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PPEPR for Enterprise Healthcare Integration

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Abstract. PPEPR is software to connect healthcare enterprises. Healthcare is a complex domain and any integration system that connects healthcare enterprise applications must facilitate heterogeneous healthcare systems at all levels - data, services, processes, healthcare vendors, standards, legacy systems, and new information systems, all of which must interoperate to provide healthcare services. The lack of interoperability within healthcare standards (e.g. HL7) adds complexity to the interoperability initiatives. HL7's user base has been growing since the early 2000s. There are many interoperability issues between the widely adopted HL7 v2 and its successor, HL7 v3, in terms of consistency, data/message modeling, precision, and useability. We have proposed an integration platform called PPEPR: (Plug and Play Electronic Patient Records) which is based on a semantic Service-oriented Architecture (sSOA). PPEPR connects HL7 (v2 & v3) compliant healthcare enterprises. Our main goal is to provide seamless integration between healthcare enterprises without imposing any constraint on existing or proposed EPRs.

Key words: HL7, SOA, Web service, Semantic and Interoperability solutions

1 Introduction

The average patient going to hospital presumes that no matter where he/she goes, that every specialist has access to his/her complete medical record. This is sadly not the case. Instead, in a hospital with 40 departments there will exist at least 40 specialist electronic patient record systems, some or all of which may exist in isolation. To enable interoperability between these systems the IT department typically has to employ a software programmer to develop interfaces between those systems. The proliferation of interfaces approaches n^2 where n is the number of EPRs in a hospital environment. In many cases this programming task not achievable and the result is the movement of paper files between departments which have perfectly functioning IT systems. HL7 is the most widely used standard the transfer of messages between EPR systems, which helps in reducing the amount of software development to be done in order to make EPRs interoperable. HL7 v2 is the version most commonly used, while HL7 v3 has been released as a standard since 2003. HL7 v3 adoption has been slow to date, but this is improving as newer EPR systems are developed and installed.

2 PPEPR: Plug and Play Electronic Patient Records

In PPEPR our focus on HL7 is due to the fact that it is the most widely used message based healthcare communication standard. In the HL7 Standard, there are two major versions, HL7 v2 & v3. While the HL7 v2 standard was created mostly by clinical interface specialists, the v3 standard has been influenced by medical informaticians. HL7 v2 messages are unstructured and flexible involving optional fields and segments whereas HL7 v3 is structured and provides greater consistency across the entire standard. HL7 v3 has published Web-service[1] and SOA4HL7[2] profiles to support healthcare workflows and benefits from interoperability features offered by Web service technologies.

Web services provide the technology foundation for implementing and delivering service-oriented architecture (SOA) platforms. However, a clear development methodology is missing and "gaps" between HL7 and Web service and SOA artifacts exist. The two core challenges of conventional computing - search and integration - (also known as "semantic gap" of SOA) are not addressed by SOAs [1–3]. Therefore, SOA itself is not a complete solution for the integration of information systems. The integration and/or interoperability requirements of information systems have resulted in the development of new breeds of SOAs, called semantic Service-oriented Architecture(sSOA). The "semantic gap" between HL7 versions and SOA-HL7 artifacts are solved by using ontologies-An ontology is a specification of a conceptualization [4]. The ontologies are used in the context of SOAs to resolve ambiguity in data, service and process definitions. We have introduced a functioning EPR integration platform in [5], called PPEPR: Plug and Play Electronic Patient Records. In this paper, first we analyse HL7 from the EPR integration perspective and benefits of PPEPR over existing integration solutions. Secondly, we briefly describe the PPEPR's semantic Service-oriented Architecture(sSOA) and types of integration it supports. Then we present a example scenario that briefly explains how PPEPR integrates heterogeneous EPRs. Next, we briefly explain how healthcare message, service, and process definitions are semantically annotated, grounded and mediated. Finally, we explain PPEPR assessment that shows PPEPR's effectiveness which is evaluated on various integration parameters.

3 HL7, EPR, and PPEPR

One of the issues with HL7 v2 is that it is not a structured standard and EPR vendors were given the flexibility of interpreting the standards. This resulted in many EPRs implementing variations on the standard, thus reducing interoperability. In the cases where HL7 v2 is used, engines are employed to ease the integration burden. These HL7 engines are used to map between these non standard implementations. HL7 engines do work between HL7 v2 systems but suffer a number of drawbacks: (1) Significant manual effort (2) initial set up is

[1] http://www.openhre.org/local/HL7WSP_August2003.doc
[2] http://www.hl7.org/v3ballot2008jan/html/infrastructure/soa4hl7/soa4hl7.htm

expensive, and (3) it creates a maintainability problem. By using HL7 engines hospital IT departments are replacing the n^2 interface development problem with an n^2 mapping problem. Replacing or upgrading one EPR system will mean the reimplementation of n sets of mappings. (4) HL7 engines currently in use mostly cater for EPR systems implementing HL7 v2. They will not cater for systems implementing HL7 v3.

PPEPR can work as a standalone product directly interfacing with EPR systems or can be used as an add-on to existing HL7 engines. The PPEPR software consists of two parts: The Design-Time and the Run-Time. The design-time portions of the system are used when installing PPEPR and configuring the various EPR systems which are to be made interoperable. The benefits of PPEPR over existing offerings are:

Semi Automatic: The work involved in modelling the environment into which PPEPR will work is semi-automatic. The only manual effort to be done during the design time is validating the internal representations of the messages and Web services involved in the workflow. The operation of PPEPR is completely automatic.

Flexible: PPEPR allows the easy addition and modification of models reflecting the changing environment within a hospital. Upgrading an EPR system from HL7 v2 to one which uses HL7 v3 is no longer a problem. Once the models are created then new system can be incorporated into the hospital without any additional software development.

Robust: With the hub-and-spoke topology inherent in using PPEPR the system is more robust than a peer-to-peer topology more typical of a system-by-system integration effort. Allied with the hub-and-spoke topology is the suite of models built for use with PPEPR. These models are built at a conceptual level and are more resistant to change than the low-level mapping functionality available with other systems.

HL7 v2 and HL7 v3: As noted above PPEPR will seamlessly cater for HL7 v2 and v3 EPR systems.

4 PPEPR's sSOA for EPR Integration

As discussed above, healthcare is a complex domain, comprising vendors, standards, legacy systems, and information systems which differ inherently from one another. PPEPR provides a unique approach to interoperability. The core solution lies in enabling semantic interoperability between existing and new EPR systems. PPEPR is based on the design principles of a semantic SOA Reference Architecture[3] and is built around semantic Web service technologies [Web service execution environment (WSMX), Web service modeling language (WSML), Web service modeling toolkit(WSMT) [6–8] and the conceptual framework, the Web service modeling ontology (WSMO)]. The details of semantic Web service

[3] http://www.oasis-open.org/apps/org/workgroup/semantic-ex/

technologies are outside the scope of this paper. The PPEPR architecture considers three types of integrations between EPRs based on their Web service capabilities (or lack thereof) [5].

1. EPR (HL7 v2) (non-Web service) ↔ EPR (HL7 v2) (non-Web service).
2. EPR (HL7 v2) (non-Web service) ↔ Web-Service enabled EPR (HL7 v3)
3. Web-Service enabled EPRs (HL7 v3)

5 Example Scenario

This section presents an example scenario described in figure 1, which consists of six messages including the request for a patient's lab test, lab test result, response, and confirmation messages.

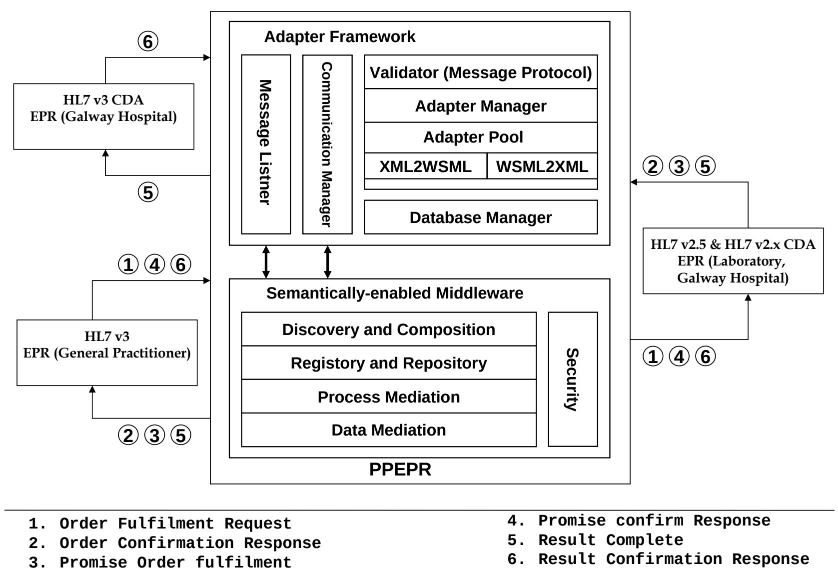

Fig. 1. PPEPR Architecture and Lab Test Order Use Case

EPR System, General Practitioner (GP): This EPR is HL7 v3 compliant and it places a Lab test order fulfilment request to another independent EPR system [hospital laboratory].

EPR System, Hospital Laboratory: This EPR is HL7 v2.5 and HL7 v2 Clinical Document Architecture (CDA) compliant. The hospital Laboratory receives the order for patient's lab test results from HL7 v3, HL7 v2.x, and HL7 v2/v3 Clinical Document Architecture (CDA) compliant EPRs.

EPR System, Galway Hospital: This EPR is HL7 v3 CDA (Clinical Document Architecture) compliant and receives lab test result from HL7 v (2.x, v2/v3 Clinical Document Architecture) compliant Hospital Laboratory.

Each actor has a specific 'application role' [e.g. Order Placer as General Practitioner (GP), Order Fulfiller as Hospital Laboratory, and Result Receiver as Galway Hospital and General Practitioner (GP)] and PPEPR acts as an integration platform. Figure 1 shows the significant elements of the PPEPR conceptual architecture. Starting from the bottom up, Web service execution environment (WSMX) [i.e. semantically-enabled middleware] is the primary engine which allows PPEPR to mediate upon the messages being transferred between heterogeneous EPR systems. WSMX uses the Web service modeling language (WSML) as the internal representation of the Web services and messages. The first step in the run-time use of PPEPR is lifting the incoming XML and EDI messages from EPR systems to their semantic definitions. This lifting process is performed within the adapter framework which transforms XML messages to their internal WSML representations. Once the message is represented in WSML, PPEPR can then mediate upon the message using the Data Mediator. The design-time components of PPEPR are used during the configuration of existing EPR systems. This involves schema level integration (grounding and ontology mapping) of the messages to be exchanged. As noted in the next section much of this work is automated, and what manual work remains is the verification of the modelled messages. Currently PPEPR can process messages in two formats[EDI, XML]. In PPEPR, semantic service(WSML) and process(sBPEL [9]) definitions are developed at design time where grounding(WSDL to WSML and back) and invocation of services are performed by the semantically-enabled middleware (WSMX).

6 PPEPR Assessment

The following parameters are used to measure the impact of Semantics within PPEPR and effectiveness of PPEPR as an integration platform :

1. **Design-Time**
   (a) *Modeling HL7 message:* The time taken for modelling HL7 ontologies, creating transformation rules (e.g. XSLT), and mapping definitions takes on average 1.5 days. A typical HL7 engine takes 0.5 days for mapping (syntactic). Similarly, PPEPR also takes 0.5 days for mapping (semantic). Therefore, extra work using PPEPR is 1 day for ontological modelling. The measurement was based on developers-recorded observations with good level of knowledge in HL7 and semantic technology tools. Each message within HL7 v3 consists of 49-51 ontological concepts. Each message within HL7 v2 consists of 36-40 ontological concepts. On an average 102 mapping rules are required between ontological concepts of two equivalent HL7 v3 and v2 messages. Approximately, 230-245 types of messages are contained in each version of the HL7 standard.

(b) *Syntactic vs. Semantic Mapping:* Syntactic mapping is predominantly based around the XML/XML Schema level of expressivity. Due to the inherent nature of XML/XML Schema, mappings are more at an implementation level and that causes a significant increase in amount of mappings. In PPEPR mappings are at the semantic(ontological) level which by nature maps two equivalent elements (concepts) at a higher level. The results have shown that the number of mappings reduced by up to 50 percent-PPEPR's major milestone.

2. **Run-Time**
   (a) *Execution-time:* The total message exchange time [message transformation, mediation and transmission] measured between two EPRs on typical broad-band connection is 2-3 seconds.
   (b) *Transformation:* During the first stage of PPEPR development we tested the correctness of message transformation. The purpose of this test is to ensure that transformation (lifting/lowering) process is not losing the original message content and structure.
   (c) *Stability:* In the last 2 months 190 messages has been exchanged on a PPEPR prototype with 100 percent success rate.
3. **Commercialization Potential**
   PPEPR can work as a standalone product directly interfacing with EPR systems or can be used as an add-on to existing HL7 engines. The PPEPR software consists of two parts: The Design-Time and the Run-Time. The design-time portions of the system are used when installing PPEPR and configuring the various EPR systems which are to be made interoperable. The outputs of the PPEPR project are fourfold:
   (a) *The Software:* Components, which aid in the automation of many tasks associated with modelling of the system, are included with PPEPR. The run-time software which adapts and mediates upon the messages is also included.
   (b) *Modelling:*
      i. `Ontologies:` HL7 v2, HL7 v3, and HL7 v3 & v2 CDA
      ii. `Mappings between Standards:` Segments and Fields, Data Types, and Vocabularies
   (c) *Modelling Process Description:* This is a key component of our project and is focussed on easing the handover of the technology to companies who wish to license PPEPR for use either as is, or as part of an existing product set.
   (d) *Return of Investment(ROI) Measurement:* We are making significant efforts to measure the benefits of PPEPR. At this point in our development we have automated most parts of the design-time operation and have fully automated the run time portions. We have measured the resources it takes to model messages and get them operational in PPEPR. Work remaining here relates to comparing that effort to that required to use traditional methods. We are also cognisant of the knock-on benefits of using PPEPR in any environment, where the models created for data mediation can subsequently be used in other contexts to potentially allow Case Based Reasoning.

7 Related Works

COCOON [10][4] **& ARTEMIS [10, 11]**[5] are 6th Framework E.U projects aimed at setting up semantics-based healthcare information infrastructure and developing semantic Web Services based Interoperability framework for the healthcare domain. The major differences between the eHealth projects described above and PPEPR are:

- PPEPR requires no changes to existing EPRs.
- Other projects are Web-scale projects. The major focus of PPEPR is to ease the integration burden of healthcare enterprises. Additionally, PPEPR's architecture is flexible enough to include Web-scale integration.
- PPEPR architecture is flexible enough to integrate the Web service enabled EPR (HL7 v3) and the traditional EPR (HL7 v2).

RIDE[6] **& SemanticHEALTH**[7] are E.U roadmap projects with Special Emphasis on Semantic Interoperability. PPEPR has been influenced by the **RIDE & SemanticHEALTH** guidelines to design and develop a *semantic* solution to a core eHealth interoperability problem.

8 Conclusion and Future Work

PPEPR is of immediate benefit to healthcare organisations wishing to integrate their Electronic Patient Records systems. The PPEPR running demo[8] shows the messages exchanged between actors of the above defined example scenario. We have used the growing field of semantics within IT to produce a system capable of mediating between heterogeneous systems. We are in the process of validating our software within a clinical setting and the output of this will be an evaluation of the methodologies and technologies used throughout PPEPR. This will give us direct feedback on the use of PPEPR and will fuel further development of the product. Next steps for PPEPR already identified include the addition of functionality to mediate upon heterogeneous healthcare processes. This means extending beyond the individual messages to the conversations within which those messages are exchanged, so that clinical processes can be executed in a manner consistent with the EPR systems supporting the clinicians. Secondary uses of PPEPR relate to its use in clinical decision support and enabling guided navigation of patient records represented by semantically modeled messages. PPEPR will also provide a means to integrating telehealth applications into the healthcare enterprises, by accepting sensor readings and by using PPEPR to mediate upon those reading. We can provide sensor-integration with existing HL7-compliant EPR systems. We will also focus on further easing the transfer of this new technology into environments unfamiliar with semantics.

[4] http://www.cocoon-health.com/
[5] http://www.srdc.metu.edu.tr/Webpage/projects/artemis
[6] http://www.srdc.metu.edu.tr/Webpage/projects/ride/
[7] http://www.semantichealth.org/
[8] http://www.ppepr.com/

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