SaaS based Interoperability Service for Semantic Mappings among Health-care Standards

Wajahat Ali Khan, Maqbool Hussain, Asad Masood Khattak, Muhammad Bilal Amin, Sungyoung Lee
Department of Computer Engineering
Kyung Hee University
Seocheon-dong, Giheung-gu, Yongin-si, Gyeonggi-do, Republic of Korea, 446-701
{*wajahat.alikhan, maqbool.hussain, asad.masood, mbilalamin, sylee*}*@oslab.khu.ac.kr*

***Abstract*—Semantic differences of data representations results in bottleneck for interoperability among heterogeneous health-care systems. Heterogeneities relates to lack of health-care standards practice, as a consequence leads to problem of data interoperability. The proposed solution is based on mediating services among health-care systems compliant to different health-care standards. These mediation services behave as Software as a Service (SaaS) used to resolve heterogeneities among different health-care standards. The paper also describes the methodology used for resolving heterogeneities to achieve the goal of data interoperability. Ontology mappings and bridge ontology resolves semantic differences of data. SaaS service model automatically brings scalability and flexibility as the benefits to the system, enables health-care systems to exchange patient data. The proposed system combines semantics and SaaS based service model for timely provision of health-care services to patients. Health-care systems needs to consume the services from cloud for communication with other systems compliant with incompatible standard. This will lead to achieve the goal of data level interoperability among different HIS compliant to heterogeneous health-care standards.**

***Keywords*-Ontology Mapping; Semantic Interoperability; Health-care Standard; Bridge Ontology; SaaS; Cloud Computing;**

I. Introduction

Complexity due to continuously evolving nature of health-care data ensures the critical nature of health-care systems integration and interoperability problems. One way to resolve these issues is the use of common data model. But the degree of health-care systems integration depends on the flexibility of the common data model employed by different health-care systems. Health-care standards are based on content models specifically called as Reference Information Models. These standards plays major role in tackling integration and interoperability problem. However, there exists multiple health-care standards following their own information models. Some of the standards have the same objectives but different information models. This leads to the complexity and bottleneck for integration and interoperability among health-care standards. A platform is required to enable integration of different heterogeneous health-care systems for interoperable exchange of information.

Although some standards have same objectives but different approaches based on information models having semantic differences. Health Information System's (HIS) compliant to these heterogeneous standards can enable communication or exchange of information when these semantic differences are resolved. Health Level 7 Clinical Document Architecture (HL7 CDA[1]) and openEHR[2] are two standards that resembles in managing and storing, retrieval and exchanging health data as Electronic Health Records (EHR). The objective is the same but semantic differences exists due to differences in the information models. The interoperability challenges exists in various terminologies standards as well like LOINC[3] and SNOMED CT. LOINC medical terminologies information is only related to laboratory domain but that can still be mapped to the laboratory related information of SNOMED CT. Therefore the problem occurs when health-care systems compliant to these heterogeneous health-care standards want to communicate with each other. Resolving these semantic differences results in achieving the objective of semantic data interoperability.

The objective of data interoperability is attainable through mediating services based on mappings among health-care systems. The relationships between heterogeneous standards of same domains can be established by ontology matching. This paper is based on mediating services that employs ontology matching of different standards. We consider ontologies i.e., HL7 RIM V3 ontology[4] and openEHR ontologies[5] for ontology matching functions, whereas, the mappings will be provided as services. In addition, SaaS based service model can substantially reduce the complexity, infrastructure cost, and redundant system processing of clinical information. We propose a conceptual architecture based on SaaS service model showing the overall process of achieving

[1]http://www.hl7.org/v3ballot/html/welcome/environment/index.html
[2]http://www.openehr.org/
[3]http://loinc.org/terms-of-use
[4]Based on HL7 RIM Ballot May 2006, also partly based on Bhavna Orgun's RIM ontology http://www.ics.mq.edu.au/ borgun/Software.html, Developed by Helen Chen and Anju Sharma, Agfa Health-care
[5]Based on the openEHR EHR Reference Model, Developed in owl by Isabel Roman

semantic data interoperability using services.

Semantic mappings between HL7 V3 and openEHR standards are generated using Falcon [1] and Agreement Maker [2] ontology matching tools, for matching purpose. The role of bridge ontology is highlighted as a mediator between multiple health-care standards' ontologies. Some key aspects related to ontology matching that need to be worked on are also investigated and explained in this paper.

The rest of the paper is organized as follows. Section 2, explains the existing work in the health-care field. In Section 3 we provide insight in to the role of ontology mapping, bridge ontology, and SaaS model for achieving semantic data interoperability. Section 4 talks about the proposed architecture and its components. In Section 5, detailed explanation of mapping services is provided with extended architecture. Section 6 discusses about the bottlenecks for achieving semantic data interpretability between different standards. Section 7 is the conclusion and our future directions.

II. Related Work

Healthcare standards interoperability is an interesting area that has captured the attention of many researchers and practitioners. Lots of work has been carried out in this area with still many open challenges to be analyzed. Some of the work closely related to the proposed system is explained in this section;

In [3], semantic transformation among RMIM and archetypes is described with the help of the proposed algorithm. It focuses on transformation of clinical statements represented in EHR standards formats. Also the data loss is not described while transformation. The work in [4] and [5] discusses resolving incompatibilities between HL7 standards V2 and V3. Ontologies are used for generating and implementing mappings between the two standards. The authors in [6] proposed a framework Jini Health Interoperability Framework (HIF-J), the main purpose is to exchange health standards based clinical information among systems. It uses XSLT transformations for defining translation services. In [7] and [8] the focus is on achieving semantic interoperability between HL7 V2 and V3 standards using semantic web services. The proposed system in [7] uses OWL-S technique to incorporate semantic web services while [8] uses WSMO techniques.

The above mentioned systems mostly describes integration and interoperability between HL7 V2 and V3 standards. In [9], the authors proposed a standard by integrating messaging standard HL7 and imaging standard DICOM. The proposed standard is Ortho EPR that is used for storage and communication of orthodontic patients' records. The work in [10] also discusses another aspect of semantic interoperability that is related to resolving heterogeneities in processes of HL7 V3. Process level interoperability is discussed using an ontology called Interaction ontology. Although these work are step forward towards semantic interoperability by resolving heterogeneities among different standards; however, accuracy of mappings, degree of automation, and data loss are the main issues that needs to be resolved.

III. Semantic Data Interoperability: Health-care Standards, Ontology Matching and SaaS service model

In order to provide semantic interoperability between Health-care Information Systems (HIS) that are complaint to different heterogeneous standards, we need services that are based on ontology mappings. We provide SaaS based architecture for providing semantic interoperability via mapping services as shown in Figure 1 and details are given below.

A. Health-care Standards

Health-care standards are considered as the prime source for bringing interoperability between health-care systems. These include standards related to messaging (HL7), terminologies (SNOMED CT), clinical information and patient records (openEHR and HL7 CDA), imaging (Digital Imaging and Communications in Medicine (DICOM)) and health-care enterprize integration (Integrating the Health-care Enterprize (IHE)[6]). These standards have information overlap and at the same time differences. The information overlap is good enough to bring the standards close to each other and make them interoperable. Ontology matching is one of the methods for achieving semantic data interoperability between different health-care standards. This paper will focus on ontology mapping between openEHR and HL7 V3 standard ontologies.

[6]http://www.ihe.net/

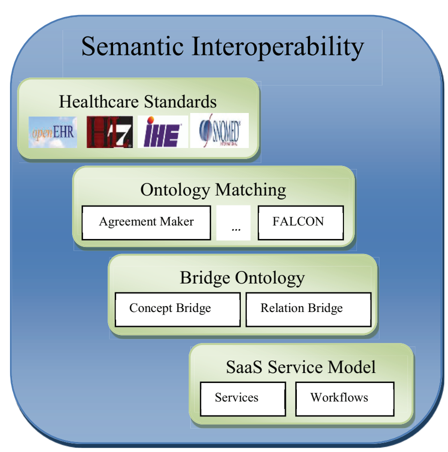

Figure 1. Layered Approaches to achieve Semantic Interoperability among Health-care Standards

B. Ontology Matching

Ontology Matching is the process of eliminating the terminological and conceptual incompatibilities and discovering similarities between two ontologies [11]. It provides the methodology as interoperability enabler for data exchange, merging, and integration techniques. The available ontology matching tools are based on different matching techniques that define their level of accuracy for mapping results. For testing purpose, Falcon and Agreement Maker are used in this research work to establish mappings between HL7 and openEHR. These mappings are published as services for creating the base for SaaS service model.

C. Bridge Ontology

Bridge ontology is useful when complex relations between multiple ontologies are required. Its advantages include low cost, scalable, robust in the web circumstances, avoiding the unnecessary ontology extension, ontology integration, and ontology reuse [12]. It is based on bridge relations that are the associated rules between different ontologies. MAFRA ontology matching tool is based on Semantic Bridge Ontology (SBO) [13]. SBO is taxonomy of bridges that constitute the mappings. OntoMerge [14] is an example of Bridge Ontology in which source ontologies are maintained after the merge operation is performed. In bridge ontology the original ontologies are not changed and a merged ontology is created that can be used for interoperability between heterogeneous data sources.

D. SaaS Service Model

SaaS is form of cloud computing that deploys the software on cloud infrastructure that can be used as a service later. Its benefit is hiding the ICT infrastructure complexity and decreasing the upfront cost that would directly allow the users of the system to take benefit of the functionality.

IV. Proposed Architecture

In order to provide semantic interoperability between HIS's that are complaint to different heterogeneous standards, we need services that are based on ontology mappings. We provide SaaS model based architecture for the purpose of providing semantic interoperability through mapping services. The proposed architecture shows the use of mapping services for achieving interoperability (see Figure 2). Detail description of the components are given below.

A. Service Layer

This layer is responsible for providing and executing interoperability services to the consumers. Any SOAP based client can consume these services to achieve its interoperability goals. It consists of three sub components: Service Discovery, Service Selection, and Service Invocation. The service discovery component discovers relevant services, Service Selection component selects the most relevant one and Service Invocation component invokes the selected service.

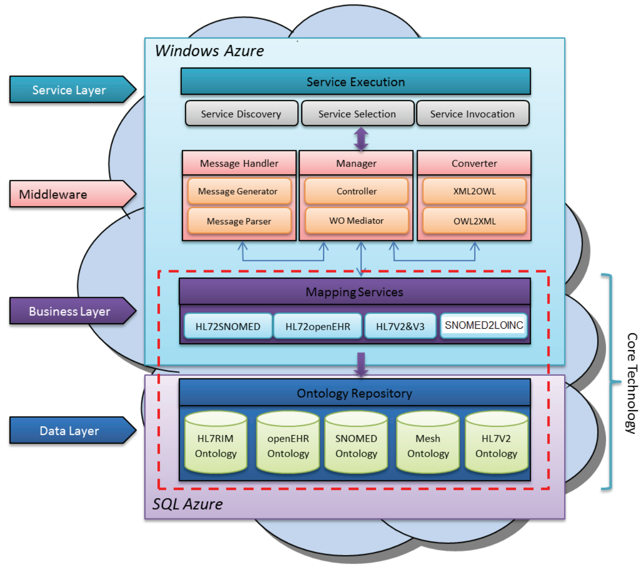

Figure 2. Proposed Architecture

B. Middleware

This layer is responsible for handling messages for the standards and also managing the information transfer between different components. Also it is used for conversion purposes as well for the semantics to take effect.

1) Message Handler: This component is responsible for handling the message generation and parsing at the sender and the receiving sides of the communicating parties. It consists of sub components; Message Generator and Message parser. Message Generator is responsible to generate messages, which will be communicated to another party. Message Parser is responsible to parse received messages for checking the validity of the message syntax.

2) Manager: This component is responsible for controlling the overall flow of information between different components. It consists of Controller component. It provides output of one component as input to another component for processing. For Example, providing the generated message as output from Message Handler component to Converter Component as input. The Mediator component is used for providing mediation services between Service and Ontology repositories. For example, Mediator component will provide mediation between HL72openEHR service with HL7 and openEHR ontologies, as this service is dependent on these ontologies.

3) Converter: This component is used for transformation of the message to a formal representation for the semantics to take effect. The two sub components of this component are XML2OWL and OWL2XML. XML2OWL performs its operation by taking message as input from the sender in XML representation for the mappings services to convert to OWL representation. OWL2XML component is used for providing the message in XML representation to the receiver after the mappings have been performed.

C. Business Layer

This layer is responsible for making the communication possible between different health-care systems by providing the mapping services. This layer achieves eventual interoperability. Mapping services perform the mapping between two different heterogeneous standards and eventually achieve interoperability between HIS. These are the most important components of the proposed architecture.

D. Data Layer (Ontology Repository)

This layer stores ontologies that are relevant to achieve the purpose of semantic interoperability. It consists of Ontology Repository. The Ontology Repository consists of health-care standard ontologies. Some of these ontologies include HL7, SNOMED CT, openEHR, and Mesh.

E. Cloud Computing

For ubiquitous availability of services and efficient resource management, our system will be leveraging cloud computing SaaS model of implementation. Our system is built using Microsoft .Net framework and over Microsoft Azure. Windows Azure provides the needs for service layer hosted as Web Roles. Middle-ware Layer and Business Layer are hosted as Worker Roles for services to utilize. Data Layer is hosted over SQL Azure. Ontologies are persisted as Blobs. Stored Procedures are written to provide CRUD operations on Ontologies and their mappings.

V. Mapping Services Functionality

Mapping Services are used to make two HIS systems, compliant to heterogeneous standards, interoperable with each other. The detail architecture of the mapping services is shown in Figure 3. The architecture is divided in to main three layers: Input, Middleware, and Output. In this research, the mapping service of HL7 and openEHR is required to be invoked.

A. Input Layer

The Input layer takes Generated Message from HIS as input in a standard format. The generated message is converted from XML representation to OWL ontology. This OWL format is compliant with the standard ontology used by the HIS. This OWL message is then provided to the middleware component.

B. Middleware Layer

Depending on the requirements, one of the three components of the middleware layer will be invoked. Ontology mapping component stores the mapping information of different standards. As we are considering HL7 and openEHR, therefore the mappings from the ontologies of both standards are stored in this component.

1) Ontology Mappings: The mappings are the result of ontology matching using different open source ontology matching tools available. We used Falcon and Agreement Maker for matching ontologies of these standards. The ontology mappings generated by ontology matching tools are verified by human experts for their validity.

2) Bridge Ontology: It can be used when multiple ontologies are required to be mapped. We take the scenario of communicating parties are based on different health-care standards for messaging and terminologies. The sender HIS is HL7 compliant and uses SNOMED CT for terminologies. On the other hand the receiver HIS is openEHR compliant and uses Mesh terminologies. To handle this situation, complex mappings are required which are provided by bridge rules in Bridge Ontology.

3) Manual Mappings: It is important to eliminate any discrepancies from the mappings generated by tools and found in Bridge Ontology. For this reason human experts performs the mapping refinement process. It assures the end to end accuracy in the whole process. Manual Mappings or human involvement is preferred as compared to Ontology Mapping and Bridge Ontology Component due to its precision level. Also ontology mapping tools have some limitations which can also be handled by Manual Mappings.

C. Output Layer

The Middleware layer generates the output message using mappings and provides it as input to the Output layer. This layer performs the functionality in reverse order of the input layer. The ontology taken as input is converted from

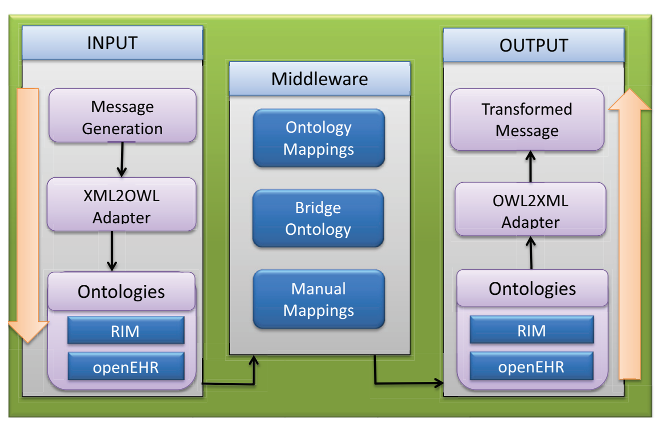

Figure 3. Extended Architecture of Mapping Services

OWL to XML message format of the receiver. The receiver understands the transformed message and performs message parsing. This architecture is explained further with the help of a scenario in the next section.

VI. Health-care Standards Mapping Services

The main concern of these health-care standards mapping services are the level of accuracy of mappings and the data loss while transformation of instances. The settlement of these issues would lead to effective use of mapping service deployed on cloud. We consider EHR standards related mappings in this section.

A. HL7 CDA and openEHR

HL7 CDA and openEHR standards are based on management of clinical information. These standards have differences as well as common aspects that can be used for interoperability among health-care system compliant to these standards. CDA is based on Reference Information Model for clinical information modeling while openEHR is based on two level modeling approach, separating reference models and clinical information.

1) Model Level Mapping: Mappings among these standards would be divided into different levels. The first level is mappings defined at model level. Reference models of both standards would be mapped using ontology matching tools. Expert verifications of the mappings would be carried out to cover the deficiencies of the matching tools. Participation class in both standards reference models refers to an actor or role participating in an activity. Therefore, ontology matching tools (Agreement Maker and Falcon in this case) shows both the entities in ontologies as exact match applying string matching techniques. Same is the case with Person, Organization, Role and other entities matching that are part of both the ontologies. The limitation of ontology matching tool paves way for expert verification. One case is the Actor class of demographic information model of openEHR standard, matches with Entity class of HL7 V3 RIM. This type of matching is not captured by these tools, so manual mappings are needed. Both Actor and Entity classes refers to any real-world entity capable of taking on a role.

2) Attribute Level Mapping: The second level is the attribute level matching. Accomplishment of instance level transformation with high level of accuracy is based on attribute level matching. In order to capture this, instances of both standards needs to be converted to ontologies initially for mapping purpose. Figure 4 shows code attribute of CDA used to depict the standard terminology used, which is mapped to term bindings attribute of openEHR standard.

3) Issues with Mappings and Transformation: Accuracy of mappings and handling the data loss are the critical factors for interoperable mapping and transformation system. Expert intervention is required while generating mappings due to limitations of matching tools and sensitivity of medical domain. On the other hand attributes and even concepts that are part of one standards but missing in other would play a significant role in instance transformation for ensuring the integrity of the document. Degree of automation is another factor influencing the effectiveness of the whole process. These factors plays key role in designing and implementation of interoperable system.

VII. Discussion

Most of the ontology matching tools support matching between two ontologies as source and target ontologies. They cannot tackle multiple ontologies matching and creating mappings for them. This is another challenge for achieving data interoperability between health-care standards. Communication between health-care organizations compliant to different health-care standards would require mappings between multiple ontologies. This is due to the fact that messaging and terminologies standards both are required for messages creation. Messaging health-care standards and EHR related standards are dependent on medical terminologies standards. One can use SNOMED CT in HL7 messages to handle terminologies or even ICD 10, LOINC or HL7 own vocabulary. Same is the case with openEHR archetypes; where terminologies are handled using terminologies standards. We take the scenario of sender compliant to HL7 standard having HL7 message based on SNOMED CT terminologies and receiver compliant to openEHR standard using ICD 10 terminologies for openEHR archetypes. The standards used for communication between these are heterogeneous and thus mapping of the four standards are involved in this scenario for interoperable communication. Therefore a technique is required for handling multiple ontologies mappings. Bridge Ontology can be used for handling heterogeneities between multiple ontologies. It provides the concept of bridge rules that defines complex relationships between concepts of multiple ontologies. Manual mappings is required in bridge ontology mappings as well. Ontology Mappings and Bridge Ontology helps in resolving the heterogeneities between data and provides interoperabil-

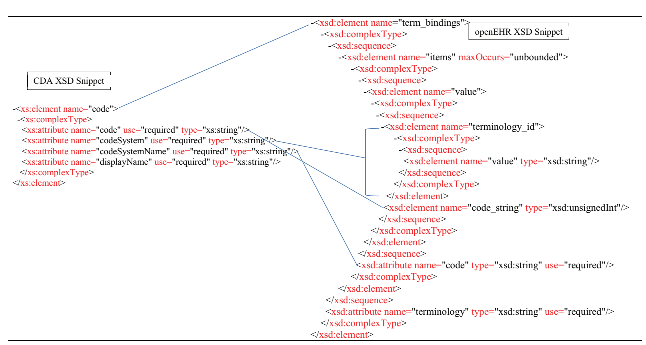

Figure 4. Attributes Matching of CDA and openEHR

ity at the data level. But it is limited when it comes to process workflows heterogeneities. Therefore services used widely as representation for SOA can help in resolving process workflows level interoperability. Services provide loosely coupled architectures that allow building flexible and scalable systems. Services that resolve data heterogeneity and their workflows builds a SOA based architecture for providing interoperability. But in order to achieve true semantic interoperability, systems should support seamless communication and automation. To achieve these goals the role of Semantic Web Services and Semantic SOA based frameworks becomes important. Web Service Modeling Ontology (WSMO)[7] and OWL-S [8] are the frameworks that are based on the use of semantic web services. The overall seamless interoperability will be achieved when ontology mapping, SOA, and Sematic Web Services concepts are combined for building health-care systems that are standard compliant.

VIII. Conclusion

Semantic interoperability is of prime importance for health-care systems to communicate with each other and provide better health-care facilities to patients. Ontology Matching techniques and Bridge Ontology resolves the data level heterogeneities between different health-care standards. It also results in the integration of messaging and terminologies standards. Services based on ontology matching helps health-care systems to communicate with any other system. In future we will be working towards establishing more accurate mapping services and more detail level interaction study of existing health-care standards.

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