eHealth – Unified Healthcare Logical Space through Applied Interoperability

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Abstract— **The current paper presents a patient-centric approach that implements a unified healthcare logical space model for medical information environment. We focused our work on interoperability features with extensive usage of standards in order to develop a distributed information framework: a pilot system called CardioNET. This eHealth system was designed to integrate medical services from various healthcare providers and improve the quality of services, through some of latest medical and IT&C technologies. Modern healthcare activities require a patient-centric vision, where patients must receive medical attention or treatment anytime, regardless of their physical location. CardioNET embodies this approach where hardware, software and medical activities become "services" of a "logical cardio-health care domain-space". This distributed environment also offers tools for remote interactions between patients, doctors, medical entities (e.g. hospitals, labs) and authorities. Based on international domain standards (IDC10, LOINC, HL7), the system creates an infrastructure for interoperability and data exchange using widely accepted formats (HL7 messages, or XML records). High level protocols (UDDI, SOAP/HL7 and HTTP) provide the presented framework the means to exchange of HL7 or XML compliant messages between the systems' main healthcare actors. CardioNet subsystems have specialized metadata registries and shared data repositories, which altogether create a distributed healthcare pilot environment for medical decisions support, research and educational activities.**

Keywords— **e-health, interoperability, tele-medicine.**

I. Introduction

Healthcare data flows and associated data structures are very complex and are formalized with a lot of methods, by different institutions. Joined-up, these „objects" are more difficult to handle when patients with multiple problems are treated by several specialists in jurisdictionally different locations. Solutions? Domain standards utilization to achieve the full health systems interoperability. All aspects of the medical processes: data flows, the practice of Evidence-Based Medicine (EBM - one of the most important developments in the clinical practices over the last years) require the integration of clinical expertise with the external facts and with patient's life parameters and circumstances, to create a realist Electronic Health Record (EHR) as support for medical decisions. Recent developments in healthcare data standardization processes create large interoperability opportunities between different healthcare information systems. Nowadays IT&C, offers the possibility to quickly develop, access, change and share meaningful information, about patients and their health, beyond organization boundaries.

The domain's standards utilization must be extended beyond their primary definitions, in order to achieve interoperability and bring together disparate systems. For healthcare entities the goal is cross-borders access to observations, reports and results of medical procedures (trials, claims, infectious disease reports, patient summaries), access that will eventually extend across jurisdictional (national or regional) borders. Interoperability is a prerequisite for the process of the old Health Information Systems reengineering, that will reduce the costs, errors, delays, and development repetition efforts.

The transformation of healthcare services depends critically on interoperability, enabling computers to share data and deliver information from where it originates to where they are needed. When interoperability will be a commonplace, patients, clinicians, managers, and researchers will enjoy secure access to the right information at the right time and at the right place, leading to better patient outcomes and fewer mistakes.

The current paper presents the results of an interdisciplinary research effort to develop a framework for medical data exchange. We present here, an enterprises-cross border service-oriented approach, CardioNet distributed information system, HL7&IHE based.

II. Background: standards, organisations, trends

Worldwide the HIS (Healthcare Information Systems) interoperability is one of the core themes. The US Federal Health Information Technology Strategic Plan, states: "to effectively exchange health information, health IT systems and products must use consistent, specific data and technical standards", [1]. The main goal of NESSI(Networked

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European Software and Services Initiative) is to develop a visionary unified European Strategy for Software and Services[2]. The National Health System (NHS) Informatics Review 2008, set out a vision to support patient-centered care in a way that empowers patients to be more involved in their care and staff to improve Great Britain's NHS performance [3].

For the lack of space we present only a small number of examples, still there are a lot of other countries who make large efforts towards this coming globalized market, not only in the healthcare field.

Besides international organizations for standards development: ISO, CEN, BSI, ANSI, IEEE, we remind here several specialized standards and organizations in healthcare area: SNOMED, IHE, HL7, ICD10, DICOM, LOINC, and some IT&C standards: SOA, SOAP, ISO/OSI, SaaS, Web Services and UDDI. All of them are deeply implied in the interoperability implementation processes between healthcare information systems.

SNOMED CT - Systematized Nomenclature of Medicine Clinical Terms, provides a comprehensive clinical terminology, analogous to a dictionary [4].

ICD-10 - International Classification of Diseases (ICD), was endorsed by the World Health Assembly in May 1990 and came into use in WHO Member States as from 1994[5].

LOINC - Laboratory Object Identifier and Numerical Code, LOINC® and RELMA® are trademarks of U.S. Regenstrief Institute, Inc. Codes and other information from the LOINC are used in electronic messages building for labs test results and clinical observations [6].

DICOM - Digital Imaging and Communications in Medicine standard is required by all EHR systems that include images' information, as a part of the patient records [7].

HL7 - Health Level 7, a non-profit organization, developing standards for the exchange of clinical and administrative data. HL7 provides a grammar as standardized structures for healthcare communications using messages [8].

IHE - Integrating the Healthcare Enterprise was established in 1999 by the Healthcare Information Systems and Management Society (HIMSS) and the radiological Society of North America (RSNA) to improve the way healthcare computer systems share information. IHE has defined an integration profile called Cross-enterprise Document Sharing (XDS) [9]. IHE – XDS allows healthcare documents to be shared over a wide area network, between hospitals, primary care providers, and social services. Documents are discovered using UDDI-Universal Description Discovery and Integration and exchanged using SOAP and HTTP protocols, largely based on HL7 messages standard, while SQL is used for information retrieval. The model developing within the U. S. suggests that medical data sharing will happen first at a local level, as part of Regional Health Information Organizations (RHIO) and then between RHIOs.

Usually healthcare information systems have been organized hierarchically, with the government at the top, then healthcare-provider organizations (hospitals), followed by departments, clinicians, and eventually the patient, at the end of chain. This hierarchy reflects the flow of power, authority and money, but has little in common with the natural flow of healthcare data, resulted from the actual care of patients. In reality „patient care looks like a social network, where each individual patient is in the centre of a healthcare net"[10]. Nowadays, the interoperability between healthcare systems is a challenge and a corner-stone. The documentation for all the previously presented aspects runs to thousands of pages and creates a steep learning curve and barrier for starting point.

III. UNIFIED HEALTHCARE LOGICAL SPACE - CARDIONET PROJECT

The new patient-centric vision is quite different: the center of systems is the patient with his data and episodic or long term problems, and not the healthcare organizations. This model is based on continuous healing relationships, customized according to individual patient needs and values, with the patient as the ultimate source of control. Knowledge is shared, information flows freely, and decision-making is evidence-based. Transparency and collaboration are common behaviors, patient needs are anticipated, and effort is devoted toward reducing any activity that delivers no benefit to the patient. An electronic health record (EHR) is not necessarily stored as a single physical entity in a centralized system.

The idea is to build patient records on the fly from a variety of clinical documents created by different healthcare organizations. The record required (EHR-Electronic Health Record) can be aggregated into a single coherent record, at request, from data stored at various geographical locations. We take all these new ideas to design and implement a „Unified Healthcare Logical Space"- UHLS pilot for our healthcare information distributed system.

The CardioNet project is an interdisciplinary applicative research project in concordance with the Romanian Ministry of Health public health program. It was designed to comply with national and international standards and trends in cardiology. The UHLS distributed environment includes several local (Cluj-Napoca) healthcare organizations and aimed:

- to create a surveillance and medical data acquisition unified infrastructure;
- to create a set of medical applications deployed at different medical entities and institutions;
- to create a distributed medical data repository built upon a domain ontology (cardiology);

- to share a set of software services necessary for real-time medical data acquisition, classification, decision support, statistical analysis, long term storage and controlled access.

The system was designed as SOA model where hardware, software and medical activities become services. CardioNet connects a group of healthcare entities that have agreed to work together using a common set of policies and to share a common infrastructure. Figure 1 shows an overview of the CardioNET's „medical logical space", emphasizing the actors of the system, their roles and interactions. During the implementation stages of the CardioNet distributed environment the following main integrated subsystems were identified:

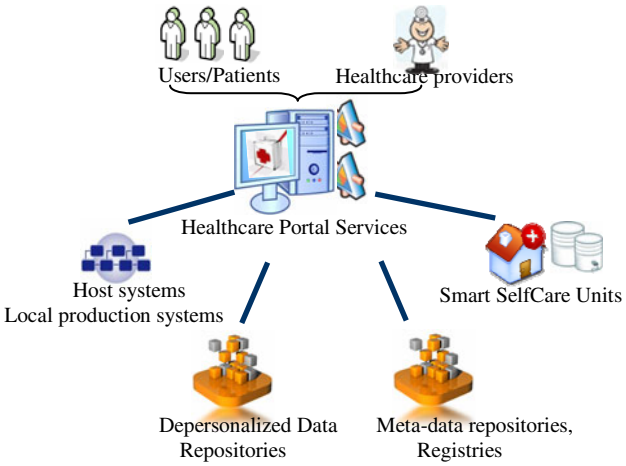

Fig. 1 UHLS – CardioNET Overview

- Host systems, as local production systems (with local operational databases, h-DB) [11]:
  a. General Practitioner systems [Figure 2];
  b. Analysis Laboratory systems [Figure 3];
  c. Hospital systems [Figure 4].
- Portal services: education, resources registries and repositories, data exchanges [11] [Figure 5];
- Smart Self Care Units - SSCU as home systems with personal databases, p-DB [12].

At the portal level, "patient-centric" medical services are discovered using specialized registries that among other functions, allow controlled access to data stored in the shared repositories.

In this boundary-less environment, the proper identification (patients, practitioners, and healthcare facilities) is a key feature for the platform subsystems. Currently four types of centralized registries were defined: Persons, Providers, Facilities and Locations. For each registry a master index was built – set of software tools that assure better identification and access to the resource. EHR-Electronic Health Record will be dynamically built at run-time, as Virtual Patient Records, from a variety of clinical events and documents managed by different healthcare organizations and providers, who agreed to operate in this way.

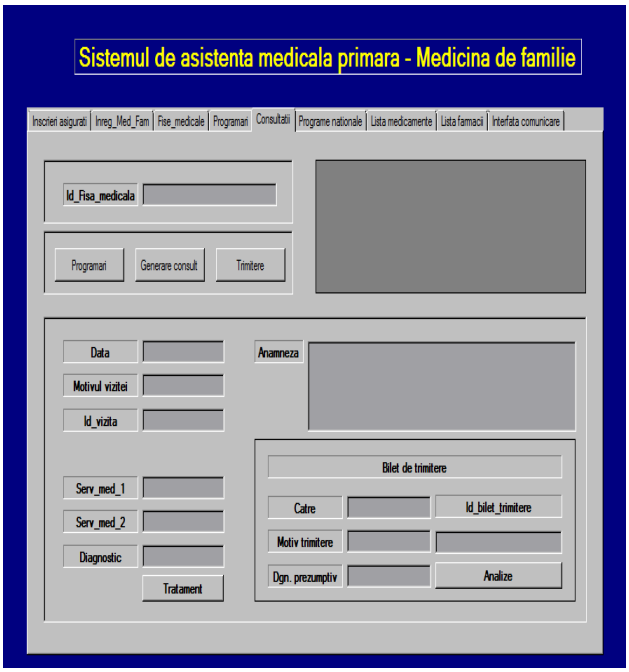

Fig. 2 UHLS- General Practitioner – Observations UI

The innovation is the logical and physical separation of the indexed metadata built from current information registrations, used then to retrieve documents through this unified virtual space. CardioNet distributed subsystems can operate in two modes:

Local Mode as an enterprise-internal mode.

Network Mode as integrated components of a logical unified virtual space.

In the local mode CardioNet enables actors to operate intranet (enterprise-internal mode), with local administrative and clinical data. In the network operating mode, CardioNet system provides secured access to local databases and offers a range of services for: health insurers, clinical decision-making entities, management authorities or other health services providers/consumers (depersonalized databases analysis, resources monitoring, etc.).

A. *Local Hub Centers (L-HC) or Portals*

L-HCs' repositories and services assure controlled access to electronic medical record containing patients' medication

histories, lab results, allergies and other vital health information. The access is available, not only to the doctors, but to pharmacists too, as well as other members of the patients' team of care providers. The CardioNet portal (located at SC CIA SA project partner) enables users (consumers) to retrieve different types of documents (letters, results, images) contained in one or more repositories in a quick and reliable manner. We also created the way to integrate „in house – standalone" systems: for instance we integrated in our system a Radiotherapy Information System [Figure 3], running Filemaker 9 server located at Cancer Institute "Ion Chiricuța" [13].

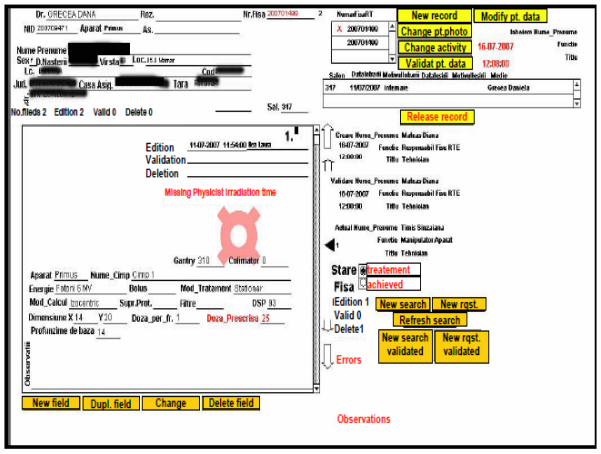

Fig. 3 Radiotherapy system – Observations UI, [13]

B. *Host Systems*

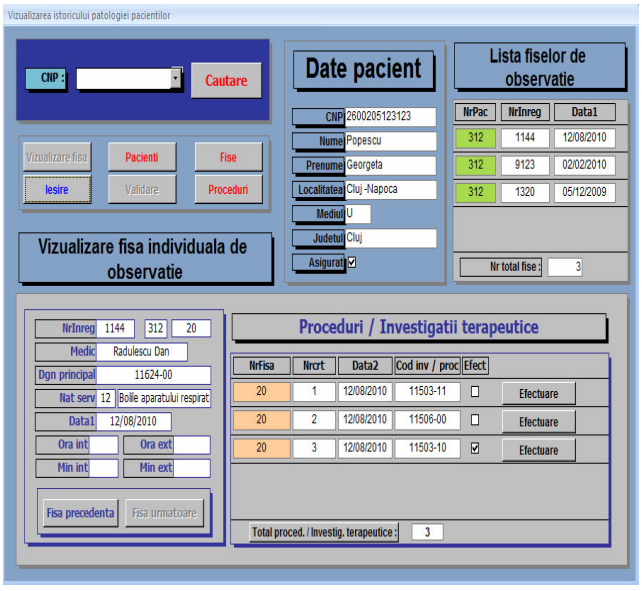

Fig. 4 Clinical host system – Observations UI

Host Systems are built of information systems and database servers [Figure 4], access points and fixed/mobile interconnected medical devices. The clinical information system was tested at clinical hospital UMF Medicala V (project partner). The CardioNet portal provides the infrastructure required to collect information from the mentioned local systems into shared repositories. At the portal level, "patient-centric" services [Figure 5] was tested and will be assured using data stored into the local repositories.

C. *UHLS through Registries, Web Services, Master Indexes and HL7 Messages*

UHLS critical functions are provided through portal registries and web services collections. [Figure 5] presents the UHLS portal – unifying B2B&B2C services, grouped for: User authentication, Demographic matching and Patient registration, Resources for unique identification, Identifiers mapping, Records and documents discovering services, Records and documents exchange services, etc.

Fig. 5 UHLS CardioNet portal – Educational section

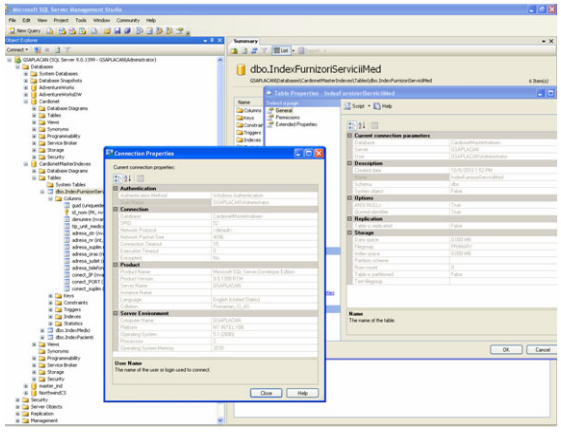

Fig. 6 UHLS-Portal providers' master index tables

***Portal resources**: master indexes, registries and web services.* CardioNet portal implements master indexes and registries for: Persons, Providers [Figure 6], Facilities and Locations. Master indexes by GUIDs (global unique identifiers) and dedicated methods provide the means to uniquely identify any networked and shared resource. Using UDDI services(Universal Description Discovery and Integration) on the CardioNet portal the resources are discovered, identified and eventually used to call web services and collect data from production systems (using HL7 messages). All the methods of the web services [Figure 7] use SOAP messages in order to expose functionality: both the requests and the replies are embedded in soap envelopes that respect the format of each particular web method. Invocation of the web methods returns data objects available in the system's metadata repository. Cross platform interoperability is obtained by serializing data objects in widely accepted standards (such as HL7 and XML).

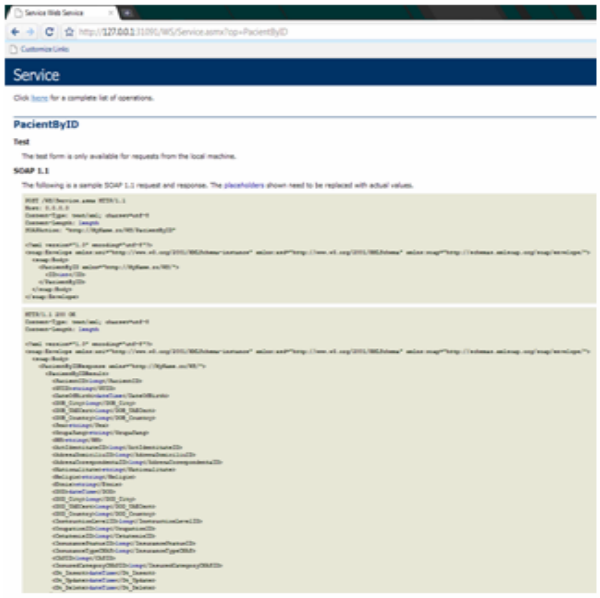

Fig. 7 UHLS – Portal web service example: PatientByID

HL7 Messages. Cardionet-IUI is a pilot project that provides interoperability through HL7 User Interface. The system was designed based on HL7&IHE and LOINC standards. This approach proposes standardized HL7 messages formats and codes for automatic data exchanges between clinical, hospital and commercial laboratories to complete Electronic Health Records of production systems. A sample HL7 message instance shown in the following:

MSH|^~\&||^IOCN^Labs|||200808141530||ORU^R01|123456789|P|2.4
PID|||123456^^^SMH^PI||POPESCU^VASILE||19620114|M|||4 Republicii^ClujNapoca^^^MM1 9DL
PV1|||5N|||||G123456^DR POPESCU ION
OBR|||54321|666777^CULTURE^LN|||20080802||||||||SW^^^FOOT^RT|C987654
OBX||CE|500152^AMP|01||||R|||F
OBX||CE|500155^SXT|01||||S|||F
OBX||CE|500162^CIP|01||||S|||F

Note : The OBX segment repeats information about the susceptibilities of detected organism (linked by using the Observation Sub-ID field).

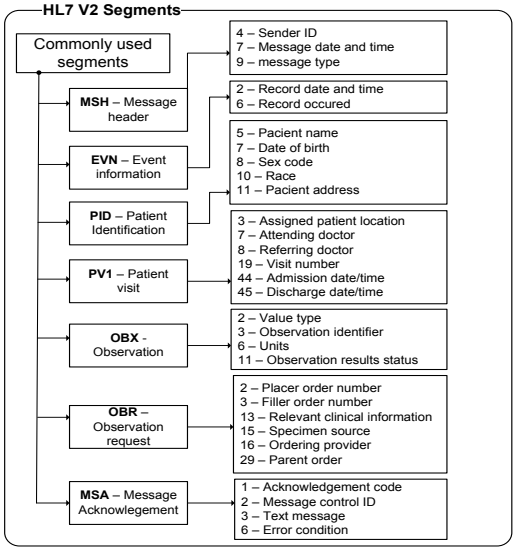

Fig. 8 List of the main HL7 v2.x used segments

This approach has selected a subset of HL7 v2.x [Figure 8] messages for observations and patient registration activities. [Figure 9] - UI sample to present data exchanging between Clinical and Labs information systems [14].

SSCU – Smart Self Care Units. A typical SSCU's is composed of several medical sensors for patients' vital sign monitoring. The data acquisition layer in the SSCUs has two versions: medical sensors are integrated in custom hardware platforms or the sensors are embedded in commercial solutions available at different vendors [15][16]. Data collected at the SSCU is stored locally on the patient's PDA and computer and eventually transferred in the CardioNET system for persistent long-term storage.

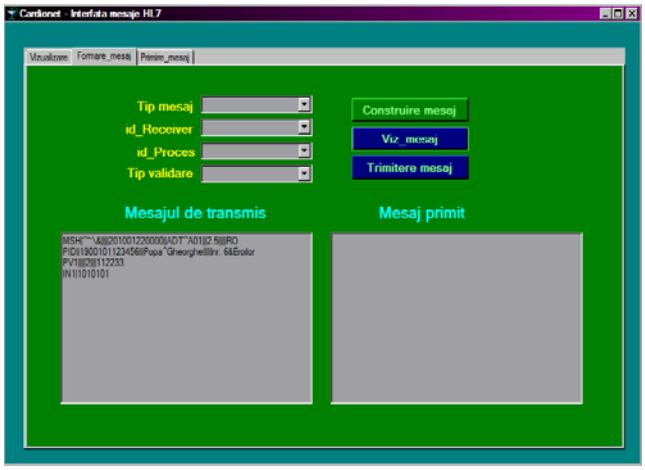

Fig. 9 Cardionet – HL7 exchanging message UI sample

IV. Conclusions and Future Work

The implementation of a distributed eHealth system is a complex task that involves: remote data acquisition and monitoring, data logging and information exchange between medical entities, applications and users. This paper presents a model for an eHealth system providing solutions to both medical and IT related problems including the remote monitoring of patients' medical status. The information gathered through web-services is preserved into specialized databases built as a domain metadata repository. This approach reviles complex relations between different concepts involved in a medical act and assures both interoperability and transparent exchange of data between different medical applications while providing support for better medical diagnoses and treatment. The proposed pilot solution was implemented for monitoring and treating patients with cardio-vascular diseases. This approach reduces significantly the time spent by patients in hospitals, allows remote monitoring of patients with chronic diseases and facilitates a flexible patient-doctor interaction over the Internet. The project partners interoperability tests show that HL7 standard is a reliable solution and can be applied for intercomunication at application level.

As future work, the authors intend to add more elements of intelligence to the system, such as: data-mining procedures for specialized clinical trials, statistical evaluation facilities and alternative decision support services.

Acknowledgment

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