Home-Based Telemonitoring Architecture To Manage Health Information Based on Ontology Solutions

N. Lasierra, A. Alesanco and J. García

Abstract—**This paper presents an architecture for home telemonitoring scenarios based on ontology model solution. It can be divided into physical and conceptual layer. In the conceptual layer, the ontology is used as a common knowledge representation of involved data in the telemonitoring process. In this way, a formal solution to integrate information in both end sites of a telemonitoring scenario and also to the communication between them is provided. In the physical layer, the communication between the main sites of the architecture is done through ontology instances exchange using web service technologies. The main modules developed in the architecture and their functionality are also reported. Finally, a communication data flow example between the units of the architecture for a generic patient telemonitoring process is presented.**

I. Introduction

Nowadays, home-based care of patients with chronic conditions by means of telemonitoring solutions is becoming widely used. The increase in sanitary costs produced by a growing population (mainly the elderly people) with chronic conditions in western countries, on the one hand, and the improvement in the quality of life these solutions provide for these patients, on the other, have encouraged the development of this type of telemedicine systems [1].

A general home-based telemonitoring architecture is composed by two entities: home site and healthcare site, linked using a communication network. In the home site, patients themselves acquire periodically measurements (e. g. the blood pressure) to monitor their current health condition according to guidelines provided by a physician. Patient's data acquired from medical devices and also from patient feedback are collected in a concentrator device used to integrate the collected data and send it outside patient's home, if necessary. Depending on the telemonitoring scenario, the obtained results could alert patients to carry on some actions and/or have to be transmitted outside patient's home in order the physician to be aware of them and take actions if it is required. In the healthcare site, a central server device is used to manage information from home site as well as to manage and to store patient's monitoring guidelines defined by physicians. Besides, this device can be used to retrieve data from patient's electronic health record (EHR) and/or to integrate into it the complete information involved in the telemonitoring process. All this information involved in a home-based telemonitoring scenario i.e. monitoring guidelines, patient data results and related actions to be taken if necessary, constitutes what in this paper has been termed as patient profile.

Both sites of the telemonitoring scenario have to deal with heterogeneous information coming from different data sources. For example, in home site, the standard protocol ISO 11073 [2] can be used by a medical device to transfer data to the concentrator but another one can use a manufacturer's proprietary protocol to do it. Besides, patient can provide additional information. By the same way, in healthcare site, physicians provide information and also, it can be retrieved from patient's health record (EHR) and/or integrated there using different standards such as EN 13606 [3] or HL7 [4] for transference. Each one of these data sources has its own conceptualization about the shared information. Therefore, in order to integrate data in each site of the architecture and avoid semantic mismatches is necessary a common formal schema to represent the shared knowledge. Although not the same information is managed in both end sites, telemonitoring data provided by the different sources is related for each patient constituting what has been termed as patient profile. Hence, an interesting solution is to use the same conceptual model in both end sites to unify managed information. Thus a common knowledge representation for home site and healthcare site is provided that also can be used in the communication-link by them to exchange information in a formal way. This aim can be achieved by the use of ontologies.

Ontology-based solutions have become recently the most used approach to represent knowledge in a formal way and they have already been applied in home-based telemonitoring scenarios. See for example [5] where a context-aware platform based on ontology for continuous caregiver for patient with chronic conditions is developed or [6] where an ontology-based mobile platform is proposed to integrate clinical data from patient's sensor.

In this paper, an architecture proposal for representing and sharing information in a home-based telemonitoring scenario based on ontology model and web service technologies is presented. Unlike other home-based telemonitoring systems proposed in recent years [7], our

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approach deals with ontologies to semantically integrate information in both end sites of the architecture. It's important to highlight also that although other works [5][6] also propose the development of an ontology as a formal solution, in the architecture presented in this paper, the physical communication between home site and healthcare site is based on ontology instances exchange in a generic way. Hence, great flexibility is provided in the communication architecture.

The paper is organized as follows: Section II exposes the general system architecture divided into two layers (conceptual and physical), describes the developed modules and also the communication between both end sites. Section III describes an example of the data flow communication involved in the home-based telemonitoring process and also describes briefly the ontology used for it in the architecture. Finally Section IV concludes with a summary about all the issues achieved with the proposed architecture.

II. General system architecture

The general architecture of the proposed home telemonitoring system is depicted in Fig. 1. It is divided into physical and conceptual layers thus providing a flexible and reusable communication structure. At the physical layer, the telemonitoring system is composed by the Monitoring Server, MS, placed in the healthcare site, and several Compute Engines, CEs linked to it, placed, each one, in a different home site. They are used to gather all the data provided by medical devices, sensors and patients themselves and also to transfer information to the healthcare site. The MS is a central server used to manage the information provided and collected from the CEs. It can be used also to retrieve data from patient's electronic health record and to integrate there further all the telemonitoring information.

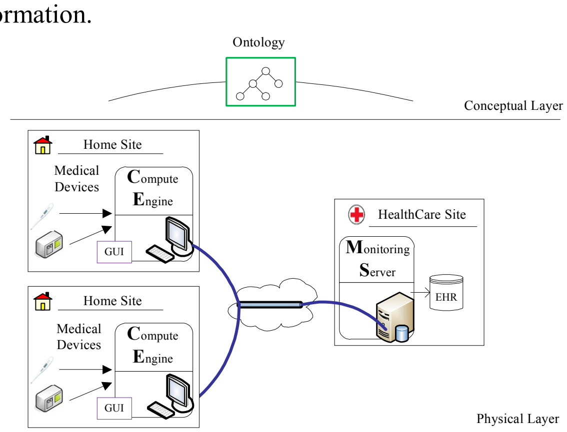

Fig. 1. General Telemonitoring Architecture.

A. Conceptual Layer

As it is represented in Fig. 1, in the conceptual layer, the communication between both end sites is done through the ontology. In practical terms, an ontology is a hierarchy of concepts with a set of properties and relations that provides a formalized representation of a common view of a determined domain. Hence, the ontology provides with a common view of involved data in the telemonitoring process. Thus, the telemonitoring solution is supported by a formal and generic model with a clear semantics not conditioned by any data model used to collect information from home site or storage model in the healthcare site or any other further transmission outside the MS.

OWL (Ontology Web Language) [8] has been selected as the ontology language to describe the ontology used in the conceptual layer. The communication module of our architecture is based on OWL instances exchange in a generic way by means of a developed object structure. Thus, any ontology developed in OWL that describes a patient profile could be used in the conceptual layer of our architecture to generate individual monitoring profiles for each patient.

B. Physical Layer

In the physical layer, the developed modules for the MS and for the CE have been grouped in the *MS management module* and in the *CE management module* respectively, as it can be seen in Fig. 2. These modules are based on Jena, a Java framework used to develop semantic applications.

1) MS Management Module. As it is represented in Fig. 2 this one contains next modules:

-- *Ontology Knowledge Base*. It is used to store the ontology knowledge and also the generated instances of patient profile information. That means, configured information provided by physicians and collected results from all home sites. A MySQL database has been selected to implement it.

-- *Web Service*. As it shown in Fig. 2, the communication between the CE and the MS is done through the exchange of ontology instances using Web Services technology standards (SOAP, Simple Object Access Protocol, and WSDL, Web Services Description Language). In the MS, a web service has been developed in order to deal with information from all linked CEs.

-- *Individual Health Middleware*. The communication between the *Ontology Knowledge Base* and the *Web Service* is done through this module. It processes incoming information and tests if it verifies the ontology model before saving it. It converts OWL objects from Jena Model to the developed object to exchange instances in a generic way and also to the other way round.

-- *Data Evaluation module*. It is used to detect out of range measurements values or to evaluate other detailed alarms. In some scenarios, the evaluation function could be interesting to be performed in the MS rather than in the CE (e.g. if the CE software has any memory resource limitation), that's the reason why it is implemented in both sites.

-- *Alarm Transmission*. It is used to manage clinical alarm communication targeted to physicians or patient's relative.

Furthermore, inside the MS, but outside the *MS Management Module*, two modules have been represented in Fig. 2*: Information Provider* and *Information Collector*.

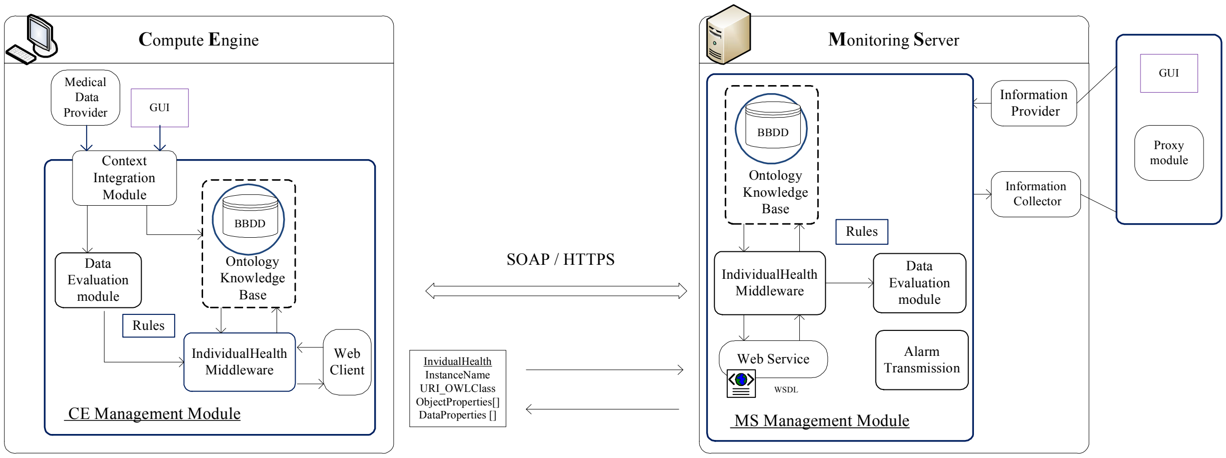

Fig. 2. Telemonitoring Architecture: Management Modules and Communication link.

They represent any information source used to provide patient's monitoring guidelines (physicians, who manage patient profiles through a software tool, or/and information retrieved from patient's EHR through a proxy module to the selected method to transmit the information) and to transfer outside MS telemonitoring acquired results respectively.

2) CE Management Module. This one is composed by next modules:

-- *Context Integration Module*. It is used to assemble measurements results obtained by medical data providers (which can retrieve information from medical devices and sensors) and contextual data provided by patients.

-- *Web Client*. It is used to collect monitoring guidelines from the MS and transfer there the obtained results.

Data Evaluation Module, *Ontology Knowledge Base* and *Individual Health Middleware* have the same functionality than the described in the MS, however, in the *Ontology Knowledge Base*, just the ontology knowledge and the instances related to the patients associated to this CE will be stored there.

3) MS-CE communication.

In the architecture presented in this paper, the communication between CE and MS is based on generic instances OWL exchange by means of web service technologies. Using OWL language, an individual of the ontology can be described as a membership of a class with individual axioms or facts as individual properties values (data properties and object properties). Our proposed structure to exchange information permits to describe individuals, thus containing the instance name, the URI of the class it belongs to, the list of data properties values it has and the relations it has with other individuals of the ontology that means the list of object properties it has. As the object properties link individuals to others individuals, this object structure allows to chain individual definitions, so, when a result is sent from CE to MS, not only the result's instance is sent but also the individual instances related to it what place in context the received result. In the architecture workflow, the assumption that different names refer to different things is made, so no facts about the identity of the individuals are included in the interchanged objects. In Fig. 2, this object structure has been referred to as Individual Health.

To provide with security in the communication link, TSLv1 protocol (Transport Layer Security) over HTTP (or HTTPS) is used between the web ends points, thus the integrity and reliability of exchanged data are guarantee.

III. Data Flow Communication Example

To illustrate the functionality of the home-based telemonitoring system we have developed an ontology to be used in the conceptual layer of our architecture that it is extensively described in [9]. It defines 5 sections to organize clinical data: measurements (this section covers a wide range of possible measurements that can be acquired in a home-based telemonitoring scenario to provide a flexible structure to define profiles for different telemonitoring cases), reminders (they refer to alarms targeted to patients), alarms (used to aware physicians about anomalous situations), environmental information (to report about environment conditions that can alter measurements results) and health qualitative information (used to report subjective information about patient's health status). Therefore, it provides a formal structure to define clinical guidelines, patient's data and some actions related to measurements evaluation.

The architecture information workflow between end sites is based on the exchange of ontology instances, sending configured information by physicians (monitoring guidelines, evaluation ranges and actions) from the MS to the CE and transferring monitoring results (patient's data results as well as alarm results) from CE to MS.

In order to show the communication flow between the entities involved during the telemonitoring process, a generic example of the exchanged messages since a monitoring profile is configured in the MS up to the results are sent outside MS to patient's electronic health record is detailed below step by step and represented in Fig.3.

1) *Patient Profile Configuration*. In the MS, monitoring guidelines, clinical alarms, reminders and all contextual information needed to the patient follow-up are configured through the *Information Provider module*. This information can be configured directly by physicians in the MS or it can be retrieved from patient's EHR.

2) *Patient Profile Request.* Patient site requests the associated patient profile through a connection from the CE web client to the MS web service.
3) *Ack PatientProfile.* If the required profile exists, it is sent back to the CE.
4) *Get Measurements Results.* Once the patient profile instance is saved in the *Ontology Knowledge Base*, measurements results coming from medical devices and additional information provided by patients about how the test was performed, are collected by the context integration module and will be stored in the database. In addition, the obtained results are evaluated in the CE in relation to the guidelines defined in the profile in order to detect clinical alarms.
5) *Send Measurements Results.* Measurement results will be sent to the MS according to a transmission policy if it is specified in the profile. In the presented example, all the received results are sent to the MS.
6) *Ack.* MS management module reports that the results have been saved correctly in the database. If any error occurs it will be reported also to the CE.
7) *Alarm Triggered.* Apart from measurements results, if an out of range value measurement is detected or other defined alarm in the patient profile is triggered, an alarm result will be sent to the MS, where the alarm transmission module will notify it to the associated physician or relative.
8) *Monitoring Results.* Finally, once the monitoring process is over or when the physician decides, monitoring results can be sent to the patient's electronic health record through the *Information Collector module*.

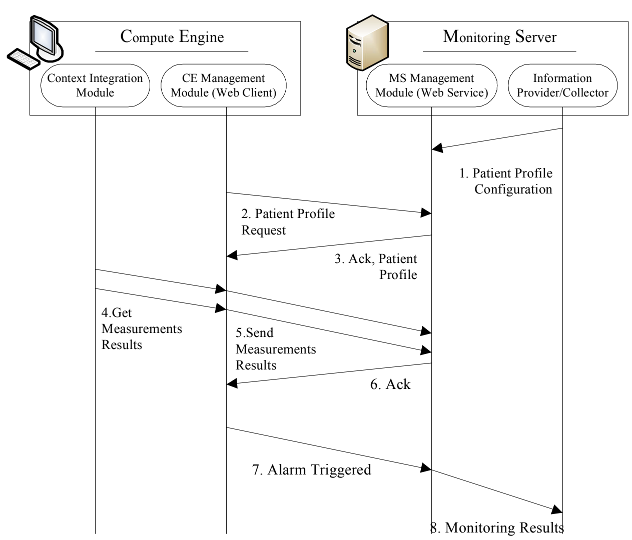

Fig. 3. Data flow communication example.

According to patient's evolution, patient's guidelines can be updated by physicians. Therefore if there is a new version of the patient's profile in the MS, it is notified to the CE which requests the new profile in order to update the saved one.

IV. Conclusions

In this paper an architecture based on ontology model for home-based telemonitoring scenarios has been presented. It is divided into physical and conceptual layers thus providing a flexible communication structure. On the proposed architecture, the ontology is used as formal solution to unify incoming data from heterogeneous sources in both end sites of a home telemonitoring scenario. As the same conceptualization can be applied in both home site and healthcare site, the ontology is used as a common knowledge to share information between sites. By this way, we achieve a formal solution to be used in the communication link of a home telemonitoring scenario.

Note that our solution does not depend on any information model source, so anyone could be used in home site for medical device communication or/and in healthcare site to integrate information in patient's health record by relating the knowledge model with the ontology.

The communication in the physical link between sites of the developed architecture is based on OWL ontology instances exchange in a generic way. Therefore the communication in the physical layer does not depend specifically on the information described in the ontology used in the conceptual layer for the communication. Thus, this communication method to exchange information could be also applied in any other application based on an ontology model.

Currently we are working in the integration of technical information in our architecture. The aim is to integrate medical devices, CE and MS technical management in the home-based telemonitoring system, thus providing an architecture to support technical and clinical information exchange simultaneously based on a formal and extensible model.

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