A Service Oriented Architecture Approach to Achieve Interoperability between Immunization Information Systems in Iran

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Abstract

Clinical decision support (CDS) systems can support vaccine forecasting and immunization reminders; however, immunization decision-making requires data from fragmented, independent systems. Interoperability and accurate data exchange between immunization information systems (IIS) is an essential factor to utilize Immunization CDS systems. Service oriented architecture (SOA) and Health Level 7 (HL7) are dominant standards for web-based exchange of clinical information. We implemented a system based on SOA and HL7 v3 to support immunization CDS in Iran. We evaluated system performance by exchanging 1500 immunization records for roughly 400 infants between two IISs. System turnaround time is less than a minute for synchronous operation calls and the retrieved immunization history of infants were always identical in different systems. CDS generated reports were accordant to immunization guidelines and the calculations for next visit times were accurate. Interoperability is rare or non-existent between IIS. Since inter-state data exchange is rare in United States, this approach could be a good prototype to achieve interoperability of immunization information.

Introduction

Health information technology systems support clinical decision-making, providing access to information or suggesting diagnostic strategies (1, 2). However, clinical information is usually scattered among several independent systems that may be syntactically or semantically incompatible. This incompatibility prevents providers' access to patients' comprehensive medical history and makes the exchange of information very challenging (3).

Standards in the healthcare domain play crucial role in facilitating health information exchange and interoperability. However, information systems today are developed based on different technologies and various proprietary protocols and communication standards are not good solutions for inter-organization interoperability (4). Interoperability between systems is one of the key aspects of enterprise solutions, but because of semantic heterogeneity between applications it is very difficult to achieve (5).

To address interoperability, HL7 works as one of the leading standards for exchange of clinical and administrative data among healthcare information systems. HL7 is a syntactic lingua franca used by healthcare computers to talk to other computers and provide information when and where needed (6). Version 2.x of this standard is largely adopted in immunization information systems (IISs) which are confidential, population-based, computerized information systems that attempt to collect vaccination data about all children within a geographic area (7). IISs can be more efficient if they are improved by immunization decision support system (DSS). Immunization DSS can generate reminder and recall vaccination notices regarding each child's immunization history. Also they can provide official vaccination reports and vaccination coverage assessments for caregivers (8).

To date, IISs are usually isolated systems and querying other systems in order to assemble immunization history is barely possible (9). Service-oriented architecture (SOA) provides a way for these isolated systems to remain viable and responsive to increasing demands for information and analysis (10). By overcoming interoperability limitations, SOA allows existing systems to be integrated by exploiting the pervasive infrastructure of the internet and offers a new chance to continue to use and reuse the business functions provided by legacy systems (11).

Currently in Iran, immunization records are captured on paper records and the information is not stored electronically. Accordingly, providers in Iran's immunization centers do not have access to complete records of an individual's hitherto received vaccines, making it difficult to forecast needed vaccines or schedule the next

immunization event. In this paper, we describe the development of two IISs and provide a solution to achieve interoperability between them. Our goal is to facilitate complete immunization history management and Immunization DSS to help providers in Immunization decision making.

System Development

Immunization Information System
To communicate with other systems, an IIS should be able to capture necessary immunization data into a local database and exchange this information with other systems. Our three main objectives for developing IIS are:

- Support basic business requirements of immunization information system according to immunization guidelines for Iran's vaccination centers (12) such as small clinics.
- Ability to interoperate with other systems through standard healthcare web services.
- Ability to send/receive HL7 v3.0 messages based on standard terminologies.

To meet these objectives, business and system requirements were analyzed and necessary use cases were specified. Then an Immunization Minimum Data Set (MDS) was designed and information model was developed in compliant with the HL7 Reference Information Model (RIM). Afterwards, the local IIS's database was designed and implemented using Microsoft SQL Server.

The HL7 RIM specifies the grammar of v3.0 messages of HL7 standard, specifically, the basic building blocks of the language (nouns, verbs etc.), their permitted relationships and Data Types. These messages are all based on XML. All of the XML tags and attributes used in v3.0 messages are derived from the HL7 RIM and the HL7 v3.0 Data Types (6).

Figure 1. Patient registration forms of implemented IIS

Required vocabularies for concept exchange was extracted from various terminologies like LOINC, ISO 3166, ISO 639-1 and HL7 vocabularies. The system was developed based on three-tier architecture and for transmission of data between these layers we used Data Transfer Object component. Data transfer object (DTO) is an object that carries data between processes in order to reduce the number of method calls. When you are working with a remote interface, each call to it is expensive. The solution is to create a Data Transfer Object that can hold all the data for

the call (13). The system was built in C# language over Microsoft Visual Studio. Figure 1 demonstrates two patient registration forms of implemented IIS which fulfills the required information for HL7 RIM domain model.

EIS and RLUS web services

When a mother takes her child to an immunization center, healthcare providers want to know when and what vaccines has the child received up to now. In other words, they are interested in knowing the child's immunization history. If the entire history is contained in the local center's IIS, there is no need to communicate with other systems to get further information. However, in many cases a child receives vaccines in other locations and data must be retrieved from multiple IISs, making interoperability an important feature for IISs. Deciding if it is required to deliver a vaccine to child, providers need to know what vaccines were previously administered at the other centers. Service Oriented Architecture can help streamline data exchange and promises interoperability between heterogeneous information systems. By using specific web services available in a network, caregivers can retrieve the most current immunization records. SOA environment allows different IISs in heterogeneous platforms and architectures, to negotiate and interoperate with web services without any need to change their architecture.

When there is no information about the current patient in the local system, the first thing the provider needs to know about the child is an identifier which specifies the child as a unique individual among multiple organizations. It is common that the information system of each organization or even department often assigns its own ID that uniquely identify the individuals for its own purposes, with the result that these ID values are meaningless outside that system or organization. These autonomously managed IDs suit the purposes of recording and retrieval of information for the single department or organization, but interoperability requires an ID or matching process to identify an individual uniquely among multiple IISs and then retrieve required information.

In this regard, HSSP recognizes the need for service specifications to support healthcare IT. HSSP is a collaborative effort between HL7 and the Object Management Group (OMG) standards group to address interoperability challenges within the healthcare sector. The activity is an effort to create common "service interface specifications" that ultimately can be tractable within a Health IT context. The stated objective of the HSSP project is to create useful, usable healthcare standards that define the functions, semantics, and technology bindings supportive of system-level interoperability (14).

The Entity Identification Service (EIS) is one of the services recommended by HSSP which is charged with defining the functional specifications of a set of service interfaces to uniquely identify various kinds of entities (e.g. people: patients, providers etc., devices) within disparate systems within a single enterprise and/or across a set of collaborating enterprises(15). EIS defines 'generic' interfaces that would allow name-value pairs to be associated with an entity. EIS is based upon the creation and maintenance of an index consisting of a linked set of Source ID/Entity ID pairs representing the same Real World Entity (RWE). A Source ID and Entity ID are supplied in pairs in order that they may uniquely identify an Entity with the Domain of the EIS. An Entity ID alone uniquely identifies an Entity within the Domain of the Source (16).

By exchanging HL7 messages between IIS and EIS web service we can obtain the child's Unique ID and his/her demographic information. In this effort EIS was implemented according to the service specifications which are published by OMG and HL7 (15, 16). Communicating with this web service, our IIS was able to search using the child's traits in web service and get respective unique ID and demographic information to register a new record in its own local data base.

After resolving the child's identification, the next step is retrieving individual's immunization history based on this unique ID. The Retrieve, Location, and Updating Service (RLUS) is another service specified by HSSP which provides a set of interfaces through which information systems can access and manage information. RLUS allows health data to be located, accessed and updated regardless of underlying data structures, security concerns, or delivery mechanisms (17).

This service is designed for general purposes in the healthcare domain, so we implemented a customized RLUS web service according to (17, 18) with constrained functions to retrieve individual's immunization information. For integrating immunization information of different IIS systems, each IIS sends the information of every Immunization event occurred in the local center to the web service through HL7 v3.0 XML based messages. Figure 2 shows a high level picture of SOA-based interoperability between IISs and web services. In the picture, HL7 messages are wrapped inside SOAP messages and they are exchanged though internet. Also it demonstrates the two immunization DSSs which are embedded in IISs.

Our EIS and RLUS Web services, were built based on Microsoft WCF technology in C# language and the protocol used to exchange XML-based HL7 messages is SOAP and the location of the services and their operations are described through the web services description language (WSDL). The service layer in both web services (EIS and RLUS) is very thin and does not include any business processes or service implementations. Service, data and operation contracts were exposed just in service layer. Regarding the security of interoperability we take advantage of WCF security. Microsoft WCF provides several security features such as transfer security, authorization, and auditing by default, which are responsible for providing message confidentiality, data integrity, and authentication of communicating parties.

Each web service took advantage of multi-tier architecture and has its own independent data base in Microsoft SQL Server. Operations in both of the web services are practically equivalent to HL7 v3.0 interactions specified in HL7 universal domains and Input parameters and return values of the operations are HL7 messages. When a remote IIS invokes one of these operations, depending on operation and its input message, the processes are performed in the web service and the results are returned in the form of an HL7 message. If any error occurs during the message processing, the error code and its description will be returned to the calling IIS. Messages are validated once received by the web service. Message validation is performed locally in EIS and RLUS servers for the pilot system. Messages are checked for both syntax (e.g., Is the message conformant with HL7 message structure?) and semantics (e.g., is valid information from standard terminologies used?). For improper messages, an error message with appropriate error description is returned to the sender.
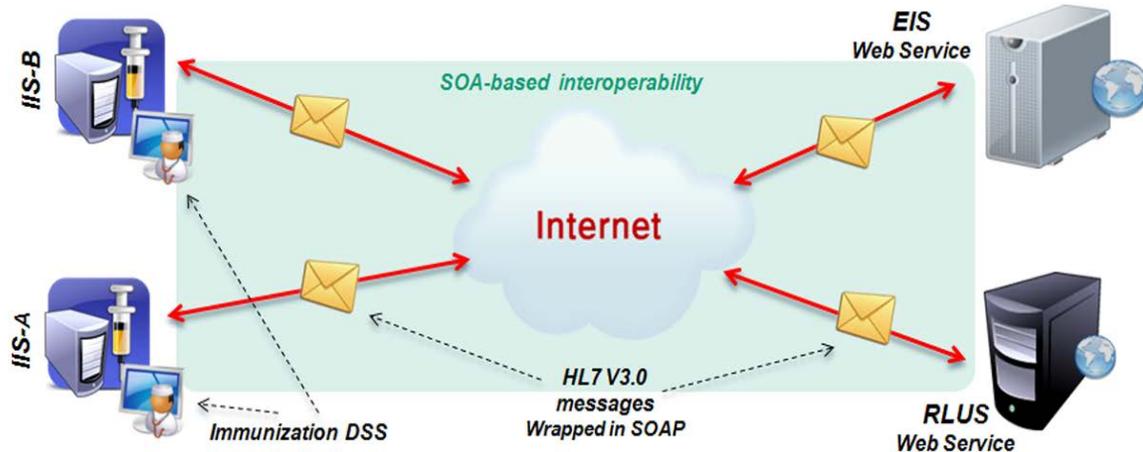

Figure 2. High level picture of SOA-based interoperability between IISs and web services

HL7 v3.0 Messages
The HL7 standard represents the foundation of many healthcare information management systems (19). Version 2.x of this standard is extensively adopted in health care domain and usually IISs use version 2.x rather than v3.0. Immunization information systems which are exchanging HL7 v3.0 messages are rare or non-existent. The reason is that the structure of messages completely changed in version 3.0 and it is cumbersome to upgrade systems from older version to newer one. However, version 2.x enables some optionality in message generation that makes it very hard to apply conformance tests and forces implementers to investigate whether the messages coming from different parties have the same structure of optional fields for a single message (6). This optionality provides multiple ways for generating the same message, therefore when you get one implementation of version 2.x it is likely that you get another one and that is different because of many optional fields and segments in message structure (20).

By presenting RIM data model and using "rigorous analytic and message building techniques", HL7 addressed the issues of version 2.x and provided messages without optionality issues in version 3.0 (6). By adoption of RIM in this study as information model of IISs and exchanging HL7 v3.0 messages, we tried to improve immunization information interoperability.

```xml
<id root="15892" AssigningAuthorityName="IdCardNo"/>
<id root="1380790681" AssigningAuthorityName="NationalCode"/>
<name>
    <given>رضا</given>
    <family>مهدوی</family>
</name>
<fatherName>
    <given>احمد</given>
    <family>مهدوی</family>
</fatherName>
<telecom use="HP" value="88909216"/>
<telecom use="MC" value="9124000456"/>
<administrativeGenderCode code="M" displayName="Male" />
<birthTime value="19720330"/>
<addr use="HP">
  <HouseNumber>56</HouseNumber>
  <Alley>کوچه وهاب زاده</Alley>
  <StreetName>خیابان ولیعصر</StreetName>
  <CityName>تهران</CityName>
  <ProvinceName>تهران</ProvinceName>
  <country>US</country>
  <postalCode>13597-55675</postalCode>
</addr>
<maritalStatusCode code="12218"/>
<educationLevelCode code="19179"/>
<disabilityCode code="10182"/>
<religiousAffiliationCode code="19208"/>
<raceCode code="15814"/>
<religiousAffiliationCode code="19208"/>
<languageCommunication>
    <languageCode code="99101"/>
</languageCommunication>
 <birthPlace>
    <addr>
       <country>ایران</country>
       <city>تهران</city>
    </addr>
 </birthPlace>
```

Figure 3. Localized HL7 message in XML format with Father Name and customized home address

According to EIS and RLUS specifications, messages are defined to cover universal needs; however the structure of universal messages does not meet Iran's needs for message exchange. For example, "Father Name" is mandatory in patient's demographic information in Iran, which is not considered in universal messages. Also the structure of patients' address is totally different in Iran. Each universal message includes plenty of classes and attributes that are not in the scope of our work. We solved these problems in two steps. First the messages were customized according to our business requirements and then an intermediary component was developed as an API which isolates the complexity of messages inside of itself and presents very simple operations for message generation. Working with this component is much easier because it plays as a mediator between operations and HL7 complicated classes and data types.

HL7 messages have many data types which are added into the web service's data contracts and by exposing the services through WSDL the local IISs can access to all of HL7 data types in order to massage making. The localized HL7 message in XML format with Father Name and customized home address is shown in Figure 3.

Immunization Decision Support System (DSS)
Timely vaccinations decrease a child's risk of contracting vaccine-preventable disease and prevent disease outbreaks. Reminders and comments generated by immunization DSS can advise providers on which immunizations are needed for a particular patient and provide valuable information for caregivers to deliver better vaccination services to individuals and help people to live healthy. Moreover, Clinical DSS can improve the adherence of providers to clinical guidelines (21).

In this study, the immunization DSS is designed as a guideline based rule engine and embedded into local IISs by which the system can forecast immunization events and give appropriate alerts and recommendations to providers. All of the information needed for rule engine component is provided through communicating with EIS and RLUS.

It is important for providers to know when and what vaccines were administered to patients up to now and whether they were delivered on time or late. Also, they need to know where a patient received the vaccines and who the caregiver was or what vaccines are required to be administered in future and what would be the accurate schedule for next immunization events according to guidelines. Identifying individuals uniquely by exchanging messages with EIS and retrieving integrated immunization history from RLUS web service, the rule engine can apply standard immunization rules on retrieved comprehensive immunization history and generate useful information for providers to address their requirements. Also system can alert the provider that what vaccine is not allowed to be administered or what is needed.

Figure 4 is translation of a sample report from Persian language to English generated by the immunization DSS. This report is based on fake immunization scenario with many delays in attending at immunization center which shows the DSS detects late delivery of vaccines to child. Also, it schedules the future events considering the information from previous events. Moreover, the implemented DSS warns the provider that the Diphtheria, Tetanus and Pertussis (DPT) Vaccination is already recorded for five times and is not allowed to be administered any more when a provider tries to add a new immunization record into system. For each immunization event, the report informs the location of vaccine delivery, provider and some necessary comments. The rules of DSS component have been extracted from guideline of immunization approved by national immunization committee of Iran (12).

Immunization Forecasting Report

Patient Demographics
Patient ID: 30005046   **Name:** Homayoun   **Last Name:** Asadi   **DOB:** 07/23/2011
Vaccine type: Diphtheria, Tetanus, and Pertussis (DPT)

Vaccine Schedule	Encounter Date	Delay (day)	Next Dose Date	Center	Provider	comments
1st time 2 month old	10/03/2011	10	11/23/2011	IIS_A	Reza Ahmadi	This dose should be delivered to baby between 2 months old to 2 months and 29 days old
2nd time 4 month old	01/31/2012	69	02/29/2012	IIS_A	Reza Ahmadi	Next dose in 1 month
3rd time 6 month old	03/04/2012	4	01/23/2013	IIS_A	Reza Ahmadi	Next dose at the age of 18 months
4th time 18 month old	02/25/2013	33	07/23/2017	IIS_B	Kazem Nabavi	Next dose at the age of 6 years
5th time 6 year old	08/06/2017	14	N/A	IIS_B	Kazem Nabavi	Administration is not allowed after this dose
6th time	07/29/2019	Warning	Warning	IIS_B	Kazem Nabavi	Administration is not allowed!

Figure 4. Sample report in Farsi language generated by the immunization DSS

Results

In order to explore the feasibility of our approach, we conducted a system test and deployed two independent IISs connected to internet without any direct connection to each other and published the EIS and RLUS web services. Then approximately 1500 immunization records for roughly 400 infants from Alzahra Education and Treatment Center in Iran were collected. These records are collected on paper and didn't include any identifying information, so the fake demographic data and ID for children were generated.

The data were randomly entered into two IISs. Considering that each child has more than one immunization record, by random data insertion we guaranteed that immunization information of each individual is scattered in different IISs. During the registration of patients' demographics and immunization records in a random way, the information automatically were sent to EIS and RLUS web services based on HL7 v3.0 messages and integrated in databases located in web services. Then we randomly selected 50 patients and searched their immunization records in both IISs. Based on received immunization history we got and immunization forecast from DSSs embedded in systems.

The HL7 v3.0 messages are specialized from abstract RIM data model to carry domain specific concepts. These messages are converted to large XML documents to transmit between IISs and web services. Although XML messages are large and complex, however, the systems' turnaround time is less than a minute for synchronous operation calls and there was no delay even when the HL7 XML messages are very large.

Due to communication in SOA environment, information is gathered from both IISs and consolidated in web services so the immunization history of patients are always identical in different systems. Systems can update their local data base by synchronizing with web services.

The reliable information supports DSS to generate reliable reports and alerts which is very important in health care sector. For the 50 individuals that we retrieved immunization history, generated warnings or forecasts for the next vaccines were completely accordant to Immunization guidelines and the calculations for next visit dates were 100% accurate. Also the result of DSS was the same in both IISs and there was no difference in generated reports.

Discussion

It has been more than a decade since Iran's government invested in Electronic Health Record (EHR) systems to overcome the challenge of data exchange between Health Information Systems (HIS). However, there has been little progress in computerization of Immunization registries and vaccination information is still captured in traditional methods in Iran. In the United States, minimum functional standards for the operation of immunization information systems were developed by the U.S. Centers for Disease Control and Prevention (CDC), however, currently IIS systems are usually state-centric and there is significant need to data exchange among states and improve data quality and interoperability of systems. Given that residents travel between facilities and across states, healthcare providers require access to comprehensive immunization history of individuals across fragmented EHR, HIS, and IIS. We present a novel prototype for integration and exchange of immunization information based on localized HL7 v3.0 messages for Iran and which takes advantage of SOA specifications. This same approach could be applied in the U.S. for integrating individuals' immunization records by exchanging data in SOA environment and accessing valid and up-to-date information in all of the states. For example, the Nationwide Health Information Network (now referred to as the eHealth Exchange) uses a SOA-based framework for the exchange of HL7 v3.0 continuity of care documents (CCDs) among health information exchanges and federal agencies (22, 23).

To date, v2.x of HL7 standard has been more popular than v3.0 in U.S., mainly due to inertia among commercial EHR companies to move away from legacy platforms. However, the implementation of CDA-requirements in compliance with the 'meaningful use' initiative has resulted in several commercial EHR vendors adopting v3.0 web services, even if they are simply wrappers (24) built on top of existing messaging endpoints. Therefore the U.S. market may see increased availability of v3.0 services in the coming years, and the pilot work in Iran might be useful for EHR vendors that wish to implement interoperable interfaces between various IISs among the various state health departments. Furthermore, given Europe's broader adoption of HL7 v3.0 messaging, the prototype described here might also be useful for sharing immunization records across nation borders.

Our system is built upon standard profiles and technical specifications that will help to be translated by US audience. IHE is one of leading organizations that tries to improve the utilization of computer systems in healthcare to support optimal patient care. EIS web service developed in this study, has many overlaps with IHE Patient Identifier Cross-Referencing (PIXV3) and IHE Patient Demographics Query HL7 V3 (PDQV3) which are presented in IHE IT Infrastructure Technical Framework (25). Both our study and IHE profiles use HL7 RIM model for design of messages and are corresponding with HL7 interactions for message calls. Also, in this study we adopted service profiles and specifications from HSSP and OMG, which are prominent organization in standard developing. Although there are some difference between our work and IHE profile such as service or message customization, however, we believe vendors can use presented model in this work along with IHE profiles which will not necessarily bad thing and they can reproduce this method.

Because of the inherent complexity in HL7 v3.0 messages, it can be confusing to extract and map all of the required IIS information into specific message fields when generating a message. We therefore encapsulated all message generation complexities inside an API component and, by exposing some simple operations to external software developers, better facilitated the process of message generation. This API can be re-used in other systems where the data model is based on the HL7 RIM.

When developing CDSSs, knowledge engineers try to use expression languages like GELLO to represent knowledge in a shareable format among other CDSSs. However, expression languages require an Object Oriented information

model to work efficiently. In this study, we designed information model based on HL7 RIM which is Object Oriented. This model enables our system to use expression languages for defining immunization knowledge and make this knowledge available for any other IIS. Furthermore, CDSSs are also moving towards SOA-based frameworks to enable distributed knowledge delivery across a range of clinical guidelines to improve health care quality, safety, and efficiency (26).

Conclusion

Providers require up-to-date access to information to accurately forecast vaccines as well as make other clinical decisions. EHR, HIS, and IISs have generally been developed and deployed as silos enabling fragmented, cumbersome access to patient information. Greater deployment of health information exchange technologies like SOA and HL7 make it possible to engineer distributed IIS and CDSS. We describe an approach for Iran that has potential for the U.S. and other nations. Future research and development is promising to incrementally advance health information technologies towards meeting provider and patient needs for real-time access to information wherever it may be located.

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