Review on Improving the Quality of Medication by Semantic Web Technologies

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Abstract: **In the past few years many organizations in the healthcare sector have provides standards and differrmt representation forms using XML. For example, blood analysis, patient records and electronic prescriptions are typically represented as XML-documents. This generalization of XML technologies sets a promising starting point for the interoperability of the various organizations in the healthcare sector. However, the introduction of XML is not enough but many other XML-based technologies have to be introduced in order to achieve a seamless interoperability between the organizations within the healthcare sector. The main aim of this article is to show the gains the interoperability of the health care systems and the deployment of the Semantic Web technologies can provide for electronic prescription systems. In particular, we present an e-prescription ontology and the querying facilities that the deployed ontology provides. We also define how the coordination of the interoperability required by electronic prescription systems can be automated by utilizing XML-based process languages.**

I. INTRODUCTION

Electronic prescription is the electronic transmission of prescriptions of pharmaceutical products from legally professionally qualified healthcare practitioners to registered pharmacies. The scope of the prescribed products varies from country to country as permitted by government authorities or health insurance carriers. For electronic prescription to be accepted by the physicians, pharmacies and patients it must provide added benefits to all participants. The problems related to prescribing medication are discussed in many practitioner reports and public national plans, e.g., in (Bobbie, et al., 2005) and (Chadwick and Mundy, 2004). 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.

A salient trend in medication is that the number of new medications increases every year. As each drug has its unique indications, cross-reactivity, complications and costs also the prescribing medication becomes still more complex every year. However, applying computing technology for prescribing medication this complexity can be alleviated in many ways.

Today there exists a great diversity of competing technological solutions for electronic prescription systems. For example, a citizen may have a memory card, or electronic prescriptions may be transferred via the internet or EDI. There is also diversity in used distribution, e.g., drugs may be transferred to home or they may be picked from pharmacies. In addition, many prescription writer applications take advantage of internet and other applications such as expert databases, and systems that include information about patients' demographic data and medication history. So, modern prescription writers are internet-based applications that interoperate with many other health care information systems.

During the past few years several organizations in the healthcare sector have produced standards and representation forms using XML. For example, patient records, blood analysis and electronic pre-scriptions are typically represented as XMLdocuments (Jung, 2006; Liu et al, 2001; Mattocks, 2005; Stalidis et al 2001; Woolman, 2001). This generalization of XML-technologies sets a promising starting point for the interoperability of the various organizations in the healthcare sector. However, the introduction of XML itself is not enough but also many other XML-based technologies have to be introduced in order to achieve a seamless interoperability between the organizations within the healthcare sector.

In this article we illustrate the interoperability within the healthcare sector from electronic prescriptions point of view. In particular, we illustrate:

- How XML-based technologies can be utilized in modelling the concepts that are related to prescription writing.
- How Web service technology can be used in implementing the interoperability of electronic prescription system and other healthcare systems.
- How the coordination of the interoperability required by electronic prescription systems can be automated by utilizing XMLbased

process modelling languages. In particular we show how the Business Process Modeling Notation (BPMN) (BPMN, 2006) and Business Process Execution Language for Web Services (BMEL4WS) (BPEL4WS, 2006) can be used for automating the coordination of electronic prescription processes.

The rest of the paper is organized as follows. First in Section 2, we give a motivation by illustrating a paper based prescribing system and electronic prescribing system. Especially we will illustrate the way the physician can utilize the new querying facilities the EPS (Electronic Prescription System).

Then, in Section 3, we first give a short introduction to ontologies and then we present a simple eprescription ontology. We also illustrate how the ontology can be utilized in prescribing medication.

Then, in Section 4, we consider the architecture of an electronic prescription system based on service oriented architecture. In Section 5, we illustrate how Business Process Modelling Notation can be used in automating the coordination of electronic prescription processes. Finally, Section 6 concludes the paper by discussing the advantages and disadvantages of our proposed approach.

II. PRESCRIPTION PROCESSES

We now illustrate a scenario of an electronic prescription process that interoperates with other health care systems. The process goes as follows: first a patient visits a physician for diagnosis. In prescribing medication the physician uses a prescription writer. 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 holding store. The EPW may also query patient's records from other health care systems.

Once the physician has constructed the prescription the EPW may send the prescription to the 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 a medical database system, which checks whether the dose is appropriate.

The medical database may also provide drugspecific 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 a pricing system, which checks whether some of the drugs can be changed to a cheaper drug.

(This activity is called generic substitution and it aims to promote cost effective drug therapies and to clarify the responsibilities of the prescriber and the pharmacy as well as to enhance both patient autonomy and the efficacy of the pharmaceutical market.) Once 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 includes two barcodes. The first identifies the address of the prescription in the holding store, and the second is the encryption key which allows the pharmacist to decrypt the prescription.

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 both barcodes by the dispensing 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.

III. DEPLOYING ONTOLOGIES IN PRESCRIBING MEDICATION

The term ontology originates from philosophy where it is used as the name of the study of the nature of existence (Gryber, 1993). In the context of computer science, the commonly used definition is "An ontology is an explicit and formal specification of a conceptualization" (Antoniou and Harmelen, 2004). 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 eprescription are typical concepts. These concepts and their relationships are graphically presented in Figure 3.

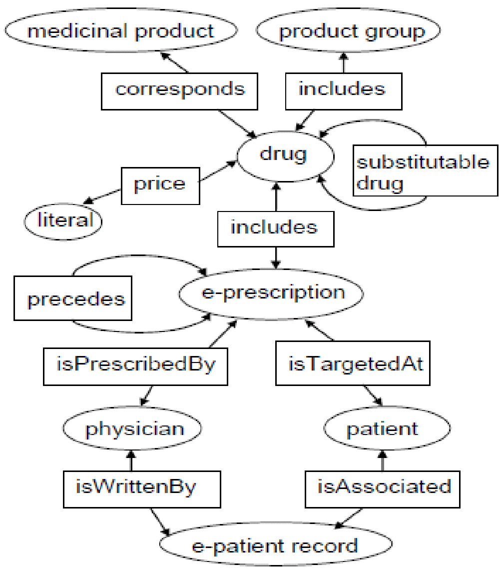

Fig 1. An e-prescription ontology.

In Figure 1, 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 1 can be utilized in many ways. For example it can be in automating the generic substitution, i.e., in changing meciucinal products 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 Figure 2, the ontology of Figure 1 is extended by instances, i.e., it includes the instances of the classes drug, medicinal product, physician, patient and e-prescription. So allows a wide variety of queries including:

- Give me all medicinal products that corresponds the drug asetylsalicylic acid.
- What drugs is included in the medicinal product Aspirin.
- Give me all prescriptions prescribed to Jack Taylor
- Give me all prescriptions prescribed by physician John Smith
- Give me all prescriptions including medicinal product named Panadol.

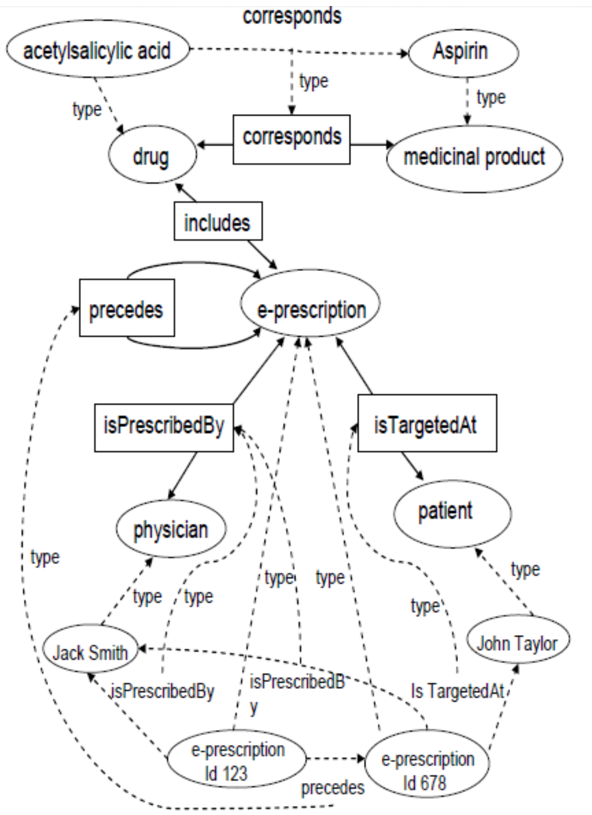

Fig 2. An extension of the e-prescription ontology.

The graphical ontologies of Figure 1 and 2 can be presented by ontology language in a machine processable form. The most commonly used ontology languages are XML (Harold. and Scott Means, 2002), XML Schema XML (Harold. and Scott Means, 2002), RDF (Daconta et al. 2003), RDF Schema (Daconta et al., 2003) and OWL (Singh and Huhns, 2005).

XML (Extensible Markup Language) is a metamarkup language for text documents. It is the syntactic foundation layer of the Se-mantic Web. All other technologies providing features for the Semantic Web will be built on top of XML. Particularly XML defines a generic syntax used to mark up data with simple human readable tags. An important feature of XML is that it does not have a fixed set of tags but it allows user to define tags of their own.

For example, various communities have defined their specialized vocabularies (set of tags) for various domains such as MathMl for mathematics, BSML for bioinformatics and GovML (Governmental Markup Language) for government.

IV. THE ARCHITECTURE OF THE SERVICE ORIENTED EPS

We now describe the architecture that can be used for providing the services described in Section 2 and 3. The architecture is based on the service oriented computing paradigm. Basically, services are a means for building distributed applications more efficiently than with previous software approaches.

The main idea behind services is that they are used for multiple purposes. Services are also used by putting them together or composing them.

Therefore every aspect of services is designed to help them to be composed. In the health care sector service oriented computing paradigm provides flexible methods for connecting electronic prescription system to the other relevant health care systems. For example, electronic prescription writer can interact through a Web service with the health care system that supports patient records. There may also be components that are used by different healthcare systems. For example,

medical database may provide services for medical information systems as well as for electronic prescription system.

The communication is based on Web services and SOAP-protocol. Originally they provided a way for executing business transactions in the Internet.

Technically web services are self-describing modular applications that can be published, located and invoked across the Web. Once a service is deployed, other applications can invoke the deployed service. In general, a web service can be anything from a simple request to complicated business or ehealth processes.

The components of the electronic prescription system are presented in Figure 1

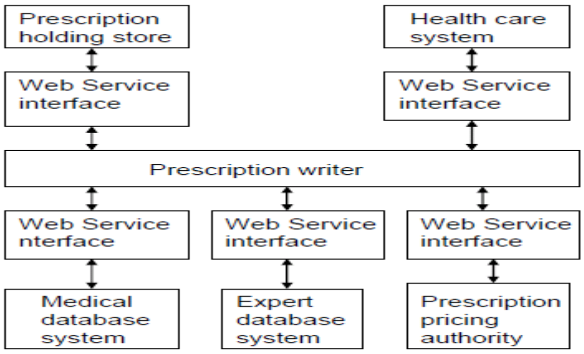

Figure 3. The interaction of a prescription writer.

Each component in the architecture communicates through a Web service interface. Further each message is presented as an XML-document and each XML-document is carried by the SOAP protocol.

V. USING BPMN IN MODELLING EPRESCRIPTION PROCESSES

The Business Process Modeling Notation (BPMN) is a standard for modeling business process flows and web services. The BPMN 1.0 and the UML 2.0 Activity Diagram from the OMG are rather similar in their presentation. However, the Activity diagram has not adequate graphical presentation of parallel and interleaved processes, which

are typical in workflow specifications.

We now give an overview of the BPMN. First we describe the types of graphical objects that comprise the notation, and then we show how they work together as part of a Business Process Diagram (BPD).

After it we give a simple electronic prescription process description using BPD. In BPD there are tree Flow Objects: Event, Activity and Gateway:

• An Event is represented by a circle and it represents something that happens during the business process, and usually has a cause or impact.

• An Activity is represented by a rounded corner rectangle and it is a generic term for a work that is performed in companies. The types of tasks are Task and Sub-Process. So, activities can be presented as hierarchical structures.

• A Gateway is represented by a diamond shape, and it is used for controlling the divergence and convergence of sequence flow.

In BPD there are also three kind of connecting objects: Sequence Flow, Message Flow and Association.

• A Sequence Flow is represented by a solid line with a solid arrowhead.

• A Message Flow is represented by a dashed line with an open arrowhead and it is used to show the flow of messages between two separate process participants.

• An Association is represented by a dotted line with a line arrowhead, and it used to associate data and text with flow objects.

In Figure 4 we have presented how the process of producing electronic prescription (described in Section 2) can be represented by a BPD.

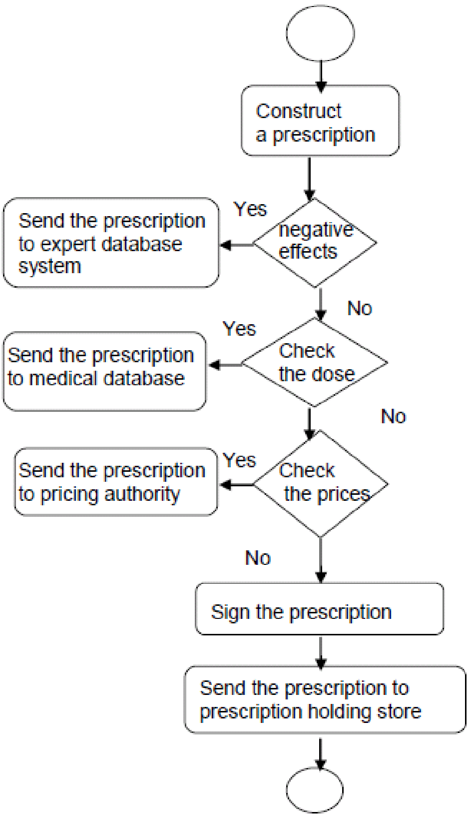

Figure 4. A BPD-description of the prescription process.

VI. CONCLUSIONS

In this article we have illustrated the interoperability within the healthcare sector from electronic prescriptions point of view. In particular, we illustrated how XML-based technologies can be utilized in modelling the concepts that are related to prescription writing, and how web-service technology can be used in implementing the interoperability of electronic prescription system and other healthcare systems.

In addition, we have illustrated how the coordination of the interoperability required by electronic prescription systems can be automated by utilizing XML-based languages BPMN and BPEL4WS. The reason for using BPMN is that the BPMN notation is readily understandable for the employees of the health care sector. It is also readily understandable for the business analyst that create the drafts of health care processes as well as for the technical developers responsible for implementing the technology that will perform those processes. Also a notable gain of BPMN specification is that it can be used for generating executable BMEL4WS code.

A consequence of introducing Semantic Web technologies in health care sector 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.

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