Application Integration and Semantic Integration in Electronic Prescription Systems

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Abstract

Enterprise Application Integration (EAI) is a strategic activity and a technology set that can enable an organization to run much more efficiently, and thus provide a significant competitive advantage. Today, in the emergence of many new technologies based on Web services, there are still more approaches for EAI each approach having its limitations and opportunities. We have analyzed the limitations and opportunities of database-oriented, process-oriented, service-oriented and portal-oriented integration strategies from electronic prescription systems' point of view. It has turned out that we cannot satisfy all the requirements by any of these strategies but rather we have to develop the electronic prescription system which supports various strategies. We have also developed ontologies for semantic integration. Semantic integration has been a long-time challenge for the database community. However, by semantic integration we refer to the process of analyzing the relationships of data (i.e., their semantics) stored at communicating systems, and then using this semantics to automate the communication between computer systems. Our reason for semantic integration is the observations that within medication terms are not used in a consistent way, which have caused many serious errors in medication. In semantic integration we have used XML-based ontology languages RFD, RDF Schema and OWL.

Keywords: *E-health, Electronic prescriptions, Semantic Web, Ontologies, Application Integration, Semantic Interoperability.*

1. Introduction

Enterprise Application Integration (EAI) concept is not new: we have been dealing with mechanisms to connect application together since we have had more than two business systems and a network to run between them. Technically, EAI is a strategic approach to binding many information systems together and supporting their ability to exchange information and leverage processes in real time. It can take two forms: organization's internal application integration and organizations external application integration. While the both forms have their own set of peculiarities they both share many common patterns.

Traditionally EAI strategies are divided into database-oriented, process-oriented, service-oriented and portal-oriented integration strategies. Today, in the emergence of many new technologies based on Web services, there are still more service-oriented approaches for EAI each approach having its limitations and opportunities.

Semantic integration has been a long-time challenge for the database community. It has received steady attention over the past decades, and has become a prominent area in information integration research. From our point of view, semantic integration is one dimension of application integration. It is the process of analyzing the relationships of data (i.e., their semantics) stored at communicating systems, and then using this semantics to automate the communication between computer systems. This process requires the development of appropriate ontologies, which are usually represented by XML-based ontology languages.

For example, during the past few years several organizations in the healthcare sector have produced standards and representation forms using XML: patient records, blood analysis and electronic prescriptions [22, 19, 12, 9, 10] are typically represented as XML-documents [1, 7] which are transferred through the SOAP-protocol [18] by accessing Web services [6, 15]. This generalization of XML-technologies sets a promising starting point for semantic integration. However, the introduction of XML itself is not enough for semantic integration but also many other more expressive XML-based technologies have to be introduced in order to achieve a seamless interoperability between the organizations within the healthcare sector.

Electronic prescription system (EPS) is an integrated system comprising of several interoperable parties. Its main function is to manage electronic prescriptions. An electronic prescription is the electronic transmission of prescriptions of pharmaceutical products from legally professionally qualified healthcare practitioners to registered pharmacies. In addition the EPS should provide a variety of services for other parties.

Choosing or developing an appropriate application integration and semantic strategy for electronic prescription systems is of prime importance as it enables health care organizations to run more efficiently, and thus provide a significant competitive advantage. In addition, the strategy should provide a suitable way for satisfying the functional requirements of all the parties of the interoperable system.

In this article we restrict ourselves on the interoperability requirements of the electronic prescription system (EPS), and describe an application integration and semantic integration strategy that aim to satisfy the requirements of the whole system. A salient feature of our approach is that it utilizes a variety of application integration strategies. At the lowest level of application integration the interaction is carried out by storing and retrieving data from the database, while at the user level interaction is hidden behind the Web services accessed by the users. In addition the EPS support process-oriented interaction through a workflow engine which in turn orchestrates Web services [15, 21], and in this sense provides a higher level integration strategy than mere Web services.

The rest of the article is organized as follows. First, in Section 2, we motivate the need of EPSs. Then, in Section 3, we describe an electronic prescription process and its functional requirements. In particular, we illustrate what kind of new facilities the deployment of the new technology should provide for electronic prescriptions processes. Then, in Section 4, we consider how three integration approaches can be adapted together in developing the EPS. Section 5, describes the XML-based standards and technologies that are used in the EPS. Then, in Section 6, we focus on semantic integration. First we give a short introduction to ontologies and then we present a simple e-prescription ontology. We also illustrate how the ontology can be utilized in prescribing medication. Finally, Section 7 concludes the article by discussing the limitations and advantages of the developed integration strategy.

2. Motivation for Electronic Prescriptions

The permanent trend in medication is that it increases every year. Moreover as each drug has its unique indications, cross-reactivity, complications and costs also the prescribing medication becomes still more complex every year. Fortunately, applying information and communication technology (ICT) for prescribing medication this complexity can be alleviated in many ways.

Since prescriptions are increasingly produced by the aid of ICT, it is reasonable to use ICT for transmitting prescriptions between healthcare practitioners and pharmacies, i.e., for supporting e-prescriptions (electronic prescriptions). The scope of the prescribed products varies from country to country as permitted by government authorities or health insurance carriers. The information in an electronic prescription includes for example, demographic information about the subject of care, prescribed products, dosage, amount, frequency and the details of the prescriber. The products that can be described vary from country to country as permitted by the government authorities or health insurance carriers.

The academic research of electronic prescriptions is discussed in many practitioner reports and public national plans, e.g., in [8, 2, 5, 14, 16, 10, 20]. These plans share several similar motivations and reasons for the implementation of electronic prescription systems (EPSs). These include reduction of medication errors, speeding up the prescription ordering process, better statistical data for research purposes and financial savings. The priority of these motivations varies in practitioners' reports and national plans.

3. The Requirements of E-Prescription Processes

We now shortly describe the e-prescription process and the data access facilities that the EPS should provide. The electronic prescription process goes as follows: first a patient visits a physician for diagnosis. In prescribing medication the physician uses the EPS. The EPS should provide versatile querying facilities on the data located in prescription holding store as well as on the data located on other healthcare systems. For example, queries about patient's previous prescriptions focus on the data stored in the prescription holding store while the queries focusing on patient's record and digital X-ray films requires the interaction with other healthcare systems.

Once the physician has constructed the prescription the EPS may automatically communicate with medical database system in order to check (in the case of multi drug treatment) whether the drugs have mutual negative effects, and whether some of drug can be changed to cheaper ones.

After the checks and possible changes have been done the physician signs the prescription electronically. Then the prescription is encrypted and sent to an electronic prescription holding store. Basically the holding store may be centralized or distributed store. The patient will also receive the prescription in the paper form, which also includes the address of the prescription in the holding store.

The patient is usually allowed to take the prescription to any pharmacy in the country. At the pharmacy the patient gives the prescription to the pharmacist. The pharmacist will then scan the address of the prescription in the holding store by a pharmacy application, which then requests the electronic prescription from the electronic prescription holding store. After this the pharmacist will dispense the drugs to the patient and generates an electronic dispensation note. Finally they electronically sign the dispensation note and send it back to the electronic prescription holding store.

Periodically a governmental authority makes queries on the prescription holding store. These queries are statistical, focusing on the prescriptions given by certain physician or focus on the prescriptions of a patient.

The components of the EPS and the communication between the components are illustrated in Figure 1.

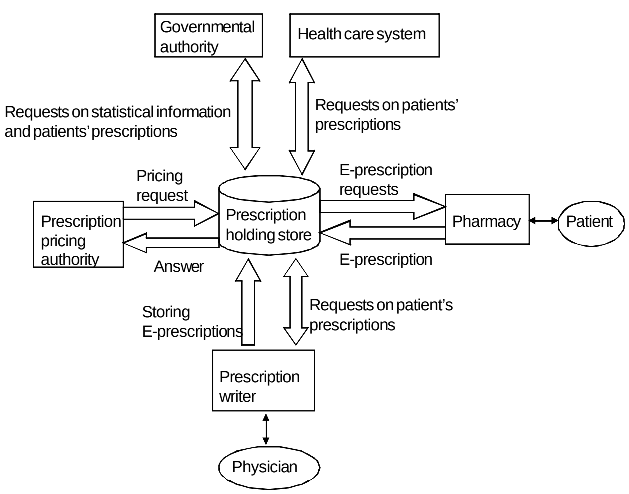

Fig. 1 The communication with the Prescription holding store.

4. Application Integration in Electronic Prescription Systems

Even though the approaches for the interoperation of various applications vary considerable, the principal distinction between Information-oriented, Process-oriented and Service-oriented and Portal-oriented application integration can be done [11].

- In Information-oriented approaches applications interoperate through a database.
- In Process-oriented (also called workflow–oriented [13]) approach the interoperation is controlled through a process model that binds processes and information within many systems.
- In Service-oriented interoperation applications share methods (e.g., through Web service interface) by providing the infrastructure for such method sharing.
- In Portal-oriented application integration a multitude of systems can be viewed through a single user interface, i.e., the interfaces of a multitude of systems are captured in a portal that user access by their browsers.

In our application integration strategy we use the three first of the above approaches. To illustrate this combined approach we now consider the architecture of the EPS and explain how the three integration strategies appear in it.

As illustrated in Figure 2 the EPS includes a variety of components: the users, the service requesters, the service provider and the services .

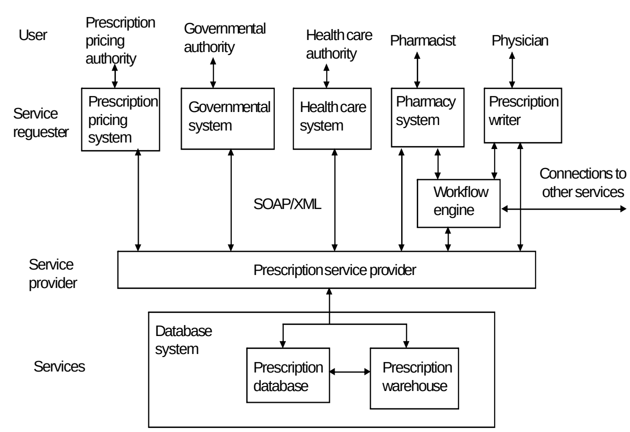

Fig. 2 The layered architecture of the EPS.

The users interact through their local applications with the Prescription service provider. Thus from users' point of view the integration strategy is service-oriented. However, at the implementation level users interact by storing and retrieving data from the Database system which includes the Prescription database and the Prescription warehouse. In this sense the integration strategy is database-oriented. In addition, with respect to the electronic prescription process Physicians and Pharmacist interact (through Prescription writer and Pharmacy system) with the Workflow engine. The Workflow engine coordinates the execution of the prescription process which is specified by a process modeling language (explained more detail in the next section). In this sense the integration strategy is also process-oriented.

Technically the Service requester and Service provider communicates with each other using the SOAP-protocol [18]. This requires that the Service provider generates WSDL (Web Service Description Language) [17] documents which describe the interface used to invoke the services. The Service provider also provides access to the services by enabling marshalling between SOAP and the target service (Prescription database server and Prescription warehouse server). This implies interpreting the SOAP-messages and invoking the Prescription database system, and then receiving the service response and creating a SOAP response to be sent to the Service requester.

The dependencies between the Prescription database and the Prescription warehouse are the followings. Prescriptions are first stored in the Prescription database. After the prescription is dispensed, it is not necessary to store it any more in the Prescription database. Therefore the prescriptions are extracted from the Prescription database and stored to Prescription warehouse for later analysis and retrieval. However, before storing the prescriptions in the warehouse they are processed in a way that they are suitable for statistical analysis.

Basically there are three approaches to construct the data in the Prescription warehouse:

- The Prescription warehouse is periodically reconstructed from the Prescription database. During the reconstruction the Prescription database have to be done. Thus a disadvantage is the requirement of shutting done the Prescription warehouse. .

- The Prescription warehouse is changed immediately, in response to each change or small set of changes in the Prescription database. However the disadvantage of this approach is that it requires too much processing to be practical.

- The Prescription warehouse is updated periodically (e.g., each night) based on the changes that have been made to the Prescription database since the last time the warehouse was modified. This approach seems to be most suitable for the Prescription warehouse though also this choice has its disadvantages. The main disadvantage of this approach is that the changes that have been done to the Prescription database have to be calculated. Thus the update is rather complex as compared to the first approach where the Prescription warehouse is simply constructed from scratch.

5. The Standards and the Technologies in EPS

The architectures that use Web services require that services can be found and used. This in turn requires that the services are exactly described. The WSDL (Web Service Description Language) is an XML-based language for describing a programmatic interface to a Web service. A WSDL-description [17] includes definitions of data types, input and output message formats. For example assuming that the electronic prescription presented in Figure 3 is the input message then it is described by the XML-Schema of the prescription.

```
<Eprescription>
        <Patient>
                <Patient_name>Jack Smith </Patient name>
                <Identification> 135766677</Identification>
                <Medicine>
                        <Medicine_name>Panadol</Medicine>
                        <Disease>fewer</Disease>
                        <Quantity>15</Quantity>
                        <Refills>1</Refils>
                        <dose>One tablet three times a day</dose>
                </Medicine>
        </Patient>
</Eprescription>
```

Fig. 3 An electronic prescription in XML.P

We next consider WSCI [17] and BPEL4WS [3, 4], which are focused toward electronic prescription processes, focusing on interactions among services, as opposed to models of the services themselves (e.g., WSDL-descriptions). Thus these specifications are above the WSDL layer (Figure 4).

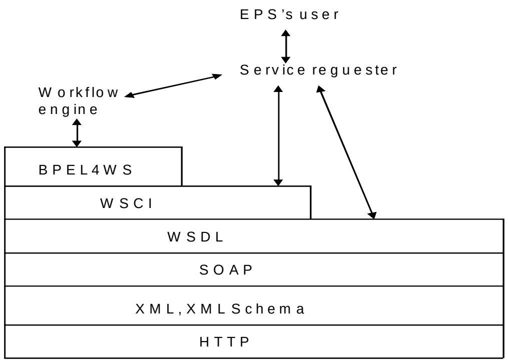

Fig. 4 The relationship of the XML-based standards.

WSCI (Web Service Choreography Interface) is an interface description language. It describes the flow of message exchanged by a Web service. By capturing the temporal and logical dependencies among the messages it characterizes the externally observable behavior of the Web service. WSCI is an enhancement of the WSDL in the sense that a WSCI specification is intended to be part of a WSDL document describing a Web service.

From electronic prescription point of view the action construct of the WSCI is very useful as it can be used to make each operation into an atomic unit of work. For example, the operations related to the retrieving an electronic prescription from the prescription database (login, prescription request, prescription response and the logout) can be made into an atomic unit.

We next illustrate the dependencies of the notion of workflow and BPE4WS. The term workflow refers to the collection of tasks organized to accomplish some business process. In out context we make the distinction between two kinds of workflows. First, we model the electronic prescription process as a workflow. Second, there are other healthcare workflows having a task which uses the services provided by the EPS. Such tasks typically retrieve patient information from the electronic prescription database. That is, retrieving information of the prescription database is a task of the workflow [13], which is implemented as a Web service request.

The tasks and their execution dependencies of the electronic prescription workflow are presented in Figure 5. In the first task the physician uses an electronic prescription writer (EPW) to construct a prescription. The electronic prescription writer (EPW) used by the physician may interact with many other health care systems in constructing the prescription. For example, the EPW may query previous prescriptions of the patient from the prescription database through the Prescription service provider. The EPW may also query patient's records from other health care systems. We assume that those health care systems provide appropriate Web services.

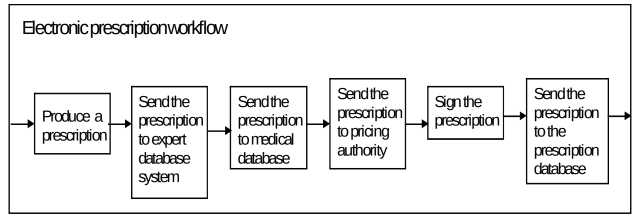

Fig. 5 An electronic prescription workflow.

Once the physician has constructed the prescription the EPW sends the prescription to the Web service of a medical expert system which checks (in the case of multi drug treatment) whether the prescribed drugs have mutual negative effects, and whether they have negative effects with other ongoing medical treatment of the patient. Then the EPW sends the prescription to the Web service of a medical database system, which checks whether the dose is appropriate. The medical database may also provide drug-specific patient education in multiple languages. It may include information about proper usage of the drug, warnings and precautions, and it can be printed to the patient. Then the EPW sends the prescription to the Web service of a pricing system, which checks whether some of the drugs can be changed to a cheaper drug. Once the checks and possible changes have been done the physician signs the prescription electronically. Then the prescription is encrypted and sent to the prescription database through the Prescription service provider.

BPEL4WS (Business Process Execution Language for Web Services) is a process modeling language for modeling the workflows which tasks are the executions of Web services. In particular, BPEL4WS description defines how multiple Web service interaction among the process's participant, called partners, are coordinated to achieve the business goal. The interactions with each partner occur through lower-level Web service interface, as might be defined in WSDL. Using BPEL4WS it is also possible to define the operations related to exception handling, including how individual or composite process components are to be compensated when exceptions and faults occur or when a partner requests an abort.

6. Semantic Integration in Electronic Prescription Systems

Semantic integration is one dimension of application integration. Through semantic integration we try to achieve the consistency in using terms in participating systems. This requires the development of appropriate ontologies.

The term ontology originates from philosophy where it is used as the name of the study of the nature of existence. In the context of computer science, the commonly used definition is "An ontology is an explicit and formal specification of a conceptualization" [1]. So it is a general vocabulary of a certain domain. Essentially the used ontology must be shared and consensual terminology as it is used for information sharing and exchange. On the other hand, ontology tries to capture the meaning of a particular subject domain that corresponds to what a human being knows about that domain. It also tries to characterize that meaning in terms of concepts and their relationships.

Ontology is typically represented as classes, properties attributes and values. So they also provide a systematic way to standardize the used metadata items. Metadata items describe certain important characteristics of their target in a compact form. The metadata describing the content of a document (e.g., an electronic prescription) is commonly called semantic metadata. For example, the keywords attached to many scientific articles represent semantic metadata.

Each ontology describes a domain of discourse. It consists of a finite set of concepts and the relationship between the concepts. For example, within electronic prescription systems patient, drug, and e-prescription are typical concepts. These concepts and their relationships are graphically presented in Figure 6.

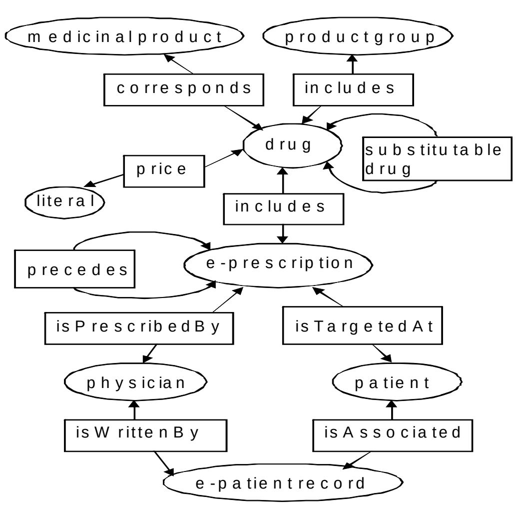

Fig. 6 An e-prescription ontology.

In the figure, ellipses are classes and boxes are properties. The ontology includes for example the following information:

- E-prescription is prescribed by a physician, and it is targeted to a patient.
- An e-prescription of a patient may precede other e-prescription of the patient, i.e., the e-prescriptions of the same patient are chained.
- Each e-prescription includes a drug.
- Each drug has a price, and it may have one or more substitutable drugs.
- Each drug corresponds a medicinal product, e.g., acetylsalicylic acid is a drug and its correspondence medicinal product is Aspirin
- Each drug belongs to a product group, e.g., aspirin belongs to painkillers.
- Each patient record is associated to a patient and it is written by a physician

The information of the ontology of Figure 6 can be utilized in many ways. For example it can be in automating the generic substitution, i.e., in changing medicinal products to cheaper medicinal products within substitutable products. It has turned out that in Finland the average price reduction of all substitutable products has been 10-15 %. In addition the automation of the generic substitution decreases the workload of the pharmacies.

In semantic integration the main problem is when we have two or more ontologies (i.e., the ontologies or conceptual scheme of various healthcare systems are not consistent), how do we find similarities between them, determine which concepts and properties represent similar notion and how to find the relationships between them. To solve these problems we capture all the concepts in the same ontology and specify the relationship of the concepts. To illustrate this, the relationships of used medicinal terms are illustrated in Figure 7. It states, for example, that the concepts tablet and pill are similarities.

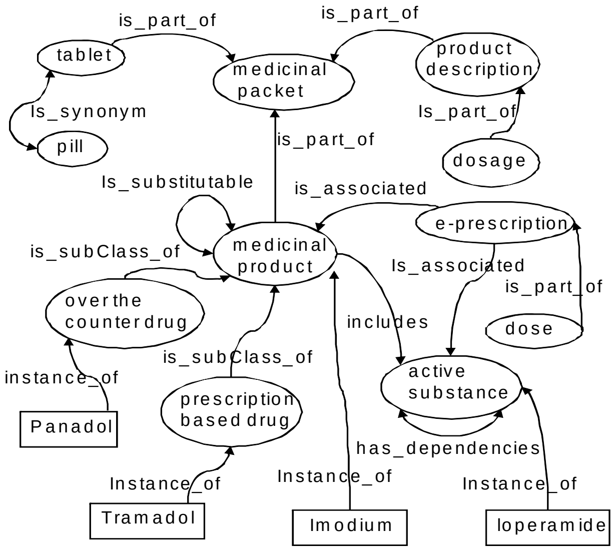

Fig. 7 A medicinal ontology.

The ontology languages we use in defining ontologies are RDF [6], RDF Schema [6] and OWL [17]. The RDF model [6] is called a triple because it has three parts: subject, predicate and object. Each triple is an RDF-statement. In order that RDF-statements can be represented and transmitted it needs syntax. The syntax has been given in XML. So an RDF-statement can be represented as an XML-document.

RDF Schema [6] provides the vocabulary for the RDF-statements. In the stack of the Semantic Web RDF-Schema is a language layered on top of RDF. It allows creating classes of data. A class is a group of things with common characteristics. For example, we have specified class e-prescription, patient and physician. Then by an RDF statement we can for example, specify that physician Jack Smith is an instance of the class physician, and by another RDF statement we can specify that prescription no. 72543 is an instance of the class e-prescription.

RDF Schema is a weak ontology language in the sense that it offers only the modelling concepts class, subclass relations, property, subproperty relation and domain and range restrictions. There are many modelling primitives that are useful in modelling documents in health care sector but are missing from RDF Schema. For example, neither we can specify that classes (e.g., physicians and patients) are not necessary disjoint nor can we build new class by set operations, e.g., class doctors is the union of the classes physicians and dentists. However, these kinds of features can be declared by the OWL (Web Ontology Language) [17].

7. Conclusions

Application integration is a strategic activity and a technology set that enables organizations to interoperate and to run much more efficiently, and thus provide a significant advantage. In the context of electronic prescription system the advantages arise in many ways including reduction of medication errors, speeding up the prescription ordering process, better statistical data for research purposes and financial savings.

In this article we have illustrated interoperability from electronic prescription systems point of view. In particular, we illustrated how we use different application integration strategies and XML-based semantic integration languages in developing the electronic prescription system. It has turned out that a consequence of introducing these new technologies is that it significantly changes the daily duties of the employees of the health care sector. Therefore the most challenging aspect will not be the technology but rather changing the mind-set of the employees and the training of the new technology.

The introduction of the new integration technology is also an investment. The investment on new technology includes a variety of costs including software, hardware and training costs. Training the staff on new technology is a big investment, and hence many organizations like to cut on this cost as much as possible. However, the incorrect usage and implementation of a new technology, due to lack of proper training, might turn out to be more expensive in the long run.

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