 2006 the Bluetooth SIG announced the formation of a *Medical Devices* working group. This group initially comprised 19 industry companies and aims at defining an application profile for personal health and fitness devices. As the group desires to leverage existing standards where possible, it can be expected that it will adopt the data models and format of the x73 PHD working group. Also, the group's profile itself might be adopted by the Continua alliance.

It is expected that the formation of a similar working group will be pursued in the ZigBee alliance as well. The ZigBee Application Framework group has already issued a call for participation in a *Personal / Home Health Care* study group in September 2006.

VI. CONCLUSIONS

Personal telehealth systems have the potential to cope with today's major healthcare challenge of improving the quality of care for an increasing number of chronically ill patients using limited financial and human resources. Today, there exist a lot of technologies and technology standards, but still being isolated solutions to the overall complex problem. However, there is significant activity in industry and in standardization organizations aiming at enabling real plug-and-play multi-vendor interoperability in the personal telehealth ecosystem. An industry consortium as the Continua Health Alliance is a step towards the right direction. However, one of the next steps should also be building a large-scale real-world demonstration that shows the realization of the vision.

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