Interoperability of eHealth Systems – selection of recent EU's Research Programme Developments

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Absract. European Community Research and Development Programmes have been supporting eHealth for the last eighteen years, resulting in many eHealth applications being put into practice throughout Europe. The main emphasis of the projects during the nineties was connectivity among all the points of care of health delivery systems at regional and national levels. Despite the many successes in deploying the research results at local and regional level, the lack of interoperability on nation-wide and international levels is one of the major challenges to the wider implementation of eHealth Services. Since 2004, the European Commission has taken the lead in coordinating the EU-wide deployment of eHealth services by adopting the European eHealth Action Plan, which emphasises the importance of interoperability of eHealth systems and applications. In parallel with the aim of this Action Plan, the Commission is currently working on a Recommendation focusing on a set of guidelines for good practice regarding eHealth interoperability in Europe. This Recommendation will highlight the importance of common approaches to interoperability for all Member States in order to support mobility and safety of citizens anywhere in the EU as well as the growth and transparency of the eHealth market in the EU and beyond. In support to these policy initiatives the European Commission has supported several research projects that build on projects in the area of Electronic Healthcare Records (EHR) as well as latest developments in standardisation. The concept of interoperability of eHealth systems is not limited only to health information systems dealing with patient care but considers also the link between the information systems used for research and system storing and processing any information related to healthcare such as genomics and proteomics data as well as environmental data. In this paper, the interoperability of eHealth applications is restricted mostly to health information systems deployed for patient care. The requirements of transport layer and message layer interoperability, interoperability of EHR's, semantic interoperability, business process interoperability and the security and privacy of eHealth applications are discussed through underlining the results of a selection of European Commission projects that particularly address these issues.

[α] The views developed in this paper are those of the authors and do not reflect necessarily the position of the European Commission

Introduction

Since the late 1980s, the European Commission has supported over 450 projects worth more than one billion Euros through a series of research and development programmes on medical informatics, health telematics and eHealth. For some years, these programmes formed a 'unique' international research and development programme in the world with its focused funding on health telematics research and development. These initiatives helped to create a strong European community in the field, demonstrated the benefits of many eHealth solutions and supported EU industry in its drive to become globally competitive. Many of the research results have now been tested and actively put into practice. As a result Europe has a lead in the deployment of Regional Health Networks, Electronic Health Records, Healthcards and services such as e-referral and e-prescription [1].

In order to coordinate the Europe-wide deployment of eHealth services, in 2004 the Commission prepared an Action Plan [2] that advocates the development of common interoperability approaches and standards for patient identifiers, medical data messaging, and electronic health records. The ultimate goal is to enable secure access to the patient's electronic health records and emergency data from any place in Europe, whenever required and agreed by the patient [3]. On top of this action plan, recently the ICT for Health Unit of Directorate-General Information Society and Media has set about drafting a Recommendation to be published in 2008 [4]. The recommendation will outline a set of guidelines for good practices on eHealth interoperability.

In support of these policy initiatives, in the 6th Framework Programme (FP6), the European Commission has supported several projects such as Artemis and FP6 support actions such as RIDE and Semantic Health that address the interoperability of eHealth services in several dimensions. In this paper, the results of some of these projects focusing on eHealth interoperability are briefly presented.

Interoperability is the ability of different information technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently, and to use the information that has been exchanged. Making healthcare information systems interoperable will reduce the cost of health care and will contribute to more effective and efficient patient care.

Interoperability in eHealth can be investigated at several layers: the network and transport layer (such as Internet), the application protocol layer (such as HTTP or email), the messaging protocol and message format layer (such as ebXML messaging [5] or SOAP [6]) and the content layer. Content layer interoperability includes the use of coding terms or ontologies (such as SNOMED [7] or ICD 10 [8]) and can also be investigated in two categories: the message content layer (such as HL7 v3 [9]) and the document layer (such as HL7 CDA [10] or EHRcom [11]). In order to facilitate interoperability in the level of eHealth Business Processes, integration profiles are being defined through industry initiatives. Finally in order to use interoperability solutions effectively, adequate security and privacy mechanisms must be in place.

In the following sections, we investigate various layers of interoperability in eHealth and describe the progresses achieved in each of these layers through some of the European Commission's eHealth Unit projects.

1. Transport Layer Interoperability: Developments Related to the Use of Web Services in eHealth

A prerequisite for interoperability is the ability to communicate: that is, the bits running on the wires. In transferring healthcare messages between application systems, network and transport protocols are needed, such as Internet. In fact, today, TCP/IP (Internet) is the de-facto on-line communication standard. Additionally, an application protocol standard is needed such as HTTP or SMTP (email). On top of this layer, standard messaging protocol layer is necessary such as Simple Object Access Protocol [6]. Today, SOAP is the most widely used transport binding together with the Web services.

Web services are becoming increasingly popular in the eHealth industry as a solution to transport layer interoperability problem. The Dutch national infrastructure for healthcare messaging is implemented by wrapping HL7v3 messages as Web services [12]. Also, Health Level Seven (HL7) has announced the approval of a “Web Services Profile as Draft Standards for Trial Use (DSTUs)” [13]. Furthermore, the industry initiative “Integrating Healthcare Enterprise (IHE)” has defined some of its major transactions through Web services such as the “Retrieve Document Transaction” in Cross Community Access [14] profile and all the transactions in the Retrieve Information for Display [15] profile.

One of the first implementations of Web services for the transport layer interoperability in eHealth is implemented within the scope of the Artemis Project [16]. In the Artemis project, the eHealth Web Services are semantically annotated and also published to Web Service Registries through their metadata so that they can be discovered. An essential element in defining the semantics of Web services is the domain knowledge. Medical informatics is one of the few domains to have considerable domain knowledge exposed through standards. These standards which offer significant value in terms of expressing the semantics of Web services is used in the Artemis project. The implementation experiences are described in [17, 18].

2. Message Layer Interoperability: Semantic Mediation of Messages in eHealth

Currently, the Health Level 7 (HL7) version 2 Messaging Standard [19] is the most widely implemented message interface standard in the healthcare domain. However, being HL7 version 2 compliant does not imply direct interoperability between healthcare systems. This stems from the fact that version 2 messages have no explicit information model, rather vague definitions for many data fields and contain many optional fields. This optionality provides great flexibility, but necessitates detailed bilateral agreements among the healthcare systems to achieve interoperability. To remedy this problem, HL7 version 3 [9] is developed, which is based on an object-oriented data model, called Reference Information Model (RIM) [20]. It should be noted that there is an interoperability problem between HL7 v2.x and HL7 v3 messages – there is no well-defined mapping between HL7 v2.x and v3 messages.

The Artemis [16] project addressed this problem by providing a proof of concept semantic mediation framework for the interoperability of HL7 version 2 and HL7 version 3 messages [21]. The semantic mediation is realised in two phases: In the “Message Ontology Mapping” phase, the message ontologies of two healthcare institutes are mapped to each other through an OWL (Web Ontology Language) ontology mapping tool, namely, OWLmt, also developed within the scope of the Artemis Project. With the help of a GUI, OWLmt allows to define semantic mappings between structurally different but semantically overlapping OWL ontologies, and produces a “Mapping Definition". Since message ontologies for HL7 messages do not exist yet, HL7 version 2 and version 3 XML Schemas [22] are used to generate OWL [23] ontologies. This process, called “Conceptual Normalization" produces a “Normalization map" describing how a specific message XSD is transformed into the corresponding OWL schema. The “Mapping Definitions" and the “Normalization map" produced in this first phase are used during the second phase to automatically transform the message instances one into another.

In the second phase, first, the XML message instances of a healthcare institute are transformed into OWL instances by using the “Data Normalization" engine [24]. Note that if the message is in EDI (Electronic Data Interchange) format, it is first converted to XML. Then by using the “Mapping definitions”, the OWL source messages instances are transformed into the OWL target message instances. Finally the OWL messages are converted to XML again through the “Data Normalization" engine. The details of this work are described in [21].

3. Interoperability of Electronic Healthcare Records (EHR)

The Electronic Healthcare Record (EHR) of a patient can be defined as digitally stored health care information about individual’s lifetime with the purpose of supporting continuity of care, education and research, and ensuring confidentiality at all times [25]. A patient’s healthcare information may be spread out over a number of different institutes which do not interoperate. In order to provide continuity of care, clinicians should be able to capture the complete clinical history of a patient. A number of standardization efforts are progressing to provide the interoperability of electronic healthcare records such as CEN/TC 251 EHRcom [11], openEHR [26] and HL7 Clinical Document Architecture (CDA) [10]. These standards aim to structure and markup the clinical content for the purpose of exchange. A complementary initiative addressing how to exchange EHRs complying to different content standards is the Integrating the Healthcare Enterprise (IHE) [27] Cross-Enterprise Document Sharing (XDS) integration profile [28]. The basic idea of IHE XDS is to store healthcare documents in an ebXML registry/repository [29] architecture to facilitate their sharing.

In the following, we first briefly introduce some of the prominent EHR standards. A comprehensive survey and analysis of the Electronic Healthcare Records (EHRs) achieved within the scope of the RIDE Project [30] is available in [31].

3.1. The GEHR/openEHR Initiative

The most noteworthy concept introduced by GEHR/openEHR is the “archetype" concept [32]. This approach uses a two-level methodology to model the EHR structure. In the first level, a generic reference model that is specific to the healthcare domain but still very general is developed [33, 34]. This model typically contains only a few classes (e.g. role, act, entity, participation) and must be stable over time. In the second level, healthcare and application specific concepts such as blood pressure, lab results etc. are modeled as archetypes, that is, constraint rules that specialise the generic data structures that can be implemented using the reference model. As an example, a constraint may restrict a generic “Observation" class, for example, to “Blood Pressure" archetype.

An archetype definition basically consists of three parts: descriptive data, constraint rules and ontological definitions. The descriptive data contains a unique identifier for the archetype, a machine-readable code describing the clinical concept modeled by the archetype and various metadata such as author, version, and purpose. The constraint rules are the core of the archetype and define restrictions on the valid structure, cardinality and content of EHR record component instances complying to the archetype. The ontological part defines the controlled vocabulary (that is, the machine readable codes) that can be used in specific places in instances of the archetype. It may contain language translations of code meanings and bindings from the local code values used within the archetype to external vocabularies such as SNOMED [7] or LOINC [35]. It may also define additional constraints on the relationship between coded entries in the archetype based on the code value.

3.2. CEN EN 13606-1 EHRcom

CEN 13606 [11] consists of five parts:

- The Reference Model
- Archetype Interchange Specification
- Reference Archetypes and Term Lists
- Security Features
- Exchange Models

The Reference Model (EN 13606-1) EHRcom defines a generic information model for the purpose of exchanging the EHR of a patient. An “EHR_Extract” is the root node of part or all of the EHR of a single patient and contains EHR data as “Composition” instances which may be organised by a “Folder” hierarchy. A “Composition” consists of “Entry” instances which are optionally contained within a “Section” hierarchy. An “Entry” contains “Element” instances which are optionally contained within a “Cluster” hierarchy.

3.3. HL7 Clinical Document Architecture (CDA)

CDA [10] is organised into three levels where each level iteratively adds more markup to clinical documents, although the clinical content remains constant at all levels. “Level One" focuses on the content of narrative documents. It consists of two parts, the CDA Header and the CDA Body, which are based on the HL7 data types. The document header is derived from RIM and unambiguously defines each entry in the document. The body contains the clinical document content, and can be either an unstructured text, or can be comprised of nested containers such as sections, paragraphs, lists, and tables through structured markup. Hence there is no semantics in Level One body; it offers interoperability only for human-readable content. In fact, CDA Level One describes a kind of HTML document with a standardised header that contains additional information on the document.

Level Two CDA models the fine-grained observations and instructions within each heading through a set of RIM Act classes. With Level Two, it is possible to constrain both structure and content of a document by means of a template and thereby increase interoperability since the receiver “knows what to expect". However, a completely structured document where the semantics of each information entity is specified by a unique code will only be possible with “Level Three" providing for machine processing.

3.4. IHE Cross-Enterprise Document Sharing (XDS)

In the IHE XDS integration profile, a group of healthcare enterprises that agree to work together for clinical document sharing is called an “XDS Domain". Such institutes agree on a common set of policies such as how the patients are identified, the consent is obtained, the access is controlled, and the common set of coding terms to represent the metadata of the documents.

IHE XDS handles healthcare documents in a content neutral way, that is, a document may include any type of information in any standard format such as simple text, formatted text (e.g., HL7 CDA Release One), images (e.g., DICOM [36]) or structured and vocabulary coded clinical information (e.g., CDA Release Two, EHRcom or DICOM SR). Given this, to ensure the interoperability between the document sources and the document consumers, the XDS domains also agree on the document format, the structure and the content.

The IHE XDS profile is currently being used in the implementation of several national or regional eHealth implementations for exchanging EHRs. In the USA, the Healthcare Information Technology Standards Panel [37] provided interoperability specifications based on the IHE Profiles for the implementation of Nationwide Health Information Network [38]. In these specifications, IHE XDS is recommended for exchanging EHRs. Similarly, in the implementation blueprint of the Health Infoway Project in Canada, IHE XDS Profile is recommended. A health information exchange network is planned to be implemented by the first quarter of 2008 covering Quebec, Ontario, Alberta, and British Columbia regions. In the EU, IHE XDS is being considered or implemented in several regional healthcare networks such as in Italy -Genoa Region, Austria -Lower Austria Region, Netherlands - Amsterdam Region and Sweden –Gotteborg Region. Finally in France the National DMP (dossier medical personnel) will be implemented based on IHE-XDS. [39, 30].

For IHE XDS implementations covering many regions as mentioned, it is not realistic to have a single XDS domain: there is a need for the XDS domains to be federated, that is, they should continue being able to decide on the domain related policies such as how patients are identified and which set of coding terms are used to represent metadata of the documents in the registry and still be able to exchange information. IHE has a new profile called “Cross Community Access” to address some of the problems involved [14].

The work accomplished within the scope of the Artemis project addresses some additional problems in achieving the federation of XDS-based domains to align different policies in different domains which may affect their information exchange capability.

In an XDS domain, most of the metadata are defined through domain specific coding lists. Hence, given the metadata in one XDS domain, it may not match the metadata in another XDS domain. To alleviate this problem, in the Artemis project metadata ontologies are used rather than the coding lists. It is shown that when metadata ontologies are defined through formal ontology languages like Web Ontology Language [23], it becomes possible both to map the metadata concepts to each other through ontology mapping and to use rules to further enhance their semantics [40]. In this way, access to documents across XDS domains is greatly facilitated.

Another problem is that when XDS domains are federated, in order to identify a patient in another XDS domain, patient identification across domains must be addressed. A master patient index that spans multiple XDS domains is not feasible to create and maintain manually. Therefore, in the Artemis project a secure and fault-tolerant patient ID look-up mechanism is introduced based on patient demographics such as name, birthdate, place of birth etc. to be used in federated IHE XDS [40].

4. Semantic Interoperability in eHealth

Semantics is implemented as metadata describing data, described through ontologies. An ontology can be defined as "a formal, explicit specification of a shared conceptualization" [41]. Formal means that the meaning specification is given in a machine processable language, called the ontology language. An explicit specification means that the concepts and the relationships in the abstract model are given explicit names and definitions. An important feature of ontology languages is that they provide for automated inference to derive new, implicit information from these explicit specifications. Shared means that an ontology describes consensual knowledge, that is, it describes meaning which has been accepted by a group, not by a single individual; in other words, it provides a common vocabulary for those who have agreed to use it. An ontology together with a set of concrete instances constitute a knowledge base. Currently, Web Ontology Language (OWL) [23] is a widely accepted ontology language.

A common usage of the term "semantic interoperability in eHealth" can be found in [42]:

"*Semantic interoperability implies that the structure of the 'documents' is interpretable, and that their content is understandable. Making this content understandable sometimes requires that the keys for its correct and safe interpretation, such as the terminological systems used, are identified and easily available*."

An overview and assessment of the currently available state-of-the-art ontologies and ontology-like artifacts (controlled vocabularies) in healthcare are given in [43]. For example, SNOMED CT which is a Description Logics supported, concept based ontology, contains over 366,000 healthcare concepts organised into hierarchies, with approximately 1.46 million semantic relationships between them, and more than 993,420 terms.

Another important use of semantic interoperability in the healthcare domain is the integration of data from heterogeneous sources through semantic mediation. Semantic mediation can be used to convert healthcare messages defined in one standard format into another as described in Section 2. Furthermore, an approach to archetype based semantic interoperability of EHR standards, as realised within the scope of the Artemis project, is described in [44].

Within the scope of the RIDE Project, a more challenging problem of the semantic interoperability of EHR structure and content is addressed. [45] describes how two different EHR standards derived from the same Reference Information Model (RIM) can be mapped to each other by using archetypes, Refined Message Information Model (R-MIM) derivations [46] and semantic tools. It is also demonstrated that well-defined R-MIM derivation rules help tracing the class properties back to their origins when the R-MIMs of two EHR standards are derived from the same RIM. Using well-defined rules also enable finding equivalences in the properties of the source and target EHRs. Yet an R-MIM still defines the concepts at the generic level. Archetypes (or templates), on the other hand, constrain an R-MIM to domain-specific concepts and hence provide finer granularity semantics. Therefore, while mapping clinical statements between EHRs, the archetype semantics is also used. Derivation statements are inferred from the Web Ontology Language (OWL) definitions of the RIM, the R-MIMs and the archetypes. Finally, [45] describes how to transform Health Level Seven clinical statement instances to EHRcom clinical statement instances and vice versa by using the generated mapping definitions.

As already mentioned, using archetypes is a promising approach in providing semantic interoperability among healthcare systems. To realise archetype based interoperability, the healthcare systems need to discover the existing archetypes based on their semantics; annotate their archetypes with ontologies; compose templates from archetypes and retrieve corresponding data from the underlying medical information systems. Within the scope of the Artemis project [16], we describe how this can be achieved. [47] explains how ebXML Registry semantic constructs can be used for annotating, storing, discovering and retrieving archetypes. For semantic annotation of archetypes, we present an example archetype metadata ontology and describe the techniques to access archetype semantics through ebXML query facilities. We present a GUI query facility and describe how the stored procedures introduced, move the semantic support beyond what is currently available in ebXML registries.

5. Business Process Layer Interoperability in eHealth

Any actual implementation of a standard requires some form of tailoring. Therefore, in developing practical and effective interoperability solutions, the industry relies on integration profiles which are business processes describing selected real-world use-cases. In the profiling approach, the basic transactions describing the interactions between the IT systems are defined and then the workflows describing the real life business processes are specified by using these transactions together with the standard interfaces.

For example, the IHE Integration Profiles first to define the basic transactions describing the interactions between the IT systems and then to define the workflows describing the real life business processes by using these transactions together with the standard interfaces. In order to facilitate establishing electronic relationships among IHE Actors and to provide an automated environment to help IHE users and vendors to exchange configuration information electronically and in a standard way, the IHE Profiles need to be described in a machine processable way. Within the scope of the RIDE Project, how to express the IHE Profiles through eBusiness eXtensible Markup Language (ebXML) Business Process Specification Schema (ebBP) language [48] is described [30].There are several benefits to be gained in defining IHE Profiles [28] through ebBP since ebBP provides standard, concise and machine processable configuration information which can be used in an automated way as detailed in [49]. A further benefit of defining IHE Profiles through a machine processable business process language is as follows: When IHE Profiles are combined by grouping the relevant IHE Actors, the result is a collaborative healthcare business process integrating the workflows defined for each profile and the sequence of the transactions coming from different profiles must be decided. How to obtain the overall machine processable multi party collaborative business process automatically when IHE Actors are grouped is realised in the RIDE Project as described in [50].

6. Privacy and Security Issues in the eHealth Domain

In providing the interoperability of eHealth systems, there is a need for mechanisms to provide adequate security, integrity and privacy since clinical data is unusually sensitive. Although a number of solutions are being developed, there is still a need for many mechanisms such as federated identity management; policy based authorization; allowing fine-grained sensitivity levels for patient data and functional roles for the requestors as the basis of patient-controlled attributes in privacy consents; assessing risks and damages through federated audit mechanisms; providing consent policy composition necessary in networked eHealth environments; developing mechanisms for establishing trust among the actors through registry based policy sharing tools.

Within the scope of the Saphire Project [51], in order to identify users across healthcare enterprises, an implementation of the Security Assertion Markup Language (SAML) [52] Enhanced Client or Proxy (ECP) [53] profile and OASIS Extensible Control Markup Language specification (XACML) [54] based authorisation mechanism are realised [55, 56]. The basis for this implementation is the IHE Cross-Enterprise User Authentication (XUA) Profile [57]. Recommendations are also made relating to the XUA profile.

7. Conclusions

The European Commission is supporting research and development in eHealth with a major aim of supporting continuity of care through timely and secure sharing of information among all the relevant stakeholders [25]. The major prerequisite for such eHealth-enabled continuity of care is the interoperability of health information system and in particular electronic health records. Interoperability is not only needed to ensure better quality of care at national and international levels, but also as one of the main conditions for a sustainable and competitive eHealth market. This market has a great potential for fast growth and contribution to the economy in a similar way to two previous booming healthcare industries, namely, pharmaceuticals and medical devices.

This paper briefly summarises the issues involved in eHealth interoperability and mentions some of the progress achieved. The European Commission is planning to issue soon a Recommendation on eHealth interoperability where it describes the different actions needed to be tackled in cooperation with the Member States to achieve this EU wide goal [4]. The recommendation aims to coordinate efforts towards so-called ‘use cases’ decided by agreeing on common priorities of Europe. Furthermore, to support Member States in these steps the European Commission, within the scope of the “Competitiveness and Innovation Framework Programme -ICT Policy Support Programme” (CIP-PSP) [58], is supporting EU-wide implementation of eHealth services to support continuity of care through patient's summary and ePrescription.

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