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eHealth: Towards a Healthcare Service-Oriented Boundary-Less Infrastructure

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Abstract

The current paper presents several interoperability features applied to a local distributed information system, CardioNET, meant to improve quality of healthcare services, through the use of the latest medical and IT&C technologies. Modern healthcare systems require a patient-centric vision, where patients must receive medical attention or treatment anytime, regardless of their physical location. The eHealth distributed system we present – CardioNET is based on a SOA producer-consumer model taking a patient centric approach where every hardware, software and medical activities become "services". The system offers tools for remote interactions between patients, doctors, medical entities (e.g. hospitals, labs) and authorities. Based on international standards (IDC10, LOINC, HL7), the system assures interoperability and data exchange in widely accepted XML formats. A logical domain bus, called Pervasive Health Service Bus-pHSB, exchanges HL7 compliant data messages between the integrated elements of the platform, through high level protocols (SOAP/HL7). The paper addresses interoperability problems between medical informational platforms proposing an eHealth architecture composed of: - production systems (nodes): General Practitioner, Analysis Laboratories, Clinics, Hospitals, Home Health Care Units (H-HCU);- portal with specialized web services, registries and shared data repositories – distributed, boundary-less environment for decision support, research and educational activities.

Keywords: Hospital Information Systems; Knowledge bases; Information storage and retrieval;

Introduction

Over the last years, the Internet has become the backbone of the information processing environments, but at the same time offers insufficient levels of reliability, safety and security for industrial quality services (ex: for health information needs). On the other hand: „Healthcare is inherently fractal. The more closely you look, the more complexity you find" [1]. Furthermore, health domain information and associated data structures are very complex and formalized with different methods and by different institutions. Given these aspects it becomes more and more difficult when patients suffering of multiple problems are being treated by several specialists in jurisdictionally different locations. The solutions rely on domain standards and interoperability among health systems.

In this context, our work tries to cover the lacks in healthcare communities, enabling communication between domain specialized networked environments, through a set of generic tools built in a framework. We present here an enterprise-cross border service-oriented approach: CardioNET distributed information system, a HL7&IHE, [2,3] based framework. The currently implemented standards require extension beyond their definitions, in order to be used among separate systems, for enterprises cross-borders observations, reports in medical domains (trials, claims, infectious disease reports, patient summaries), or across jurisdictional (national or regional) borders.

Interoperability is another prerequisite for the process of standalone Health Information Systems (HIS) reengineering that will reduce the costs, errors, delays, and development repetition efforts. The transformation of health care depends critically on interoperability, enabling computers to automatically share and deliver information from where it originates to where it is 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

Background

Evidence-based medicine (EBM) is one of the most important developments in the clinical use of information over the last years. All aspects of medical processes mean information flows. The practice of EBM requires the integration of individual clinical expertise with the external clinical evidence from systematic research, with patients' unique parameters and circumstances, with the activities of creating realistic Electronic Health Records (EHR-s).

A modern EHR requires system design rules, right from the planning stages, making extensive use of standards and medical guidelines. The usage of health data standards is a mandatory requirement for interoperability between health care information systems of different medical domains. Finally IT&C as a central point has the ability to quickly develop, access, change and share meaningful data (information), about patients and their health. Such an integrated approach is used by various actors: physicians, hospitals, healthcare providers, health insurance companies, public authorities, drugs companies, pharmacies, patients and general public.

The expanding usage of Health Information Technology (HIT) has already engaged a growing number of providers and stakeholders, many of whom are now realizing the value of interoperability and standards. These standards must be implemented starting from the planning stages for an effective use of HIT. Another step in the implementation of such standards consists in the definition of data elements with common terminologies, definitions, data types, units and other attributes; templates, clinical statements, clinical documents for data interchange; EHR; decision support algorithms; security and privacy requirements.

Organizations Involved in Medical Information Standardization

Worldwide the interoperability is a core theme. Several countries are involved in large efforts for standardization of medical information. Out of these concrete examples we emphasize two of the most relevant ones, considered reference standards for the field:

- 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" [4]. The nominal focus is "to deliver an interoperable electronic healthcare record (EHR) for all Americans by 2014" [5]. Health interoperability has been given a massive impetus in the 2009 Health Information Technology for Economic and Clinical Health (HITECH) [6] initiative, which encapsulates in its name the economic and clinical necessities for IT healthcare.

- The NHS Informatics Review, 2008 [7] sets 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 GB-National Health System performance.

Beside international organizations for standards development: ISO, CEN, BSI, ANSI, IEEE, we mention several specialized standards and organizations in healthcare domain: SNOMED, IHE, HL7, ICD10, DICOM, LOINC, and in IT&C domain: SOA, SOAP, ISO/OSI, SaaS, Web Services and UDDI [8]. All of them are deeply implied into interoperability implementation processes between healthcare information systems.

For instance:

- SNOMED CT - Systematized Nomenclature of Medicine -Clinical Terms provides a comprehensive clinical terminology, analogous to a dictionary [9].
- 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 [10].
- LOINC - Laboratory Object Identifier and Numerical Code. LOINC® and RELMA® are registered United States trademarks of Regenstrief Institute, Inc. LOINC codes and other information from the LOINC can be used in electronic messages building for laboratories test results and clinical observations [11].
- HL7- Health Level 7 is a non-profit organization, developing standards for exchange of clinical and administrative data. This framework provides a custom grammar as standardized structures for healthcare communication through the use of messages [2].
- 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 help improve the way healthcare computer systems share information. IHE organization has defined an integration profile called Cross-enterprise Document Sharing (XDS). IHE – XDS which allows health care documents to be shared over a wide area network, between hospitals, primary care providers, and social services [12]. The main idea is to build virtual patient records on the fly from a variety of clinical documents created by different healthcare organizations. Documents are discovered using UDDI and exchanged using SOAP and HTTP, while SQL is used for information retrieval. The format of the metadata is largely based on HL7 messages standard. The documentation of these features runs to thousands of pages and creates a steep learning curve and barrier for starting point.

Applied Healthcare Interoperability

Given a group of healthcare enterprises (healthcare providers) with a common distributed information system, we consider four types of communication, based on the physical distance between the sender and receiver:

- within the enterprise work-group - to manage the care of individual patients;
- between specialized departments (units) - to request services and to report results;
- across organizations boundaries: between doctors, GPs and community staff - to ensure continuity of care;
- from the healthcare provider to payers and regulatory agencies - for revenue and accountability.

Healthcare information systems have been organized hierarchically: governments at the top, then healthcare-provider organizations (hospitals), followed by departments and clinicians, and ultimately 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 needed to care for individual patients. In reality patient care looks like a social network: each individual patient is at the center of healthcare net. In such approaches the interoperability between implied systems is a challenge and corner-stone.

The term interoperability means different things to different people. For example, the HIMSS Dictionary of Healthcare Information Technology Terms, Acronyms and Organizations lists 17 definitions (HIMSS 2006) [13]. We remind here a widely used definition: „Interoperability is ability of two or more systems or components to exchange information and to use the information that has been exchanged.- Institute of Electrical and Electronics Engineers, 1990".

In the particular case of healthcare we discuss about an interoperability specialized for healthcare data flows, named healthcare applied interoperability. Applying such interoperability guides the implied actors will use the same standards, terms, thesauri, rules and medical guidelines.

Enterprise-boundary-less service oriented infrastructure

An electronic medical record becomes more prevalent when there is an increasing need to share medical data across organizations. The model developing within the United States suggests that medical data sharing will happen first at a local level, as part of Regional Health Information Organizations (RHIOs) and then between RHIO's. We developed the model for the proposed distributed eHealth system – CardioNET, based on these approaches.

The new patient-centric model (Patient-Centric Health Care-NESSI, [14]) is quite different from other healthcare models: the center of systems is not the healthcare organization, but the patient with his data and episodic or long terms problems. Care 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 towards reducing any activity that delivers no benefit to the patient.

CardioNET – A Local Distributed System

The general design of the CardioNet system aimed to solve a number of interoperability requirements, considered important for a modern medical system:

- The proposed system provides a distributed solution, with autonomous medical applications, adapted and deployed to different medical entities;
- Applications can exchange medical information through HL7 messages;
- A centralized portal provides general purpose and medical-specialized collections of web services (a set of pHSB functions [15,16]) to share patients' data, as is presented in Figure 1.
- Patients access medical services through the Internet using common browsers (including interactions with their doctors);
- Optionally the system facilitates remote patients health and environment parameters monitoring, with the use of mobile medical devices.

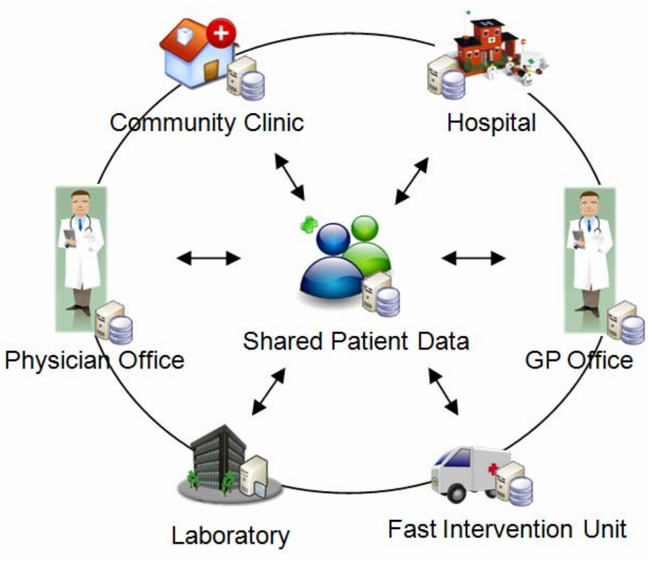

Figure 1. Patient Centric Approach. Information boundary-less data flows

To assure maximum interoperability, the CardioNET system was designed based on SOA architecture, allowing heterogeneous systems' integration. Due to its flexibility, CardioNET system offers its partners the possibility to use almost any hardware or software architecture.

In order to retrieve a patient's health history from all providers, registries will be used for services identification (directories) or identification of relationships among data objects distributed across healthcare systems. Identifying patients, healthcare practitioners, and healthcare facilities is viewed as key features for the required interoperable platform.

Currently three types of registries are being established: Persons, Providers and Services-Location Registries. Patient registries include patient health identification numbers and demographic information for patients and provide access to this information. Providers Registries assure the identification of participating providers, including doctors, pharmacists, nurses and other healthcare professionals. Finally, the Services Location Registries provide the healthcare service delivery locations where patients can receive care.

CardioNET system can operate in two modes:

- "local mode" based on the principle of an interoperable but independent portable medical record;
- "network mode" based on the principle of remote access and storage of sharable medical records.

In the local mode CardioNET enables actors to operate on the intranet, enterprise-internal mode with administrative and clinical data. In the network operating mode, CardioNET system makes it possible to securely access local databases, thus offering a range of solutions for: health insurance companies, clinical decision-making entities, management authorities or other health services providers (depersonalized databases, analysis, or the use of monitoring resources).

Local Healthcare Centers (L-HC) contain EHR repositories that assure controlled access to electronic medical record containing a patient's medication history, lab results, allergies and other vital health information. The access is available, not only for the doctor, but for the pharmacists as well as for other members of the patient's team of care providers.

From the architectural point of view the patient centric approach (shown in Figure 1) we propose for the CardioNET system has the following main components:

- Host systems, named local production systems, medical ontologies based, [15]:
  - General Practitioner system;
  - Analysis Laboratory system;
  - Hospital system;
- H-HCU- Home Health Care Units (patient home systems with p-DB personal-DataBase) [16];
- CardioNET portal (local, regional or national) for medical assistance, and long term data storage.

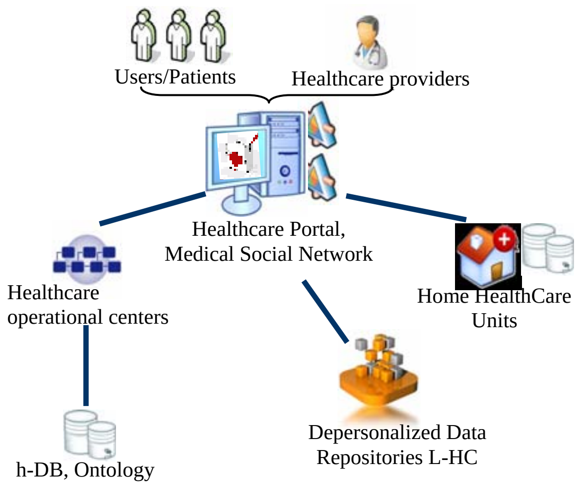

Figure 2. CardioNet - distributed healthcare system - logical overview

Host systems are built of: database servers, access points and fixed/mobile interconnected medical devices as shown in the logical overview presented in Figure 2. The CardioNET portal provides the architecture required to collect information from the mentioned local systems into a shared repository. At the portal level, "patient-centric" medical services are assured using specialized registries. Other services allow access to data stored in the previously mentioned repository.

CardioNET portal and the Pervasive Health Service Bus - pHSB

CardioNET distributed healthcare system is configured to implement business services and events in a Service Oriented Architecture with support for Event Processing. Figure 3 presents the portal's main components as it follows:

- frontend (client): uses the business services within the system (components for physicians, pharmacy, lab, others);
- services: functional implementations of specialized web-services - contract, constraint specifications and service interfaces;
- registries and data repositories: store service contracts and data records;
- pervasive Health Service Bus pHSB, interconnects frontends and services

In our context, pHSB functions' set can be generally represented by:

pHSB_ResponseM = f(pHSB_RequestM)

where *RequestM* and *ResponseM* are SOAP/HL7 messages (possibly with attachments), used to build (business and interoperability) functional features [16]. pHSB can be seen as a virtual channel for endpoint communications. A method signature of a such *f()* function, looks like:

ResponseM = SendM(pHSB_M message, string ServiceName, string MessageVersion), where

- *pHSB_M* is an XML message wrapper that process the input message;
- *ServiceName* is the name of an service in service registry;
- *MessageVersion* is the version of the messages that the client application is programmed for.

This flexibility in the application layer enables loose coupling and easy connection between platform's components. In such a complex architecture, the pHSB is a complex assembly of domain (healthcare) IT&C components that lies between the business components and enables communication among them. Ideally, the pHSB should be able to replace all direct contact between the applications, so that all communication takes place via this logical bus.

The presented implementation defines a set of messages that pHSB will use, managing both transmitting and receiving operations. When the pHSB receives data, it routes the message to the appropriate application. Often, because the application was not built with the message model in mind, the pHSB will have to transform the message into a legacy format that is understandable by the destination. The software responsible for effecting these transformations is referred to as a pHSB-adapter (analogous to a physical adapter).

To provide further details about the behavior and nature of the pHSB necessarily requires more space and specifications. The pHSB are typically built around the exchanges of XML messages. (The domain message model is defined in terms of a series of XML schema definitions describing the set of legal messages). While web services are not used exclusively, their use is common, and the message exchanges are almost always done in a HL7 compliant manner. This allows the pHSB to integrate applications that run on a variety of platforms or operating systems.

The pHSB facilitates:

- service location transparency. Business (medical or IT&C) service is exposed to consumers as a service name using a published interface, such as WSDL, which specifies the input and output structures (contracts). Service consumers have no knowledge of how a service request is fulfilled;
- a de-coupling of the exposed service from the implementation of the service.

The pHSB provides access to business (medical) services as sharable domain resources and makes their data and functionality available to all actors from defined infrastructure. The pHSB assures the sharing of resources across the entire local, regional or national specialized infrastructure (Local-pHSB, National-pHSB or Regional-pHSB).

We claim that a solution using a pHSB "mediator" for processing all domain queries is more flexible and scalable than the client-server solutions.

Further on we briefly present the main services of CardioNET system:

- services for surveillance, for medical data acquisition, classification, and storage (data acquisition on demand);
- services for real-time medical data acquisition, classification, and storage;
- interoperability services assuring communication between medical applications(servers and clients) deployed at different medical entities and institutions;
- services for exposing the distributed database system (medical data repository) built on top of a domain ontology;

Within the proposed system, the patients interact remotely with medical personnel and have access to medical services through a distributed, multi server-based application. A number of autonomous medical applications (servers) deployed in every medical center cooperate in order to offer an integrated healthcare system. Medical information concerning patients enrolled in this system is exchanged between medical entities and home healthcare units.

The platform's interoperability is assured by exposing a set of translation functions and adapters that can be used by any registered partner. These adapters are implemented as a set of services that can be discovered in the centralized data repositories, part of the pHSB presented in Figure 3. The system exposes search & discovery services to find medical features, offering to each professional or GP the possibility to seamlessly build the patient's longitudinal EHR.

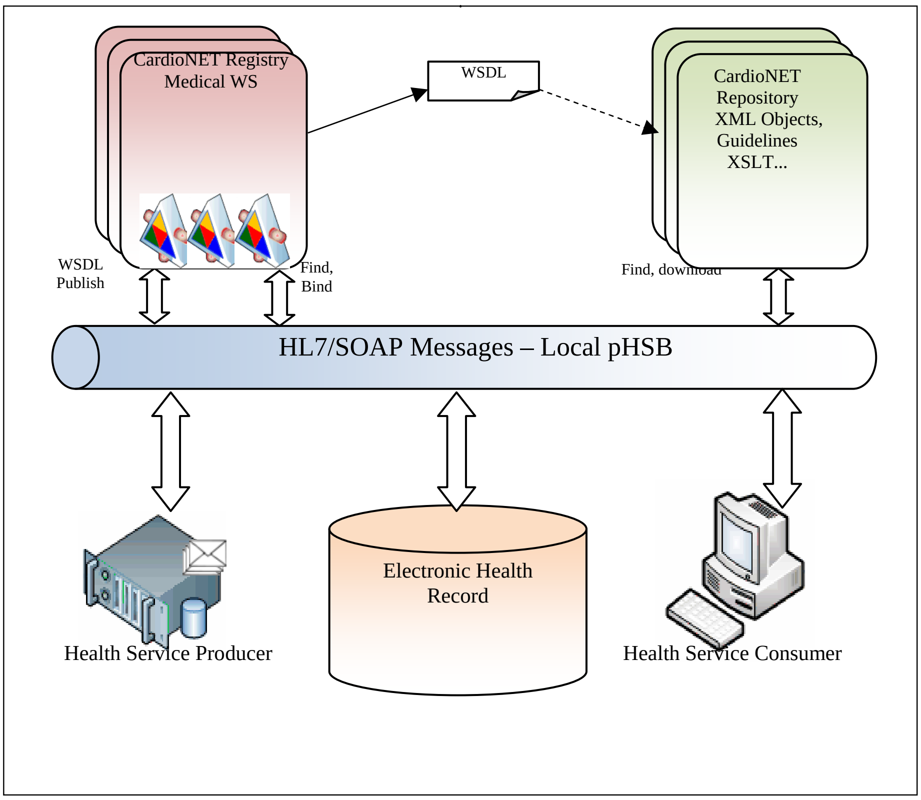

Figure 3. CardioNET - pHSB Logical Architecture

Figure 4. CardioNET HIS – clinical information system UI

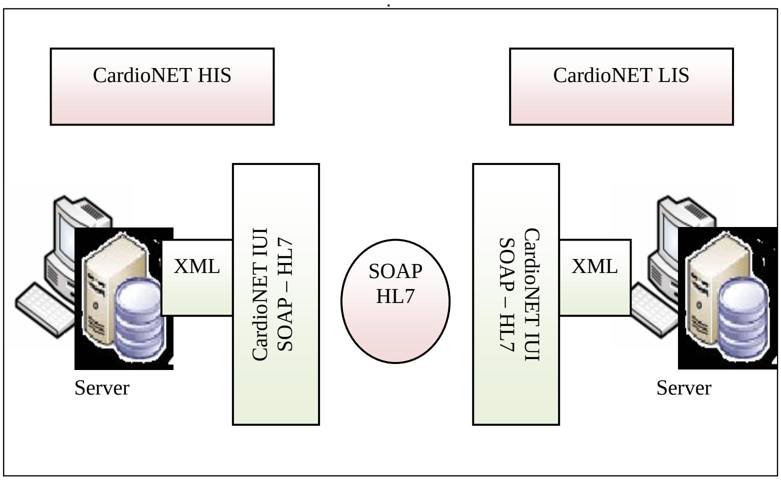

Figure 5. CardioNET IUI architectural overview

As part of Cardionet system, the portal application offers a set of useful medical services such as: information about doctors, medical units and their services, secure storage of personal medical records, discussion forum for patients and doctors, guidelines and best practices, statistical processing of medical information.

CardioNET IUI – Applied Interoperability Based on HL7 messages

A key element of a successful distributed eHealth system is interoperability, in our case achieved using HL7 messages. eHealth interoperability is assured at three major levels: syntactic interoperability, semantic interoperability and EHR interoperability [17]:

- syntactic interoperability has several sub-layers and is assured through: TCP/IP, HTTP(s), SMTP (email), SOAP, HL7 or ebXML messaging. The message content structure and the data items in the message must be standardized, as proposed by HL7 [2]. These technologies guarantee message delivery, but don't assure that the content of the message is machine-understandable at the receiver.

- semantic interoperability allows for information shared by systems to be understood at the level of formally defined domain concepts. Another important use of semantic interoperability in the healthcare domain is the integration of data from heterogeneous sources

Cardionet-IUI Interoperable User Interface presented in Figure 5, while graphic user interfaces are presented in Figure 4 and Figure 6. Cardionet-IUI is an EHR pilot subsystem interface designed for maximum interoperability, HL7&IHE and LOINC based. This approach proposes standardized formats and codes for automatic electronic messages exchanges between clinical, hospital or commercial laboratories through electronic health record EHR-systems. Samples of CardioNET HIS and CardioNET LIS user interfaces are presented here in Figure 4 and Figure 6, together with instances of HL7 messages.

Messaging in the Cardionet-IUI specification is based on HL7 version 2.4, and the interaction between components is based on the HL7 v3.0 methodology. According to this methodology, an interaction model specifies a set of distinct artifacts that, collectively, describe the dynamic (behavioral) and static (structural) aspects of data exchanges.

These interactions are, themselves, defined by the following set of components:

- Trigger events: The real-world events that causes the interactions to occur. (ex, "Inpatient registration" or "Result Available").
- Application roles: The sub-systems „actions" at the sending and receiving end of the interactions. (ex, "Order Placer", "Order Fulfiller" or their acknowledgements).
- Message Type: A precise specification of the rules that govern the construction of the HL7 message that is transmitted in the course of the interaction: the specification of fields and the contents of populated fields. These message types are based on existing HL7 v2.4 standard (such as the ORU message). Examples of message type are "MT-ORU-1" and ADT A01.
- Receiver Responsibilities: The specification of actions that must be taken by the system in the receiving role.

Further on, we emphasize the structure of messages exchanged between a laboratory unit and a clinical facility presented through CardioNet User Interfaces (Figure 4 – HIS UI, Figure 6 – LIS UI)

- A header stating the type, origin, and date time of the message
- A single patient with ID number, name, sex, date of birth, address, and General Practitioner identifier
- Specimen details of the laboratory accession number (ID), source, body site, time of collection, and requester
- A set of test results, including the test name and result and abnormality flag.

The structure of messages exchanged between the HIS and LIS systems are HL7 v2.4 compliant[18]. We present a set of message samples:

MSH|delimiters||sender|||dateTime||messageType|messageID|processingStatus|syntaxVersion
PID|||patientID^^^source^IDtype||familyName^givenName||dateOfBirth|sex|||streetAddress^addressLine2^^^postCode
PV1|||patientLocation|||||patientsGP
OBR|||accessionNumber|testCode^testName^codeType|||specimenDate||||||||specimenSource^^^bodySite^siteModifier|requester
OBX||valueType|observableCode^observableName|observationSubID|valueCode^valueText^valueCodeTypeag|||result status OBX

A populated instance is as follow :

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|0^ORG|01|STAU||||||F
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 organism detected is linked to that organism finding by using the Observation Sub-ID field.

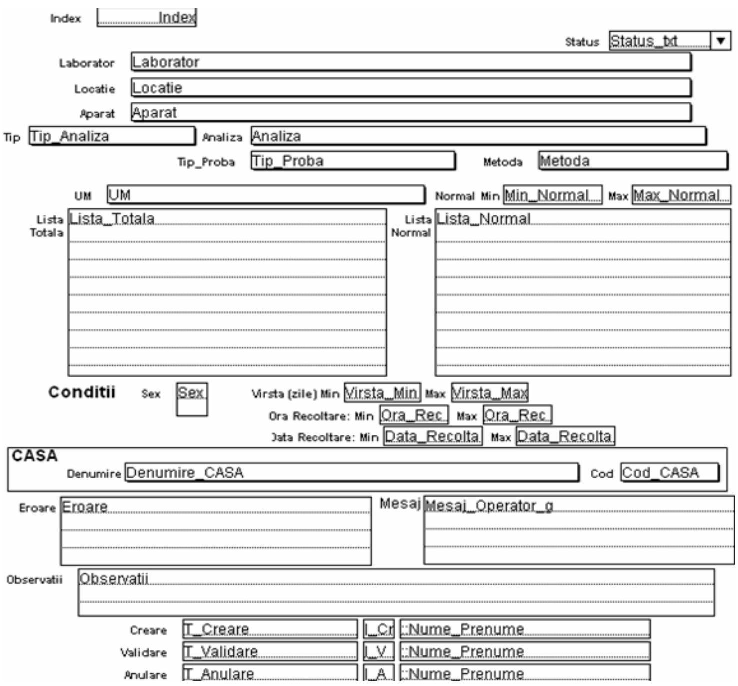

Figure 6. CardioNET LIS – Labs information system UI

Key benefits of using CardioNET IUI:

- improving efficiency: eliminates the need to manually enter lab data, scan paper lab reports or track missing results;
- improving EHR interoperability reduces the time and cost to exchange info between clinical and lab information systems;
- improving quality of care: clinicians may easier identify the patients requiring interventions, their records and prevent unnecessary treatments;
- improving efficiency in reporting between labs and multiple HER systems: allows reporting to an entire community of physicians if need;
- faster delivering of test results in a reliable and cost-effective method, preventing handling errors and reducing the costs.

CardioNET Home HealthCare Unit

The Home HealthCare Unit(HHCU) was designed as point of care at patient's residence and connects to the eHealth infrastructure through the pHSB. Remote monitoring, data acquisition and event handling are performed on the patient's stations (desktop or PDA) which are connected to a range of wireless sensing motes. The motes belong either to a body wearable sensor network or to an environmental sensor network as presented in Figure 7. The novel approach with respect to data acquisition in the HHCU unit is the separation of the two categories of networks, yet their accessing is done trough an intermediate abstraction layer that provides a virtual device interface inherited by all both networks.

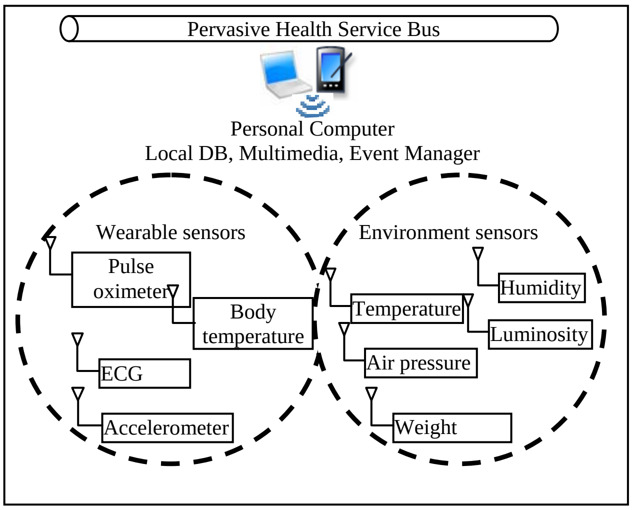

Figure 7. Components of a HHC Unit

The wireless networks act together as an integrated data acquisition system. The motes are deployed with custom applications built on top of Contiki OS. The technical details and implementation of the applications running on the motes presented less challenges [19]. State of the art WSN routing algorithms presented in CodeBlue were ported and used. Unlike CodeBlue platform which uses medical sensors, we used both medical sensors and medical acquisition boards provided by Corscience [20].

The hardware infrastructure implemented in the HHCU assures context aware physical monitoring of patients with event generation possibilities. When in monitoring state, HHCU software performs rapid notification of the patient's personal medical specialist in case of events. The patient-specialist meetings are also possible using a basic chat functionality, where the patient will be able to contact his/her own medical specialist.

Experimental results for HHcU data acquisition from wireless sensor motes are presented in Figure 8:

- The first snapshot presents the equipment used – RFID enabled PDA for identifying the patients (passive RFID tags in the form of wristbands)
- The second snapshot presents the PDA application for monitoring physical parameters (temperature/time from 3 different motes is presented)

Figure 8. HHCU: monitoring and RF patient ID

The custom applications developed can handle both ambulatory and home care monitoring services.

Patient Centric Solution with Patient History and Longitudinal EHR

The Patient Centric approach with Patient History and Longitudinal EHR offers several functionalities such as:

- Accepts and integrates information, patient-centric organized, from a large range of external systems covering also the home healthcare activities;
- Captures and manages episodic record information and creates patient history and longitudinal electronic health record information to support clinical research, public health reporting, and health decision support;
- Checks information captured or imported for reasonableness and provides logs and time stamps for audit purposes;
- Complies with approved industry standards for message and vocabulary / content, accepts information from external systems and automated devices, such as patient monitors, laboratory analysis equipment;
- Accepts and integrates health record information from outside the immediate organization;
- Provides tools for unique patient identification and information integration across systems;
- Supports electronic signature where permitted by law;
- Ideally differentiates between patient historical data (applicable across visits and across the continuum of care, e.g. allergies) vs. episodic data (applicable within a single visit, e.g. breath sounds from last respiratory assessment);
- Assists the work of evidence-based care education delivering to patients;
- Provides integrated disease management support for education, and supports mandatory and social welfare reporting.

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. The paper presents a model of such a system with a solution for remote monitoring of patients' medical state. The information gathered through web-services are preserved into specialized databases built upon a domain ontology. This approach reviles complex relations between different concepts involved in a medical act (episode). The ontology-based solution also assures the interoperability and transparent exchange of data between different medical applications and support for better medical diagnoses and treatment. The proposed solutions were implemented for monitoring and treating patients with cardio-vascular diseases. This approach reduces significantly the time spent by patients in hospitals, allows continuous monitoring of patients with chronic diseases and facilitates flexible interaction between patient and doctor through the Internet.

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

Conflict of Interest

The author(s) declare that they have no conflict of interest.

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References

1. Benson T. Principles of Health Interoperability HL7 and SNOMED. DOI 10.1007/978-1-84882-803-2_1, Phil, Springer-Verlag London Limited, 2010.
2. ***, Health Level Seven International [HL7-EDSUMMIT, November 2009, USA]; Available from: URL: http://www.hl7.org
3. ***, Integrating the Healthcare Enterprise-EU, IHE Educational Webinar , June 2010; [online]; Available from: URL: http://www.ihe.net/Events/webinars2010
4. Department of Health and Human Sciences, The ONC-Coordinated Federal Health Information Technology Strategic Plan: 2008–2012: Using the Power of Information Technology to Transform Health and Care, 3 June 2008
5. Blumenthal D. Stimulating the Adoption of Health Information Technology, The New England Journal of Medicine, April 9, 2009, Available from: URL: http://www.nejm.org/doi/pdf/10.1056/NEJMp0901592
6. ***, Part of the American Recovery and Reinvestment Act (ARRA), 2009
7. ***, Health Informatics Review, Ref. 10104, July 2008
8. Dogac A, Cingil I, Laleci G, Kabak Y. *Improving theFunctionality of UDDI Registries through Web Service Semantics*,3rd VLDB Workshop on Technologies for Eservices, Hong Kong, China, 2002.
9. ***, SNOMED-CT, Annual Activity Report, May, 2010 [online]; Available from: URL: http://www.ihtsdo.org/snomed-ct/
10. International Statistical Classification of Diseases and Health Related Problems (The) ICD-10 Second Edition, World Health Organization, 2004.
11. Stark M. A look at LOINC - The Established Standard for Lab Data Gains Visibility as Data Exchange Increases. Journal of American Health Information Management Association 2006;77(7):52, 54-5; 57-8.
12. ***, IHE – XDS - Integration Profiles, [online], June, 2006; Available from: URL: http://www.ihe.net/technical_framework
13. HIMSS –Standards and interoperability [online] July, 2008; Available from: URL: http://www.himss.org/ASP/
14. ***, NESSI Web Site – NESSI Strategic Agenda May 2009 [online]; Available from: URL: www.nessi-europe.eu .
15. Rusu M, Saplacan G, Sebestyen Gh, Cenan C, Krucz L, Nicoara T, Todor N. Distributed e-Health System with Smart Self-care Units, IEEE International Conference on Intelligent Computer Communication and Processing, Cluj-Napoca, Romania, August 2009.
16. Rusu M, Nicoara T, Cenan C, Sebestyen Gh, Olaru V, Saplacan G, Radulescu D. Distributed Smart Home Healthcare Unit in Healthcare Systems, International School on Cyber-Physical and Sensor Networks SensorNets 2009, Monastir, Tunisia, December 2009.
17. ***, IT Infrastructure Technical Framework Volume 1 (ITI TF-1), August 15, 2008; Available from: URL: http://www.ihe.net/Technical_Framework/upload/ihe_iti_tf_2.0_vol1_FT_2005-08-15.pdf
18. Lelutiu C, Rusu M, Nicoara T, Todor N, Sebestyen Gh, Saplacan G. eHealth systems interoperability through HL7 interfaces, AQTR 28-30 May 2010, p. 228-233, Cluj, RO.

19. Hein A, Nee O, Willemsen D, Scheffold T, Dogac A, Laleci GB. SAPHIRE - Intelligent Healthcare Monitoring based on Semantic Interoperability Platform – The Homecare Scenario. 1st European Conference on eHealth (ECEH'06), Fribourg, Switzerland, 2006, pp. 191-202.
20. ***, Corscience, Products and Systems - Telemedicine, April, 2009; Available from: URL: http://www.corscience.de/en/medical-engineering/company.html