Design For a Patient-Centric Medical Information System Using XML Web Services

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Abstract

Patients' medical information is dispersed on several providers' medical information systems making personal medical information management a difficult task for patients. Given this situation, there is a need for patients to be able to easily access their patient data from the different providers' systems so as to promote effective management of their medical information. The main objective of this work is to propose a design for a system that will alleviate the personal health information management process for patients by providing them a single point of access to their medical information from disparate healthcare providers' systems over the Internet. The proposed design for this system is based on Extensible Markup Language (XML) web services. An evaluation of a prototype shows that the design allows patients an easy means of managing their health information and the design is also scalable, extensible, secure and interoperable with disparate healthcare providers' information systems.

1. Introduction

Patients' medical information is dispersed on several provider's medical information systems making personal medical information management a difficult task for patients. Most healthcare services that patients receive today are usually received from different hospitals, and outpatient clinics with varying specializations. Given this situation, according to [1], effective management of information is particularly challenging for patients facing conditions (such as cancer) that require frequent visits to outpatient clinics following the main treatment at a hospital. Furthermore, from a review of the literature, [1] asserts that effective management of personal health information can help patients better cope with the stresses of the illness and hence increase the effectiveness of their treatment.

Therefore, there is a need for patients to be able to easily access their patient data from the different providers' systems so as to promote effective management of their medical information. The intent behind the work is to remove an undue burden from the patients.

The specific objectives this work is trying to accomplish are:

- Propose a design for a system that will alleviate the personal health information management process for patients by providing them a single point of access to their dispersed medical information.
- Develop a proof-of-concept prototype implementation based on the proposed design.
- Evaluate the proposed design by analyzing the developed prototype system.

The proposed design for this system is based on XML web services. The choice of XML web services was made based on the benefits of web services outlined in [2] and evaluating the the protocols discussed in [3]. The evaluation indicates that web services will meet the requirements of being flexible and interoperable with different providers systems.

2. Related Work

From the literature review, the indication is that XML is a good choice for developing data exchange systems in the healthcare domain. The research presented in [4], [5] and [6] present an evaluation of using XML web services in the healthcare domain.

The results of the study by Hori and Ohashi in [4] indicates that collaboration between various healthcare institutions is feasible. They propose the use of web services to facilitate collaboration between healthcare institutions in order to realize a patient-oriented healthcare network.

Similarly, the authors of [5] contend that retrieving patient medical information is still a difficult task, especially in the cardiology domain. The goal of the work in [5] is to automate the process of gathering a patient's information without the constraints of semantic or location diversity and to accurately display it to the physician and propose using web services for this task.

In the paper [6] the authors report on the extent to which existing web service technologies have proved to be mature enough to meet these requirements, and also assess their current limitations. Based on the report presented in this paper, it is evident that XML web

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services have certain strong points that will aid in the development of a system that integrates data from the various providers systems.

It is also evident from the literature that the majority of the work [5, 7-10] in this domain has been carried out from the perspective of the clinicians and other medical staff. Works such as these are very beneficial to medical staff, improving their efficiency, and thus indirectly improving the quality of care that patients experience. However, in order to supplement such systems and optimize the benefits of healthcare services provided to patients, it is necessary to actively involve patients in the healthcare process and promote effective management of personal health information by the patients. So, the work done here is focused on the patient's perspective.

3. Requirements

3.1. Functional Requirements

- Personal Health Information Management. The key function of this system is to facilitate personal health information management by allowing patients access to their health information from the disparate providers' systems. In this regard, the system should:
  - Allow read-access to any medical information that is made available by each providers' systems.
  - Allow editing of writeable data. For example, the system should have the ability to allow the patient to edit his/her contact information with all providers, or be able to edit appointment times. The patient should not be able to edit medical information such as interviews, prescriptions, etc.
- Authentication of Users.
- Web accessible.

3.2. System Requirements

- Interoperability with different providers' systems.
- Scalable.
- Extensible.
- Secure.

4. System Design

In the context of the system design some of the key terms are:

- Central Medical Information System (Central MIS or CMIS) is the (integration) system that facilitates the personal health information management by patients.
- Provider Medical Information System (Provider MIS) refers to the information system owned by a healthcare provider.

The general architecture for the system is illustrated in figure 1. Each providers' medical information system stores patient information in its own database and these systems are independent of each other. In this design, each providers' system is augmented with a web service having a uniform interface. The implementation of the service is carried out by the provider's information technologists as the specifics vary for each provider system with providers being able to control what information they will return to the end uses. The web service can be implemented in any programming language and is not tied to any one in particular. Most popular programming languages have toolkits [11-13] that allow developers to easily SOAP-ify or encode their data as SOAP objects.

The Central Medical Information System (CMIS) consists of a Web Service Client or Proxy that routes requests to the web service. The proxy allows for the CMIS to make programmatic calls to the web service. The CMIS also has a web server that handles Hyper Text Transfer Protocol over Secure Socket Layer (HTTP over SSL or simply HTTPS) requests from end users' (patients) browsers.

4.1. System Security Recommendations

Since the system architecture uses web services the following are recommended to protect the system and the data therein:

- The WSDL for the web services is not to be made public.
- The URL of the various web services should be kept private and also should be unguessable.
- Use of digital certificates to authenticate sub-systems.
- Encryption of SOAP messages to and from the web services.

5. Implementation

As a proof-of-concept of the proposed design, a prototype implementation was developed. The prototype was developed to emulate the scenario of providing patients a single point of access to their data from two disparate providers' information systems. In this capacity, the prototype system consists of three sub-systems: the implementation of the CMIS and two providers' medical information systems.

In this implementation, the two providers systems are implemented in two different programming languages (Perl and Java). Each providers' systems serves as a patient interviewing system with each storing different

questions and answers for patient interviews. Each system has its own format of storing patient information, i.e. each has a unique database schema.

The patient has a single point of access to their personal medical information from both provider's systems (if the patient has accounts with both providers) through the Patient Medical Information System Portal (PMISP) which is the name given to the implementation of the CMIS in this prototype.

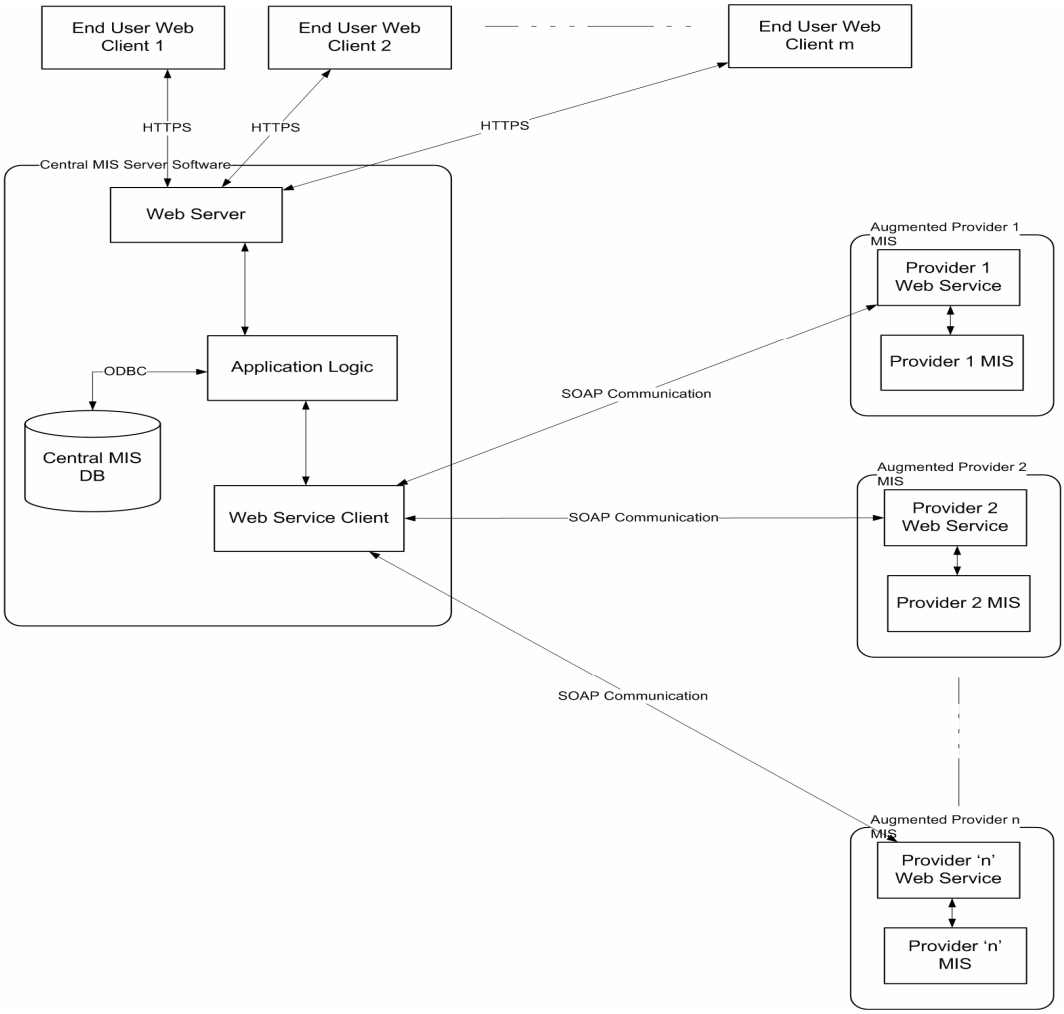

Figure 1: General Architecture of the Design

5.1. Augmenting the Clinic Systems with Web Services

As illustrated by the system architecture diagram (figure 2), the design involves augmenting each medical information system (MIS) with a web service. As the functionality of a web service is described by a Web Service Description Language (WSDL) file, developing a general and flexible WSDL is one of the key tasks of this process.

Once a WSDL has been created, the next phase of the implementation involves generating the web services based on the WSDL file and then finally deploying the web services. This WSDL file must be made general enough so that it is applicable for various providers. It should be noted that for a real implementation of such a system, based on the proposed design, it would be necessary for the various providers' information technologists involved in such an implementation to agree upon a standard WSDL file for patient oriented or patient centric web services that would permit providers with diverse specializations to join this system at a later point if they so desire. This capability for flexibility is one of the driving factors behind the design decision of using XML technologies.

5.2. Functionality

The Patient Medical Information System Portal (PMISP) is the name given to the implementation of the

Central Medical Information System. The various functions of the PMISP are:

- Registration. The PMISP uses patients' personal information (name, date of birth, SSN) to authenticate the patient with each of the providers' MISs. In order for an account to be created on PMISP during the registration process, the user must have a patient record on at least one of the provider MISs and must also agree to legal terms of use.
- Personal Health Information Management. This is the key functionality of the system. The patient is able manage his/her health information from the two different providers' MISs through a single point of access, the PMISP. Users are able to view all their available information and also modify editable items.
- Secure Communication. The PMISP web system is accessible over a secure channel. Communication takes place using HTTP secured by SSL with 128-bit encryption which is the standard used by most banks to secure online banking.
- Dynamic addition of new patient-provider relationships. If a new patient-provider relationship is established after the time when a patient has already registered him/herself on the PMISP, the next time the patient logs on to the PMISP this new relationship will be dynamically added to the list of patient-provider relationships for this patient.
- Administrator user functionality. the system also has a provision to allow super users (administrators) to use the system. The idea behind having such an 'Admin' user role is to show that in addition to providing a patient-oriented system, this design also allows the system to be used by doctors or clinicians to easily access a patient's data from a different provider where the patient has a record.

5.3. Web Service Proxy/Client

The web service proxy object provides an abstraction to access each of the providers' web services. The proxy is a class that is part of the PMISP. The proxy serves as a client for the various providers' web services. It allows the application logic of the PMISP to call the different providers' web services. The proxy abstracts out the details of calling a web service such that to the object making a call to the web service, it appears like simply calling a function on any other local object.

5.4. XML Web Services Benefits

Through the process of implementing the proof-of-concept prototype, the following items which are considered benefits of XML were validated.

- Interoperability. According to [14], web services solve some of the technical integration challenges by standardizing the infrastructure for data exchange, namely SOAP. This is a very important factor for the successful development of a patient centric system that is based around exchanging data between different information systems that may be implemented on different platforms or in different languages.
- Extensibility. Adding new features or functions to a web service does not affect the existent code. A web service can have several methods, so the addition of new methods does not necessitate a code change, but only an addition of the new method and addition of the method signature stubs in the client proxy class.
- Standardized Documentation. "WSDL (Web Service Description Language) provides a standard form of documentation to developers who need to write code accessing multiple web services" [14]. This will be a benefit to the information technologists implementing a Central Medical Information System (CMIS) as such an undertaking will be a inter-institutional effort. Therefore having a standard form of documentation for the different web services will simplify the development tasks.
- Rapid Development and Ease of Development of Solutions. This is due to the fact that web services is a standardized technology with a large community of users that have developed toolkits and utilities that ease and speed up the web service development process.
- Low-cost solution for the healthcare providers. Major software vendors are beginning to offer web service interfaces to their products free of charge. Most of these web services are simple wrappers around an existing product's API [14] indicating that the cost of development of web services or providing a web service interface is low.

6. Analysis

The various use cases for the system were tested and based on this, an evaluation of the design is presented. The system meets the specified functional and system requirements. The results of performing the various tests indicate that utilizing an XML web services based architecture to implement a patient-centric medical information system is feasible. The PMISP's key functions are carried out successfully using the XML web services architecture. The system provides the users with a simple interface to access their remotely stored data and also allows them to edit or update their information such as address, phone number, email on all their providers' systems with the click of a single button.

Such a system appears promising to alleviate the difficulties patients face managing their personal health information. The intent is that by giving patients improved accessibility to their personal health information through an actual implementation of a system like the PMISP, patients will be able to more effectively manage their own health information and consequently enjoy better health as a outcome, in concurrence with the results of studies stated in [1].

One limitation of the prototype system is that its patient authentication scheme is based on the assumption that all patients have a government issued Social Security Number (SSN). So, the prototype is designed for use only within the United States. The design is analogously limited to being used in countries where all residents have a unique government issued identification number. So, for countries that do not have such a system, it would be challenging to implement the authentication system under this assumption. An alternative means of patient authentication would have to be established.

Another limitation of this system is that the success of a real implementation is dependent on provider buy in. The providers control their information systems and decide whether or not to join a network of providers to collaboratively develop a patient-centric medical information system. Therefore, the success of such a system is also dependent on providers being willing to participate in such an effort.

Alternatively, some of the strengths of the system are:

- Ease of use of the system by patients. The system allows patients to easily access their data from disparate providers systems over the Internet.
- Encryption of transmitted data. The system uses the same level of encryption used by most banks for online transactions, which ensures the confidentiality of sensitive medical data.
- Scalability. The prototype is implemented using only a single web service client even though there are multiple provider systems. So, an increase in the number of providers is feasible with this design.

Overall, the system meets all the outlined goals and requirements. The successful implementation of the prototype is indicative of the feasibility of the proposed design. The benefits of the web services based architecture observed through the development and testing of the prototype indicate that web services are a good choice for such a system.

7. Conclusions and Future Work

This work proposed a design for a system to facilitate effective management of personal health information that is distributed over disparate healthcare providers' information systems. The system is intended for use by patients to more efficiently manage their own health information. A motivating factor to develop such a system is the results of studies that indicate a correlation between efficient management of personal health information and improved health of the patients involved [1].

The proposed design was successfully implemented as a proof of concept prototype and testing of the system indicates that the design meets the desired functional requirements, among which the most significant is allowing patients a single point of access to their personal health information from disparate healthcare providers. In addition, the proposed design meets the system requirements of being scalable, extensible, secure and interoperable with disparate healthcare providers' information systems.

The proposed design is based on XML web services. The design involves augmenting existing healthcare providers' information systems with a web service. The system that provides patients a single point of access to their data from the various providers, the Central Medical Information System (CMIS), utilizes a web service client to retrieve patients' healthcare information and then route it to the end-user patients over the Internet. Naturally, due to the sensitive nature of the information being accessed and transmitted, the proposed design also prescribes authentication and security techniques to prevent unauthorized access and other possible malicious actions.

An implementation of the proposed design in today's healthcare domain can be a tremendous benefit to patients. As most medical services that patients receive are provided by multiple institutions, their medical information tends to be dispersed across disparate providers' systems, therefore, having an efficient means of managing one's dispersed medical information can lead to lowered stress levels during times of illness and thereby lead to improved health outcomes.

There are a few possible avenues for improvement of the design and implementation of this system. One of the possible areas for future work on the system is in the evaluation of the design with provider systems that utilize different types of data, e.g. image data, video data, etc., as the current implementation has been tested to work with textual data only.

Another area of improvement is the authentication of patients during the registration process. Here there are two different issues: One is to design an authentication scheme that does not require a government issued identification number. The other issue is to dynamically generate a challenge question to authenticate the user during registration based on the patients data received from the providers' systems.

Finally, more research can be done in regards to usability of such a system by end users. The prototype utilized a simple authentication scheme that involved only the user's name, date of birth and SSN. This may not be

considered secure enough. However, complicating the authentication process may compromise the user friendliness of such a system. Therefore, additional work can be done to determine the appropriate level of required information for authentication.

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