Pharmaceutical Care: A Challenge for EAI in Pharmacies

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***Abstract*—A new trend in pharmacy practice is to move away from its original focus on medicine supply towards a more inclusive focus on patient centered care. This new trend is named pharmaceutical care. It emphasizes the responsible provision of drug therapy for various purpose of achieving definite outcomes that improve or maintain patient's quality of life. In order to achieve these goals pharmacists are expected to assume many different functions including caregiver, communicator, teacher, life-long learner and manager. These functions set new challenges for pharmacy's information systems usability as well as pharmacist's skills to use them. A problem here is that existing pharmacies' information systems are isolated in the sense that they have their own data stores that cannot be accessed by other information systems used in pharmacies. As a result a pharmacist is burdened by accessing many systems inside a user task, e.g., in giving drug therapy for a patient. In order to alleviate this problem we have designed a knowledge-oriented EAI (Enterprise Application Integration) strategy for pharmacy's information systems. Our key idea is to revolve all pharmacy systems and applications around the shared knowledge base, and in this way avoid the problems of isolated non-interoperable systems and heterogeneous replicated data. In this paper, we present how knowledge-oriented EAI strategy can be exploited in contributing pharmaceutical care. In particular, we present how Semantic Web technologies such as RDF and OWL are intertwined in our developed solutions.**

Keywords - internet; semantic web; OWL; RDF; web-based applications; EAI; knowledge managememnt; e-health; ontologies

I. INTRODUCTION

During the last years there has been a trend for pharmacy practice to move away from its original role on drug supply towards a more inclusive focus on patient care [1, 2, 3]. This new trend in pharmacy practice is named *pharmaceutical care* [4, 5, 6]. It emphasizes the responsible provision of drug therapy for the purpose of achieving definite outcomes that improve patient's quality of life [7, 8].

The provision of pharmaceutical care sets significant challenges on pharmacy's ICT and pharmacists' skills as healthcare is a field where the fast development of drug treatment and the introduction of new drugs require specialized skills and knowledge that need to be renewed frequently [9, 10].

In particular, the amount of new information concerning medication increases rapidly. Pharmacies receive this information from a variety of sources [11], e.g., from medical authority, medicinal wholesalers, educational organizations and pharmaceutical companies. These information entities arrive in variety formats, e.g., by paper mail, e-mail, and fax. The nature of the information entities may vary, e.g., an information entity may be a learning object, a regulation, a guide or a bulletin [12]. Further, some of the information gives rise for a new business rule or changing prevailing rules and practices.

Two interesting questions arising from this reality are:

- How pharmacy systems should interoperate in order to support pharmaceutical care?
- How medicinal information should be organized in order to ensure ready access for pharmacists?

In ICT (Information and Communication Technology) this kind of issues are analyzed in the disciplines of *Enterprise Application Integration* (EAI) [13] and *Knowledge Management* (KM) [14]. The former is a strategic approach to binding many information systems together and supporting their ability to exchange information and leverage processes in real time while the latter concerns with acquiring, organizing and retrieving information within an organization.

Although current pharmacy systems have proven to be valuable and powerful systems in traditional pharmacy's role [15], they fail in contributing pharmaceutical care. This is due to the fact that existing pharmacy systems are monolithic isolated systems that cannot be easily modified to be able to interoperate with relevant external sources.

Providing pharmaceutical care implies that pharmacy applications should be able to cross organizational boundaries, and in this sense they should be open. In open systems the configuration of the whole system can change dynamically. For example in supporting drug therapy, by the permission of a patient, the pharmacist should be able to access patient's PHR (Personal Health Record) [16, 17] stored in a server in internet.

Nowadays, a common practice in pharmacies information management is that the incoming information entities are not stored at all, or are stored in a variety of systems such as in Document Management Systems, Learning Content Management Systems, Content Management Systems, Database Systems and Customer Relationship Management Systems [14].

 ISBN: 978-1-61208-116-8

The problem here is that the same information may be stored in separate systems, and each system is hardcoded to only work with its own data. Using such systems is overly complicated and thereby does not contribute to pharmaceutical care.

We have analyzed various EAI and KM strategies' suitability for supporting pharmaceutical care. Our key idea has been the integration of information oriented EAI strategy [18] and knowledge management strategies, which exploits semantic web technologies. We call such a strategy *semantic EAI*.

Through semantic EAI we can avoid the common problems of the legacy systems, i.e., the problems of the systems that are built based on proprietary solutions, developed in piecemeal way, and tightly coupled through ad hoc means, and which thereby have many duplicated functions, and which are non-interoperable.

In this paper, we first in Section II give an overview of the notion of pharmaceutical care. Then, in Section III, we motivate our proposed solutions by considering the interoperability problems of existing pharmacy systems. In Section IV, we consider EAI strategies focusing on semantic EAI. We first describe our used way for integrating heterogeneous data into the format that is compatible with the pharmacy's knowledge base. Then we consider portal-oriented application integration, where a pharmacist can view a multitude of systems through a single user interface. Finally, Section V concludes the paper by discussing from pharmacy's point of view the advantages and disadvantages of semantic EAI.

II. PHARMACEUTICAL CARE AND THE ROLES OF PHARMACISTS

The International Pharmaceutical Federation (FIP) defines pharmaceutical care to be the responsible provision of drug therapy for various purpose of achieving definite outcomes that improve or maintain a patient's quality of life [1].

The introduction of pharmaceutical care sets many new requirements on pharmacy's information systems as well as for pharmacists' skills and knowledge [4]. In this context the notion of "seven-star pharmacist" is taken up by FIP in its policy statement on Good Pharmacy Education Practice. It covers the following seven roles of a pharmacist [1]:

- *Caregiver*: Pharmacists have to view their practice as integrated and continuous with those of the health care system and other health professionals.
- *Decision maker*: The appropriate use of resources such as medicines, chemicals, equipments and practices should be the foundation of the pharmacist's work.
- *Communicator*: The pharmacist provides a link between prescriber and patient, and so he or she must be knowledgeable and confident while interacting with other health professionals.
- *Manager*: Pharmacists must be able to manage effectively various resources such as human, financial and information resources. In particular ICT will provide challenges as pharmacists assume greater responsibility for sharing information about medicines and related products.
- *Life-long learner*: The role of continuing education and lifelong learning is becoming still more important as the fast development of technologies requires specialized skills that need to be renewed frequently.
- Teacher: The pharmacist has a responsible to assist with the education and training of future generation of pharmacists and the public. Teaching as well as pharmacist life-long learning assumes the exploitation of modern e-learning technologies.
- *Leader*: In areas where other care providers are in short supply or non-existent the pharmacist is obligated to assume a leadership position in the overall welfare of the patient.

For each of these roles there are many specific ICT-based systems and disciplines including ERP (Enterprise Resource Planning), CRM (Customer Relationship management), SCM (Supply Chain Management), LMS Learning Content Management) and CM (Content Management System) that are developed for improving the management of these roles. We next consider such systems and their interoperability requirements in supporting pharmaceutical care.

III. SEGMENTATION IN PHARMACY SYSTEMS

Integrating information in an ever growing internetworking world is likely to be the most urgent need for any kind of business, trade or science. Daily work in supporting pharmaceutical care is not an exception: a huge and increasing amount of heterogeneous medicinal data is distributed over network of computing system, and the usage of this heterogeneous data requires the introduction of interoperability and integration technologies.

Basically the term *integration* refers to the idea of putting diverse concepts together to create an integrated whole. Instead *interoperation* refers to making applications work together by sharing the appropriate messages but without any single conceptual integration. Further, *semantic integration* means that a new ontology is derived from existing ontologies such that the new ontology facilitates the interoperability of the systems [19].

Initially the problem of software and data segmentation was increased with the introduction of commercial off-the-shelf applications such as ERP, SCM and CRM systems

 ISBN: 978-1-61208-116-8

[18]. In particular the early versions of these systems were designed as self-contained boxes with no means for accessing internal data or processes. Though the new versions of the pharmacy systems provide better access to their data, integrating them with other systems in pharmacies is still problematic.

As a result, many pharmacies, as well as other organizations, have an environment of disparate legacy systems and applications, which typically interact by a number of connections that are poorly documented and difficult to maintain. Such systems also have their own isolated data stores and user interfaces. Such architecture of a pharmacy system is illustrated in Fig. 1.

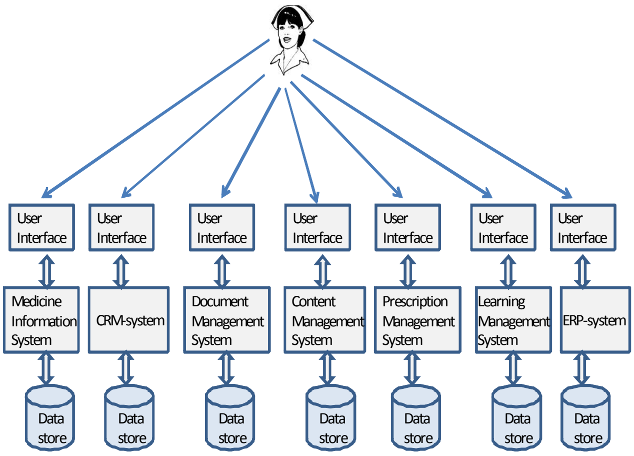

Figure 1. A segmented architecture of pharmacy system.

If the data needed in a user task is not included in one system, then the user has to log and access data from various systems. Further, if the systems do not support SSO (Single Sign-On) this may require many user activities.

To illustrate this difficulty let us assume that a pharmacist is dispensing a medicinal product, say *Diovan*, for a patient. First, in order to store the dispensation of the prescription, the pharmacist opens the prescription system. Then from customers social insurance card the pharmacist recognizes that the patient is a veteran. The pharmacist remembers that the discount of ten per cent is granted for veterans of some drugs, but she does not remember whether it concerns *Diovan.*

By accessing the business rule management system by the keywords "discounts" and "veterans" the system return the statement "discount of 10 per cent of the prescription based partially repayable drugs is granted for veterans". Next the pharmacist opens and finds from the medicinal system that *Diovan* is not a partially repayable drug. Then she retrieves from the pricing system the medicinal products that are cheaper and are substitutable with *Diovan* and are partially repayable. After this, by the permission of the client the pharmacist change *Diovan* to a substitutable medicinal product *Valsartan* and grants the discount of 15 per cent for the customer. Finally, from the drug therapy system the pharmacist prints the instructions concerning *Valsartan* and gives them to the patient.

The reason for the complexity of the pharmacist user task is that the data needed by a pharmacist is stored in separate systems, and their data cannot be accessed by other systems.

IV. SEMANTIC EAI

The need of interoperation within organization's systems led to the evolution of EII (Enterprise Information Integration) and EAI. The early work on addressing the challenges of heterogeneity involved integrating different data sources. Such a work was called EII. Later on there has been work on EAI where information flows between applications is addressed. The EAI infrastructure allows systems and applications throughout an enterprise to seamlessly communicate with one another in realtime.

EAI solutions can exist at many levels such as database level, process level, portal level and method (function call) level. Hence, the principal distinction between Information-oriented, Process-oriented and Service-oriented and Portal-oriented application integration is been done [18]:

- In Information-oriented approaches applications interoperate through a data store.
- In Process-oriented (also called workflow–oriented) 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.

Further, in the emergence of many new technologies based on Web services and Semantic Web, there are still more changes for EAI each change having its limitations and opportunities.

In our developed architecture we use the Information-oriented approach in achieving the interoperability between the pharmacy's systems and applications. That is, the systems and applications interoperate through sharing a knowledge base, and the ontology is developed by integrating the ontologies of the interoperable systems and applications.

From user's point of view our used application integration strategy follows the Portal oriented approach as the multitude of pharmacy's systems and applications can be viewed through a single user interface.

In the following two subsections we give a more detailed description of these strategies.

 ISBN: 978-1-61208-116-8

A. Information-Oriented Integration Using Knowledge Management System

Knowledge management system refers to a computer based system for managing knowledge in organizations [14]. A knowledge base is a special kind of database for knowledge management. It provides the means for the computerized collection, organization, and retrieval of knowledge for various applications.

Today an ever expanding set of knowledge management systems are using the technologies of the Semantic Web [20]. That is, knowledge is organized according to ontologies, and automated tools are used in accessing and maintaining knowledge [21].

The idea of sharing pharmacy's knowledge base is illustrated in Fig. 2.

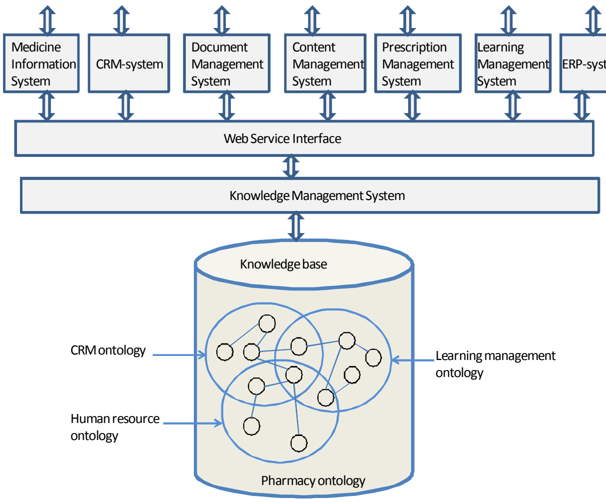

Figure 2. The architecture of semantic EAI in a pharmacy.

We follow the idea of knowledge centric organizations [14], where, the key idea is to revolve all applications around the shared ontology. In our case, as illustrated in Fig. 2, it means the integration of the data repositories of the pharmacy's systems such as business rule management system, content management system and learning object management system. To the integrated ontology we refer by the term *pharmacy ontology*. So the pharmacy's systems can seamlessly interoperate through accessing the shared pharmacy ontology.

The data of the pharmacy ontology is received and gathered up from a variety of health care organizations. However before the data can be inserted into the knowledge base (pharmacy ontology) it must be transformed into RDF/XML-format [22] that is compatible with the pharmacy ontology. Such transformations require that a specific stylesheet [14] is developed for each input data that is not compatible with the pharmacy ontology. A language associated with stylesheets is XSLT (Extensible Stylesheet Language) [23]. It is a markup language that uses template rules to specify how a style sheet processor transforms an XML document.

In order to illustrate this transformation assume that the graphical ontology of Fig. 3 is a subset of the pharmacy ontology. In this graphical ontology, ellipses represent classes and boxes represent properties.

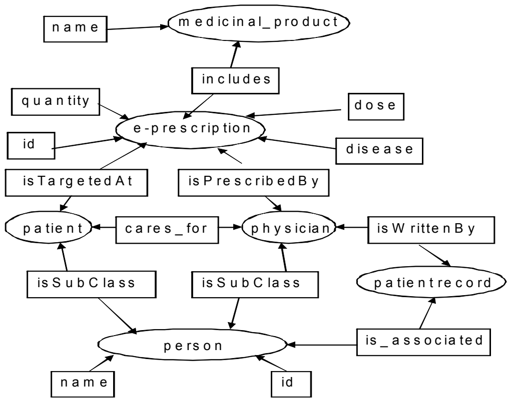

Figure 3. A subset of the pharmacy ontology in a graphical form.

Assume now that the pharmacy system receives the XML coded document presented Fig. 4. As the document is in XML it does not contain any semantics, and so it is transformed by a stylesheet engine into RDF/XML-format that is compatible with the ontology of Fig. 3. Such an RDF document is graphically presented in Fig. 5, and in RDF/XML format in Fig. 6.

```
<prescription>
    <prescription_id>abc123</prescription_id>
    <patient>
        <name>John Smith </name>
        <id> 1465766677</id>
    </patient>
    <medicinal_product>Panadol</medicinal_product>
    <disease>fever</disease>
    <quantity>30</quantity>
    <dose>One tablet three times a day</dose>
    <physician>
        <name>Lisa Taylor </name>
        <id> 98765432</id>
    </physician>
</prescription>
```

Figure 4. A precription in XML format.

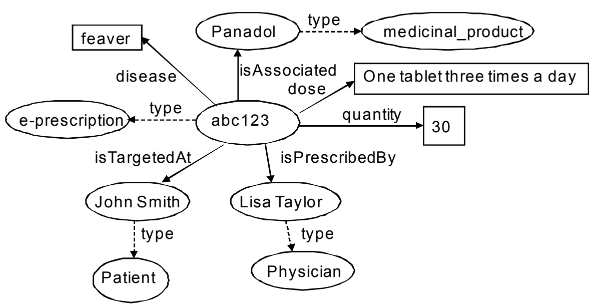

Figure 5. A precrition presented by RDF-graph.

 ISBN: 978-1-61208-116-8

```
<rdf:RDF
    xmlns : rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns : xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns : mo="http://www.lut.fi/ontologies/montology#"
    <rdf:Description rdf:about="abc123">
      <rdf:type rdf:resource="&mo;e-prescription"/>
         <mo : dose>One tablet three times a day</mo : dose>
         <mo : quantity rdf:datatype="&xsd;integer">30</mo : quantity>
         <mo: includes>Panadol</mo: includes>
    </rdf : Description>
    <rdf:Description rdf:about="1465766677">
      <rdf:type rdf:resource="&mo;patient"/>
         <mo : name>John Smith</mo : name>
    </rdf : Description>
    <rdf:Description rdf:about="98765432">
    <rdf:type rdf:resource="&mo;physician"/>
         <mo : name>Lisa Taylor</mo: name>
    </rdf : Description>
</rdf:RDF>
```

Figure 6. A prescription in RDF/XML format.

B. *Portal-Oriented Integration Using ASP*

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 (Fig. 7).

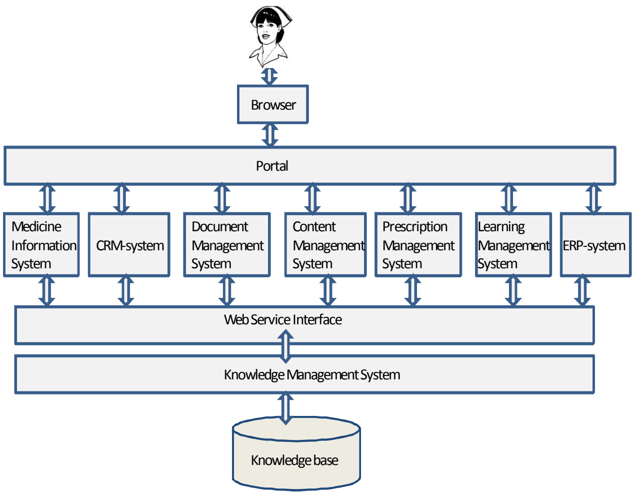

Figure 7. The architecture of portal-oriented EAI .

User (pharmacist) interacts with the pharmacy's systems and applications by a browser, and so all the data for a pharmacist are presented in HTML. However, all the content in the knowledge base are stored OWL (Web Ontology Language) format [24], i.e., represented by RDF/XML syntax.

A significant gain of accessing the portal through a browser is that instead of the proprietary pharmacy systems the whole pharmacy system can be implemented by exploiting the notions of ASP (Application Service Provider).

An ASP is a business that provides computer-based services to customers over a network. The application software resides on the vendor's system and is accessed by users through a web browser using HTML or by special purpose client software provided by the vendor.

The need for ASPs has evolved from the increasing costs of specialized software that have far exceeded the price range of small to medium sized businesses such as pharmacies. Also the growing complexities of software have led to huge costs in distributing the software to end-users. Through ASPs, the complexities and costs of pharmacy's software can be decreased.

On the other hand ASP strategy is criticized since users cannot modify the software they use. However, in pharmacies this is not a problem as they do not have personnel for software development. In some cases organizations have rejected ASP strategy since organizations data is being stored, and controlled, by third parties, thus increasing its attack surface. Within pharmacies the critical data are patients' prescriptions that are received from third parties such as prescription holding stores and physicians, and so the control of third parties cannot be avoided.

V. CONCLUSIONS

Pharmaceutical care sets significant challenges on pharmacy's ICT and pharmacists' skills as healthcare is a field where the fast development of drug treatment and the introduction of new drugs require specialized skills and knowledge that need to be renewed frequently.

On the other hand, pharmaceutical care does not exist in isolation from other health care services: it should be provided in collaboration with patients, physician, nurses and other health care providers. As each of these occupational groups has their own information systems also the medicinal information systems and applications developed for pharmaceutical care should be able to co-operate with these systems.

In ICT these kinds of issues are analyzed in the disciplines of Enterprise Application Integration and Knowledge Management. In the emergence of many new technologies based on Web services and Semantic Web, there are new chances for EAI and KM that are appropriate for providing pharmaceutical care. The key point in our presented semantic (ontology based) EAI is that all parties have a common understanding of the pharmacy ontology on which the exchanged messages (documents) are based on.

In order to exchange documents the parties need a common language through which to exchange documents between their computer systems. Though XML is rapidly becoming the key standard for data representation and transportation, XML-documents themselves do not capture any semantics. Thereby the introduction XML-messaging requires that communicating applications must be hard-coded meaning that the semantics of the message are coded in the communicating applications.

A more flexible way for achieving consensus on exchanged messages is to develop appropriate domain ontology, and use it as a vocabulary in exchanging RDF/XML coded documents. Essentially the developed ontology must be shared and consensual terminology among the communicating parties as it is used for information sharing and exchange. Hence, the corner stone of our presented solutions is that all the communicating parties must commit to the same ontology, e.g., to our developed pharmacy ontology.

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