HEALTH INFORMATION EXCHANGE NETWORK INTEROPERABILITY THROUGH IHE TRANSACTIONS ORCHESTRATION

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Abstract: Integrating the Healthcare Enterprise (IHE) is an initiative designed to facilitate the integration of healthcare information systems in order to exchange health care information in a secure, private and efficient manner. Solution vendors now offer IHE integration profiles as web services that can be integrated locally or regionally to coordinate standard heath care activities such as clinical documents management. Although IHE profiles promote the use of standards, the federation of health information systems is difficult because each node to integrate is generally very different. Each individual node has its own services, communication protocol, security scheme, performance, customization and extensibility capabilities. In addition, IHE profiles do not address workflow management process such as the mediation, routing and aggregation of the content of IHE transaction messages. In this paper, we describe an architecture solution that addresses these needs and provides the orchestration of IHE transactions (XCPD, XCA, ATNA) to support state wide-Health Information Exchanges.

1 INTRODUCTION

Integrating the Healthcare Enterprise (IHE) has gained tremendous momentum in the past few years. Started as a Healthcare Information and Management Systems Society (HIMSS) and Radiological Society of North America (RSNA) workshop in October 1998 with only 15 participants including AGFA, Cerner, Fuji, GE, HP, Philips and Siemens, the IHE initiative has more than 400 members worldwide. IHE provides a standards based-interoperable framework (IHE 2009) to share and exchange information between health care organizations across networks.

Combined with the latest technology and well established standards (HL7, DICOM, IDC9/10, LOINC, W3C), clinical data can then be securely and privately accessed (Masi et al. 2009) and transmitted locally between network end-points (e.g. within the same hospital between the practices and a lab). IHE profiles can also be used across Health Information Exchanges (HIE) of Regional Health Information Organization (RHIO), or a state level (e.g. an individual state in the US, Canada or Europe), or at the federal level (e.g. the US Nationwide Health Information Network or NwHIN). As a result, there is a strong need to integrate and combine individual IHE profiles end-points to form “hub of hubs” or “network of networks” to support health information exchange between the participating nodes entities.

1.1 Encounters and Clinical Decisions

The motivation for integrating IHE hubs and networks is to obtain up-to-date information relevant at the point of care to improve diagnosis and make better clinical decisions. This is particularly important for the care giver to have access to accurate medication, allergy, problems, conditions, medication, lab and radiology history when the

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encounter occurs far from the patient's usual medical center. For example, a patient could be treated while on vacation or at the nearest trauma center following a car accident far from his/her home. Very often, emergency encounters happen only a few miles from the clinic where the patient's primary care physician is located. But because the networks of these organizations are not connected there is no possibility for the care giver to have a direct and easy access to the patient's clinical data. In addition, there is a need for regional, state or federal level IHE integration that can be used to control specific global catastrophic events such as pandemic episodes. This type of integration also offers greater visibility to public health decision makers in general.

1.2 Integrating IHE End-points

In this paper, we present various options to integrate IHE web services end-points. We describe the requirements of a state-wide health information exchange in the USA and we explain how we have designed and built a specific solution to address these requirements.

2 COMBINING TRANSACTIONS

Because IHE transactions are most likely to be offered as Web Services, combining those transactions can be done following Service Oriented Architecture (SOA) and Service Oriented Computing (SOC) principles (Papazoglou and Georgakopoulos, 2003). SOA describes the basic web services communication protocols, functionalities and how these services are exposed, discovered and used by clients. SOC on the other hand, describes how these services can be aggregated via composition, coordination and monitoring.

For IHE transactions, an example of composition would be how to combine cross-community patient discovery (XCPD) response messages from several end-points to check which sub-networks hold data about a specific patient. An example of coordination might be necessary when querying various hubs in a network and trying to combine IHE messages from different end-points within a certain time frame. Tracking and auditing capabilities for all transactions that travel across health information exchange networks are examples of monitoring as required by healthcare regulations such as HIPAA.

2.1 IHE Profiles as Web Services

IHE profiles are generally implemented as web services that are accessible via an Internet Uniform Resource Identifier (URI) over the Hypertext Transfer Protocol (HTTP). Even though there are various ways to implement web services, IHE profiles are usually implemented using the Simple Object Access Protocol (SOAP) that transport data content as XML. SOAP uses the Web Services Description Language (WSDL) to describe the services as a collection of network end-points, or ports. WSDL files are accessed to determine which operations are available for each service. The Universal Description, Discovery, and Integration (UDDI) standard can be used for the localization and introspection of potential web service directory collections.

2.2 Enterprise Application Integration

Conventional middleware distributed system infrastructures (e.g. JMS) are generally not sufficient or flexible enough to mediate, transform, federate and route messages from and to web services. Enterprise Application Integration (EAI) goes one step ahead, trying to separate the applications from the web services end-points. EAI usually employs a centralized service broker for this, a set of connectors and an independent data model. Services can then send and subscribe to receive messages to and from the broker. However, this very centralized approach requires a large amount of up front development and business process design for the connectors, as well as high cost of maintenance in general. Enterprise Service Buses (ESB) is an infrastructure that leverages EAI principles.

2.3 Orchestration

Orchestration and choreography on the other hand offer ways to create more dynamic and flexible composite services using declarative (XML) business process modelling language.

Like EAI, orchestration uses a centralized approach (Jiménez-Peris et al., 2008); (Yahyaoui et al., 2009). Web services orchestration is realized through Business Process Execution Language (BPEL) that describe the collaboration and interaction between the web service participants (Dogac et al. 2006); (Timm et al. 2009); (Chen et al. 2006).

Business workflows, states, actions, events, control flows and exception handling can be specified. Messages can be received and sent directly from and to WSDL ports. Results received asynchronously from web services can be combined to create new messages.

2.4 Choreography

Choreography is another approach. It is more distributed and collaborative in nature (Kilic et al., 2010) and uses the Web Service Choreography Interface (WSCI) specification and the WSDL description files to represent the flow of messages exchanged between the Web services involved. Choreography seems more flexible than orchestration since it does not rely on a central element that could become a bottle neck and seems to offer more complex interaction potential between web services.

However, choreography has some drawbacks including the necessity for all web services to be aware of overall business process workflow. In addition to this, performance can be an issue if high volume message transactions between the end-points peers are not handled properly. Moreover, there is no clear responsibility for the overall workflow leading to legal issues related to monitoring and maintenance (Janssen and Kuk, 2007).

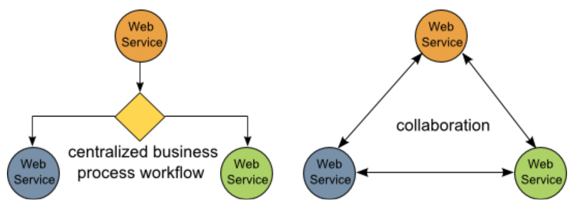

Figure 1: Orchestration and choreography.

3 STATE-WIDE HEALTH INFORMATION INTEGRATION

In the US, a certain number of initiatives (Table 1) aim at the development of state-wide health information networks. The goal is to promote the exchange of health information and improve the coordination of care and population health at the state level. These state level integration projects are generally built on top of existing Regional Health Information Organizations (RHIOs).

The nodes of the network correspond to practices, hospitals, labs, or more complex organizations such as RHIOs and services representing state agencies. Added value services encompass other highly specialized services such as patient access, CCD and lab results translation, eligibility and decision support.

Table 1: US state-wide health information networks.

State	Project
Delaware	Delaware Health Information Network (DHIN)
Indiana	Indiana Health Information Exchange (IHIE)
Tennessee	Health Partnership for Tennessee (HIP TN)
New York	State-wide Health Information Network for New York (SHIN-NY)
Utah	Utah Health Information Network (UHIN)
West Virginia	West Virginia Health Information Network (WVHIN)
Wisconsin	Wisconsin State-wide Health Information Network (WISHIN)

In this type of architecture, core services serve as the gateway through which end-point nodes can either communicate among themselves or with the other services offered by network.

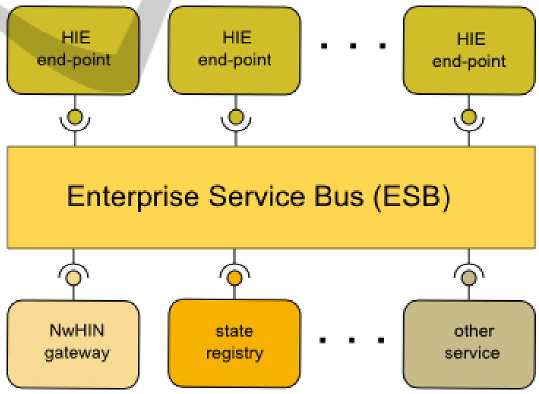

Figure 2: State-wide HIE interoperability network orchestration.

The core services can include services such as trust broker, matching (e.g. master patient index), master facilities index, master clinical index and Federal NwHIN gateway access.

3.1 Privacy and Security

As for regional integration, state-wide integration puts a lot emphasis on privacy and security for the access and manipulation of protected health information (PHI) as mandated by HIPAA.

Health information exchange at the state level have mechanisms that give the ability to the patients to indicate whether or not their data will be included in the exchange (opt-in/opt-out model) based on the state regulations. These networks also have tracking and auditing capabilities at each level such as end-point nodes transactions, orchestration mechanism and external services to enforce user accountability.

When integrated, the access to the end-point nodes, the service providers and the Health Information Exchange are limited to authorized users only. Processes and detection mechanisms are put into place to uncover breaches, security incidents, and other violations.

Transport Layer security is usually enforced by using two-way TLS. All end-points of the network that talk to each other must exchange certificates containing a certificate authority (CA) and a public encryption key to be able to encrypt messages before sending them.

The SOAP payload is frequently required to be encrypted and signed, to enforce privacy, authenticity and non-repudiation of the IHE messages that are exchanged.

Finally, valid SAML assertions (SAML 2009) can be added in the requests with all required user information for security and audit purposes.

3.2 IHE Profiles

The health exchange services use IHE profiles to communicate between each other:

- Cross-Community Patient Discovery (XCPD): to locate community end-points holding specific patients with relevant health data;
- Cross-Community Access (XCA) Query: to return the list of documents for selected patients;
- Cross-Community Access (XCA) Retrieve: to obtain relevant associated clinical documents such as Continuity of Care Document (CCD);
- Audit Trail and Node Authentication (ATNA): to establish tracking and auditing capabilities.

3.3 Interaction Overview

XPCD and XCA message exchange between end-points follow the same pattern. An end-point initiates a query (XCPD or XCA) and sends it to the exchange. The message is decrypted and its signature and SAML assertion are verified. The message is then broadcasted to all available end-points in the network. The message is repackaged for each end-point (encrypted with the public key of the destinations, signed by exchange and the SAML assertion is added). Responses coming back from end-points destinations are collected, decrypted, verified, aggregated and sent back to the initiating end-point. At each step of the process Audit Trail and Node Authentication (ATNA) messages are generated and stored for auditing.

Here are the specific steps for XCPD profile:

1. When a provider serviced by an end-point wishes to locate a patient in other communities, the end-point should initiate an XCPD query to the exchange on behalf of the provider system (such as an EHR).
2. The exchange record locator service will determine which end-points should be queried, using a service registry maintained by the exchange, and emits XCPD queries to those end-points.
3. Upon receiving the XCPD query from the exchange, each end-point will locate matching patients in its domain using local patient matching algorithms, and return the appropriate results to the exchange. The returned demographics shall include the patient’s unique ID in the end-point’s domain, along with enough key demographic data to allow the service consumer to determine the quality of the match.

4 DEVELOPMENT

Most of the development is done through the declarative design of the BPEL application. Workflows receive messages, reply and invoke actions (e.g. storing log entries in a database).

4.1 Mediation

The mediation logic and routing are added to the workflow. Message parsing, mapping and transformation are done using XSLT/XPATH expressions. When the BEPL application is ready, it is deployed on the SOA/ESB runtime platform. The end-points are configured and the application is tested by executing the workflows.

The application is composed of five BEPL workflows, associated WSDL files, style sheets and configuration files. The main workflow is in charge of message security (content attack prevention, authentication and requests validation), IHE sub-workflow forwarding and basic input/output log entries to a database.

The role of the mediation is to control the message processing and delivery based on some conditional logic. To help with mediation, the SOA platform employs a cache that can be used when aggregating asynchronous responses.

Table 2: Sample IHE integration BPEL workflow set.

main workflow	. handle security . select IHE workflows . log inputs/outputs
XCPD	patient discovery
XCA query	clinical documents query
XCA retrieve	clinical documents retrieve
worker process	generic dispatcher and aggregator workflow

4.2 Configuration

Part of the application configuration is the definition of the list of end-points (service registry), including security to specified end-points that are allowed to communicate between each other. We are also using XML as a way to describe the end-points in a very declarative manner. This file is used by the application, but can be modified at runtime. It includes the following elements: end-points URLs and ports, IHE services available, public certificates, identifiers and friendly names mapping for end-points.

4.3 Testing

We use soapUI (an open source web service functional testing tool) to easily simulate the health exchange network as well as initiating and responding gateways. With this tool, we were able to easily hard code requests and turn on or off security features (timeout, signature, encryption and SAML assertions). We also used Axolotl Interoperability Services (IS) that offer SOAP-based IHE web services (XCPD and XCA) in conjunction with soapUI to test the health exchange SOA integration solution.

The ability to quickly create and validate test cases is critical. It gave us the ability to test harness end-points individually by simulating calls coming from the exchange, but also to act as initiating end-point gateways, querying the exchange and receiving responses back from the exchange network.

We also used soapUI to test response timeout scenarios and combine this pure black-box testing approach with the analysis of transaction logs that provides a trace of each steps of the orchestration workflow.

5 CONCLUSIONS

The ability to efficiently and safely share and integrate information through local and regional Health Information Exchanges will be critical to improve healthcare around the world.

Orchestration also has the advantage to be a much more mature integration technology than choreography. In addition to this, web service orchestration offers much more than just technical benefits (Gortmaker et al. 2004):

- Organizational: standardization, narrow gap between business analysts and developers;
- Managerial: risk reduction, lower costs, more flexibility;
- Strategic: IT resilience, delivery time reduction, less technology lock-in;
- Technical: portability, reuse, interoperability of tools, less complex code, better maintainability;
- Operational: efficiency, automation, higher level tasks management.

When deployed on high performance platforms such as SOA software appliances, this orchestration solution is easy to test, extend and maintain.

We hope in a future article to describe how this architecture is going to perform in production by conducting performance measurement as well as load tests. We also plan to describe additional end-points integration such as state level immunization registries and describe how this SOA architecture can be used in regional and federal health information exchange networks.

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