The Need for Semantic Web Service in the eHealth

Emanuele Della Valle — CEFRIEL – Politecnico di Milano — dellavalle@cefriel.it

Dario Cerizza — CEFRIEL – Politecnico di Milano — cerizza@cefriel.it

Veli Bicer — SRDC - METU — bicer@srdc.metu.edu.tr

Yildirak Kabak — SRDC – METU — yildiray@srdc.metu.edu.tr

Gokce Banu Laleci — SRDC – METU — banu@srdc.metu.edu.tr

Holger Lausen — DERI - Innsbruck — holger.lausen@deri.org

Towards semantic interoperability based on Semantic Web Services

XML and Web Services are rapidly becoming the industrial standard for integrating distributed systems. XML technologies provide an efficient way of dealing with syntax and structural interoperability, whereas Web Services technologies provide a standard exchange mechanism across diversified platforms, systems and networks. As a matter of fact, Web Services and XML present an efficient solution to reduce efforts and to quicken the process of creating interfaces that allow the communication between heterogeneous systems, employing the so called Services Oriented Architecture.

This relatively easiness in creating interfaces makes thousand of niche groups proposing their own XML structures. But, a standard application protocol is much more than the syntax and the transport protocol for messages, it is a formal and largely shared agreement on the structure and semantics of messages as well as on the sequencing information for concrete interactions. Only with this semantic information systems can exchange information and the corresponding application logic of a large set of systems can be combined to a single distributed one. Additionally the dynamics of such a protocol must be considered. The application requirements (and the processes behind them) change fast and depend on the strong needs of small subsets of the organizations involved in the process. An application protocol needs to accommodate each of these additional requirements and maintenance is not an easy task.

The current trend in dealing with maintenance of an application protocol is to manage it not on a syntactic but on a **semantic** level. Data structure and sequencing information are enhanced with semantic information that encodes the definition of each element of data including its relationship with each other element. The key elements enabling the shift from a purely syntactic to a semantic interoperability are ontologies; they are semantic models of the data and they interweave *human understanding* of symbols with their *machine processability.*

Besides ontology languages, semantic interoperability requires a conceptual and formal model for services. A proposal mainly driven by US based research is OWL-S; essentially it provides an upper ontology encoded in Description Logics to capture the semantics of a service. On the other hand the Web Service Modeling Ontology (WSMO), the leading European proposal, describes four different main elements: *ontologies*, s*ervices descriptions*, *goals* (which describe aspects related to user desires with respect to the requested functionality) and *mediators* (which bypass interpretability problems). Both proposals are still evolving and joint work aiming at a unified framework has already been set up.

Semantic Interoperability in the healthcare

The practice of health care has used electronic methods for administrative tasks for long, but the health care industry has more slowly adopted technology as a way to improve delivery of its services and for a good reason: health care practice has life-and-death implications, and thus the adoption of new processes involving technology must meet the highest standards of accuracy and effectiveness.

On the other hand most of the health information systems today are proprietary and often only serve one specific department within a healthcare institute. A number of standardization efforts[1] are progressing to address this interoperability problem such as EHRcom, openEHR and HL7. HL7 is one of the early and most active standards organizations bringing electronic processes to the health care industry. HL7 version 2 is the most widely implemented healthcare informatics standard in the world today. Yet being HL7 Version 2 compliant does not imply direct interoperability between healthcare systems. Version 2 messages, contain many optional data fields. This optionality provides great flexibility, but necessitates detailed bilateral agreements among the healthcare systems to achieve interoperability[2].

This problem has been perceived also in HL7 since 1996, when the development of a **Reference information model** (RIM) began, and it became a foundation of HL7 version 3. In v.3 the RIM is the ultimate source from which all protocol specification standards draw their information-related content.

HL7 Version 2.x, as many other application protocols in other domains, has no formal information model; the model is implicit, not explicit. So, from the one hand, the various HL7 messages in v2.x are similar to programming language "structures", but without formal operations and without important object-oriented concepts, such as generalization-specialization hierarchies. One the other hand version 2.x has no formal binding of standard vocabularies to structures. The bindings are ad hoc and always site specific.

HL7 version 3 places in the RIM an explicit data semantics model from which implementing the messages locally and top-down. This emphasizes reuse across multiple contexts. Moreover, RIM has formalisms for vocabulary support. It has a strong semantic foundation in explicitly defined concept domains drawn from the best terminologies[3] (SNOMED, LOINC, CPT, ICD, etc.). which, in HL7 RIM working group opinion, makes semantic interoperability possible.

Yet, it is not realistic to expect all the healthcare institutes to conform to a single standard. Furthermore, different versions of the same standard (such as HL7 Version 2 and Version 3) and even the different implementations of the same standard, for example, some HL7 Version 2 implementations, do not interoperate. Therefore there is a need to address the interoperability problem at the semantic level.[2] The use of *mediators* is one of the possible solutions.

---

[1] EHRcom: http://www.centc251.org/TCMeet/doclist/TCdoc00/N00048.pdf, openEHR: http://www.openehr.org/ and HL7 http://www.hl7.org

[2] Bicer, V.,Laleci, G.,Dogac, A., Kabak, Y., "Artemis Message Exchange Framework: Semantic Interoperability of Exchanged Messages in the Healthcare Domain" ACM Sigmod Record, Vol. 34, No. 2, June 2005

[3] SNOMED (http://www.snomed.org), CPT (http://www.aacap.org/clinical/cptcode.htm), ICD (http://www.who.int/classifications/icd/en/), LOINC (http://www.loinc.org/) ,

Projects in the area of Semantic Web Services for eHealth

The European Commission is funding two complementary projects that are investigating the use of Semantic Web Services in the healthcare sector: COCOON[4] and ARTEMIS[5].

COCOON

COCOON is a 6th Framework EU integrated project aimed at setting up a set of regional semantics-based healthcare information infrastructure with the goal of reducing medical errors. In order to enable a seamless integration of many complex technologies with the existing regional eHealth services (e.g. the SISS[6] in Lombardy - Italy), Web Services technology was selected. But, this raised the problem of cataloguing, managing and maintaining these Web Services. To this purpose COCOON Glue was defined. COCOON Glue, in the 42 months of duration of the project (started on January 2004), will address the integration problem starting from Service Discovery and ending up with Service Composition. In this first phase of the project COCOON Glue was focused on Service Discovery and in particular on developing a prototype of WSMO compliant discovery engine.

The key idea of COCOON Glue discovery engine relies on deploying a matching mechanism based on *mediators*. As proposed in WSMO, COCOON Glue uses *Goal-Goal mediators* (ggMediators) to overcome interoperability problems that may appear when provider and requester entities cannot reach an agreement in defining, respectively, goals and Web Services descriptions using the same ontologies (e.g. some likes SNOMED, other ICD). Then, COCOON Glue uses *Web Services – Goal mediators* (wgMediators) to describe the similarities that link services and goals. As a result of these choices **the discovery mechanism becomes a composite procedure where the expansion of the requester's goal via ggMediator, the discovery of the appropriate wgMediator and the discovery of the appropriate service is combined.**

In order to use wgMediators, we distinguish between classes of goals (or classes of Web Services descriptions) and instances of these classes. In our approach requester (provider) entities must register a class of goals (services) in order to be able to submit (publish) a goal (a Web Service description). The rational behind this choice is twofold. At set up time, COCOON glue administrator can develop a wgMediator *by using rules* to assert the similarities that link a class of Web Services descriptions to a class of goals. At discovery time, it enables the use of a simple look up mechanism for selecting the most appropriate wgMediators for the submitted goal and the use of such mediators to match a goal instance against numerous Web Service description instances.

The prototype of COCOON Glue Discovery engine was developed by builing a WSMO infrastructure around an open source f-logic inference engine called Flora2 that runs over XSB, an open source implementation of tabled-prolog and deductive database system. The COCOON Glue Discovery engine in entering the field test phase supporting a usage scenario in which a General Practitioner (GP) uses

[4] http://www.cocoon-health.com
[5] http://www.srdc.metu.edu.tr/webpage/projects/artemis/index.html
[6] http://www.crs.lombardia.it/

COCOON Glue discovery engine, to find out the most appropriate advice services offered by specialists organized in communities of practice (CoP)[7].

Artemis

ARTEMIS (IST-2103 STP) is a STREP project supported in the 6th Framework by the European Commission. ARTEMIS aims to develop a semantic Web Services based interoperability framework for the healthcare domain. Artemis addresses the interoperability problem in healthcare domain in two respects:

- Functional Interoperability which is the ability of two or more systems to exchange information. In Artemis infrastructure healthcare institutes keep their proprietary systems and expose their medical applications as Web services. Web services provide functional interoperability through well accepted standards like SOAP and WSDL.
- Semantic Interoperability is the ability for information shared by systems to be understood at the level of formally defined domain concepts so that the information is computer processable by the receiving system[8] . Artemis provides the interoperability at the semantic level through semantic annotation of service messages and functionalities through OWL-S and ontology mediation.

Artemis has a peer-to-peer architecture in order to facilitate the discovery of healthcare web services. In Artemis, healthcare institutes are represented as peers. Artemis peers provide interfaces to the healthcare information systems to enable them to discover and consume the Web services provided by the other peers.

In order to facilitate the discovery of the Web services, there is a need for semantics to describe what the service does, in other words what the service functionality semantics is in the domain. For example, in the healthcare domain, when a user is looking for a service to admit a patient to a hospital, he should be able to locate such a service through its meaning, independent of what the service is called and in which language. Note that WSDL does not provide this information.[9]

In Artemis, HL7 categorization of healthcare events are used to annotate Web service functionality since HL7 exposes the business logic in the healthcare domain. OWL-S Release 1.1 also indicates that service characterization must effectively position a service within the broad array of services that exists within some domain, or perhaps in the world at large10. OWL-S proposes to construction of a "Service Profile hierarchy", with inheritance of properties by subclasses as a technique for this kind of service characterization. In the same manner, we have created the HL7 event based Artemis Functionality Ontology as a "Profile Hiearchy". If further ontologies are developed for this purpose, they can easily be accommodated in the Artemis architecture through ontology mapping.

When invoking a Web service, there is also a need to know the meaning associated with the messages or documents exchanged through the Web service. In other words, service functionality semantics may suffice only when all the Web services use the same message standards. For example, a "GetClinicalInformation" Web service may

[7] A full version of the usage scenario is available at http://cocoon.cefriel.it/RD2/usecases/semantic-discovery-of-cop-v2.0 and the related user interface is available for testing at http://cocoon.cefriel.it/COCOONGlue/Discovery/GUI/SDCoP.aspx.

[8] ISO TC/215, International Organization for Standardization, Health Informatics, ISO TS 18308:2003, http://secure.cihi.ca/cihiweb/en/downloads/infostand_ihisd_isowg1_mtg_denoct_contextdraft.pdf

[9] Dogac, A., Laleci, G., Kirbas S., Kabak Y., Sinir S., Yildiz A., Gurcan Y., "Artemis: Deploying Semantically Enriched Web Services in the Healthcare Domain",Information Systems Journal (Elsevier), to appear.

[10] http://www.daml.org/services/owl-s/1.1/ProfileHierarchy.html

include the messages to pass information on diagnosis, allergies, encounters and observation results about a patient. Unless both the sending and the receiving ends of the message conform to the same EHR standard, interoperability can not be achieved.
For this purpose in Artemis, the input and output parameters of the Web services defined in OWL-S are annotated through message ontologies. In Artemis Message Exchange Framework (AMEF)[2], the messages which may be in EDI or XML are normalized to messages represented by the messages in OWL. The most powerful aspect of AMEF is that the healthcare organizations are not expected to conform a single commonly agreed messaging format. Artemis Architecture provides an OWL mapping tool, called OWLmt[11], to handle ontology mediation by mapping the OWL ontologies in different structures and with an overlapping content one into other. In Artemis architecture, healthcare institutes define the mapping between their own message ontology and one of the "Clinical Concept Ontologies" available in Artemis P2P Network. "Clinical Concept Ontologies" are designed based on the prominent EHR based healthcare standards such as HL7 CDA, CEN ENV 13606[1]. Such mappings are defined graphically between source and target ontologies and the mapping definitions produced are advertised to the Mediators in the P2P network. When a peer wishes to invoke a web service, the mediator hosting the OWLmt mapping engine mediates the webservice input and output parameters from the source ontology instances to target ontology instances automatically using the previously stored mapping definitions.

Conclusions

The main lesson-learned in applying WSMO in the healthcare sector within COCOON Glue is that a clear separation between the ontologies, used by each entity, requires a minor consensus (always difficult to reach in large groups, but especially in healthcare). In WSMO, this is possible, mainly, due to the adoption of mediators. In particular wgMediators appears to offer a flexible way for describing similarities between goals and Web Services descriptions, hence for enabling a semantic match between them. Still a problem remains in how to transform terminologies like ICD in ontologies, but this is a topic that is not obvious to address and that will probably require lot of manual work. Moreover we believe that the subset of f-logic (OWL^- plus instance to class relations) used in COCOON Glue for describing all the components except the mediators offers a good trade-off between expressiveness and performances. Clearly this subset of the f-logic is too restricted for describing similarity in the wgMediators. Actually, we have to use f-logic rules for such task, but the layering of these rules over the rest of the language makes it easy to describe similarities between disparate concepts.
The main lesson-learned in applying OWL in the healthcare sector within Artemis is that although ontologies represent consensual knowledge; medical information systems suffer from proliferation of standards to represent the same data and it is not realistic to expect the Healthcare institutes conform to a single commonly agreed ontology. In order to tackle this problem, Artemis project enables the healhcare institutes to keep the existing applications with propritary message formats, these are wrapped as Web services and the messages they exchange are annotated with OWL ontologies which are then mediated through an OWL ontology mapping tool developed, namely, OWLmt.

[11] http://www.srdc.metu.edu.tr/webpage/projects/artemis/owlmt/