Towards, Building and Implementing a Digital Healthcare System

Khalid Aldrawiesh

***Abstract*—Healthcare industry is evolving rapidly, increasing the capability of delivering a high quality of service to the public. The rapid development of information technology (IT) has introduced many valuable directions to medical and healthcare sectors. The emergence of high-speed network communication, mobile technology and digital storage has led to a more accessible and convenient way to obtain medical facilities. It is clear that the involvement of IT in the medical sector will provide many more advantages in the development of the medical sector itself. This paper describes a technological approach to deliver health services online by using a distributed system. To make keeping health records paperless and processing them systematically, the system manages Electronic Health Records (EHR) and provides access for them to a wide variety of users such as patients, doctors, medical officers, researchers and students. The accessibility is achieved by implementing various client technologies such as web, mobile and PC to access the system. Since the EHRs are processed by system components implemented in various environments, standardization of health records is implemented along with a standard communication protocol to communicate between system components. Hence, we have introduced a novel approach to healthcare management in IT, and it is intended to contribute as much as possible to the community who are dedicated to IT in healthcare.**

***Index Terms*—Web services, healthcare and management.**

I. Introduction

Health care is a rapidly changing industry which faces constantly changing conditions and an ever-increasing demand for healthcare services. It has been estimated that in each year, medical errors account for a cost of about $37.6 billion. And $17 billion of that is related to errors which can be prevented [1]. Also with the increasing density of the human population the issues are getting worse and at the end of the day these particulars come at a great cost
to the health care industry and force them to offer enhanced health care services to the patients.

Emergence of IT and its associated parts in the medical sector will introduce many more benefits in the development of the medical sector itself. In the future, with more advanced and powerful applications, people who conduct medical research's with electronic medical records will produce more valuable findings easily. Along with those applications, EMRs are comprehensively used in many applications since we can obtain many advantages. Through EMR, clinical staff can gather patient data at any given place and automated tests can be brought for medicines and allergy interactions, prescriptions, arranging etc. The importance of having EMRs is reflected by the project done by the National Health Service (NHS) in the United Kingdom, they have accomplished one of the major projects to have a national EMR. The main target of this project is to have 60,000,000 patients to have an accumulated electronic medical record by 2010 [2].

Information technology (IT) can contribute a lot towards the health care sector by improving the quality of the service as well as the safety and efficiency. But in general, IT has a very low distribution in healthcare. Many surveys and researches indicate that the industry is always willing to make investments in IT to gain more efficiency, accuracy and quality of the service. Generally the complexity of implementation and unbearable cost are main barriers of IT applications in the medical sector.

II. Statement and Contrbution

The main purpose of this paper is to propose a system that can help to enhance the medical sector with the use of new technologies. The proposed system in this paper would reflect a novel concept that all patients, consultants and medical researchers will benefit from a distributed system which can provide a comprehensive range of medical services. The patients can consult their doctors with the use of eClinic system without wasting their time by making appointments online and they can read and send their medical records online. As mentioned above, it is essential to do research on this topic to identify critical segments within the scope that should be addressed by the proposed system. The paper elaborates on all those findings and knowledge gained in this research and will contribute to the community who are conducting researches at present and finally will be useful to the researches which are going to be conducted in the future.

III. Eclinic Framework

This paper proposes a healthcare management system for hospitals, clinics and medical centre's to make their environment paperless. It makes patient medical records more reachable not only for patients, but also for general Practitioners (GPs), private medical centre's, hospitals and people who are conducting research. These distributed electronic medical reports are proposed to be available online for afore mentioned parties by implementing Web services in such a way that information can be accessed from a desktop application, web application and mobile applications. This feature will enable doctors to access and diagnose their

Manuscript received September 15, 2012; revised December 13, 2012.

K. Aldrawiesh is with Ministry of Education at National Center for Educational Information in, Riyadh (e-mail: KAD@MOE.GOV.SA).

patients' irrespectively of them being at the hospital or somewhere else. Meanwhile, the patients will be able to access and view some portion of their medical records from their home computer or from their mobile device.

A proof of concept system will be implemented to distribute patient medical records in the eClinic concept. The software life cycle will be followed during the proof of concept development and a requirement gathering phase will be carried out before the system analysis. The system analysis and system design will be done based on requirements. Finally, the proof of concept will be tested using the software testing methods.

The following figure 1 shows the component model of the proposed solution. As discussed earlier, the system provides access to the eClinic data via multiple application types. Users will be able to access the system from different devices. The main application is developed as a desktop application. Physicians will be able to use the desktop application from within the hospital, private clinic or even from home if they prefer to install the application on their home machines or if the carry a mobile computer (laptop). The only requirement is that they have access to the internet. In addition to the desktop application, a web based application is developed with the same core features. The web based application can be accessed from any machine with a browser and internet connection. The web based application will be developed using ASP.NET which is a Microsoft framework for web application development. ASP.NET application will be hosted on IIS running behind the firewall as shown in the figure. There will also be a mobile client application developed for smart phone running on Microsoft Windows. The application will be developed using .net compact framework. This enables physicians and patients to access medical records from their mobiles. However, the information available for the mobile clients will be limited compared to the other two applications. All of these different types of applications will be accessing the same web services to get the information.

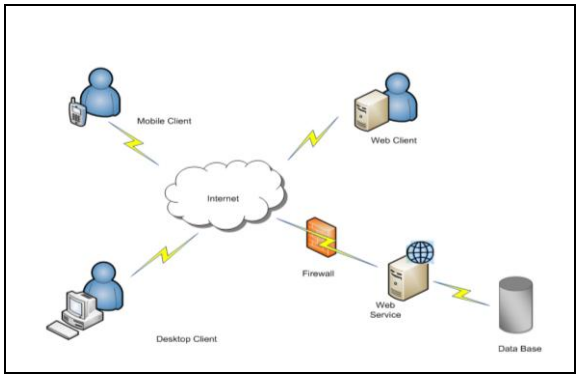

Fig. 1. E-clinic high level architecture

A. Healthcare Systems

Generally, by the use of IT, health care providers are allowed to collect and store information electronically and also to retrieve and transfer information electronically. Providers are consistently increasing their investments year by year, although the health care industry makes less use of IT compared to other industries. In accordance with the institution, the extent of application and deployment of IT differs. Improving the quality and developing the standard of the process have become the primary objective of using IT in most of the organizations.

In general, applications of IT in the medical sector can be divided into three categories such as

- Financial and Administrative systems that perform administrative tasks including accounting, billing, etc.
- Clinical and medical systems that perform direct healthcare tasks
- Infrastructure that supports both the administrative and clinical applications.

B. Server Client Technology

Client Server is a distributed computing technology that can be used to implement huge systems that are obtained from any location in the world via the network. The main advantage is the delegation of workload. There are two parties involved here to perform functionalities. They are the client and the server. The client is basically the end device that consumes the services provided by the server.

Server client technology plays a big role in the eClinic system since there are users who use the eClinic service hosted in servers. This provides users with numerous advantages. Some of these advantages and purposes are:

- Every single user accesses real-time data which is up to date.
- Huge number of users can use the same system at once.
- The system upgrades, changes can be done without disturbing clients (users)
- Advanced efficiency and accuracy.
- High degree of security.

C. Web Services

As the name implies and shows in Fig. 2, web services are services hosted on the web and these services can be found and used by users as well as by applications on the web. Therefore Web services are application components that can be communicated using open protocols. SOAP or REST open protocol is used to communicate with interoperability. WSDL is used to provide a description on the particular web service and they can be found on indexes created by using UDDI open standards. The main purpose is to use web services to communicate among businesses to use functionalities as services without knowing the implementation behind each function [3]-[5].

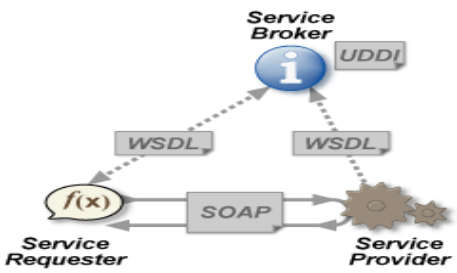

Fig. 2. Web service architecture

The main difference when compared to other web applications is that web services do not enforce any kind of user interfaces to interact with the end users. Instead, web services provide programmatically interfaces to

communicate between nodes. The concept behind this is that web services are offered to be used by various applications which are used by end users.

The exceptional feature of web services is to reduce the work load of application developers by providing all communications in by an XML. Self-descriptive data produced by XML can be easily manipulated by developers and the interoperability is achieved. Because of that web services are not restricted by technologies, as an example, a web service developed by Microsoft technologies can be communicate with a web service developed by any other technology like Java, Perl or python[6].

D. System Design

The patient care system, eClinic needs to be implemented to satisfy all the requirements mentioned in the above section as well as future needs as demanded. One of the major design principles based for the system is the extendibility. eClinic is expected to cater all for present market requirements while having the flexibility to face changing requirements as it is being used because the healthcare sector is a rapidly evolving industry which introduces new things to the world day by day.

Initially the main inputs and outputs are analyzed because manipulating inputs and producing the required output is the fundamental of any system. For eClinic, there are a wide range of inputs both identified as well as unidentified. As mentioned above, the system should have the ability to manipulate unidentified inputs as well as in the future since extendibility is enforced. Identified inputs are shown in Table I below.

TABLE I: DEFINING THE INPUTS METHODS

Input	Type
Patient basic information	Text
Patient Records	Documents
Audio	Audio files / binary streams
Video	Video file/ binary streams
Imaging Inputs	Image files
Medications	Text
News	Text

E. Database

Database can be identified as the heart of the system since it is the main asset for the system. Database should keep all data related to eClinic. Database should be able to store all the data formats discussed above and it is designed for efficient data storing and retrieving functionality to cater for large number of users at once. Concurrent processing of data is required as the medical information can be manipulated from anywhere simultaneously [7]. Since the system is accessed from remote locations via the web service, PL-SQL stored procedures are used to cater for the large traffic of usage expected by minimizing network traffic and serving users with quick response data. MS SQL server is used as the database technology which is one of the best database technologies in the market and which supports all techniques aforementioned.

IV. ECLINIC CLIENT APPLICATIONS

EClinic is designed to cater for various types of users from various locations with the help of modern communication technologies like ADSL, HSDPA, GPRS, WAP, Wi-Fi and etc. The most important feature of eClinic is its ability to cater for users having any of these technologies. To realize that requirement, eClinic provides three main user terminals which cover almost all technologies. Those client interfaces are described blow.

A. Desktop Client

Desktop client is a software program installed on a PC which provides users an interactive user friendly interface to consume eClinic services. It is intended to be used by users at home or in the office. For hospitals, offices and other medical institutes it is recommended that they use desktop clients.

B. Web Client

Web client is simply a website which allows the user to obtain eClinic services from anywhere. Users, who don't use any permanent PC or use more than one PC from time to time, are recommended to use the web Client.

C. Mobile Client

Mobile Client is a software program which runs on small devices like mobile phones, PDAs or portable PCs and is useful for users on move. They can use eClinic service via a mobile phone while they are traveling.

One of the important components of the eClinic is the web service. All the eClinic services are implemented in the web service and all end user interfaces are connecting to the web service to request services. The main component attached to the web service is the database. Interoperability and extensibility are the key features of a healthcare system and they are enforced by the web service [8]. SOAP is the communication standard of the web service and it allows users in different client technologies to get the service of eClinic [1].

Security is another major concern in the development of eClinic because medical records are considered to contain highly sensitive information. Another aspect is the privacy of the users who are reluctant to disclose their private information. Moreover, intruders may try to access the system to get medical records with malicious intentions [9]-[10]. Also, intruders may try to threaten someone's life. To overcome these issues the system has a security implementation which helps to keep the system integrity up. Only the registered users are allowed to use the system, in spite of the interface they are using and they are authenticated each time they are using the eClinic system by providing a username and password. Web services always use encryption methodologies to communicate to the client software. The use case diagram is drawn to illustrate all users and the interaction of them within the system.

D. Database Design

EClinic database is designed to store and retrieve data

efficiently and accurately. Separate tables are created for each data entity and they are linked to each other with entity relationships as illustrated in diagram Fig. 3 below.

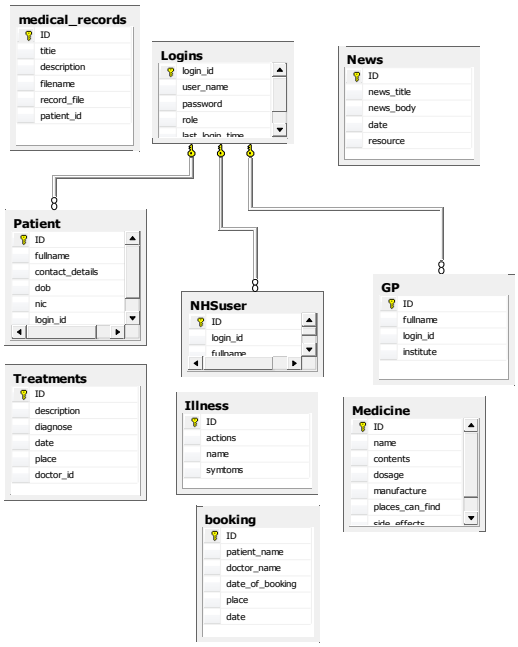

Fig. 3. Illustrates the diagram of entity relationships

V. Implementation

The health care sector is a large industry which is an aggregation of both government and private bodies including the general public. It implies eClinic should have the capability to cater for all these parties with the relevant requirements. Implementation of eClinic is considered to be conducted in several phases because it is not practical to implement such a large system at one time. From a technical point of view, high end equipment is required for the successful implementation of eClinic and the infrastructure first needs to be set in place to implement eClinic. Initially, the servers should be installed in a relevant location which has some sort of physical security. The servers required are a database server and Web server. For the database server MS SQL server is used and IIS server is used as the Web server. Advanced security features are applied for these servers to protect them from access by unauthorized users with malicious intentions.

Technologies Used: The whole system is developed using Microsoft .Net framework which provides powerful features to the system to develop it easily in minimum time duration. Visual Studio 2008 is the Integrated Development Environment (IDE) used to develop this entire system and MS SQL server is the database server used. For the windows application, the project solution was constructed as illustrated below in Fig. 4.

Basically eClinic was developed as 5 individual components as follows:

- Windows desktop application
- Web application
- Mobile Application
- Web Service
- Database

All these components were developed individually in separate solutions in a visual studio. The web service and the web application should be hosted in the IIS server. Then the database should be attached to an SQL Server and then the connection parameters are to be set on client applications.

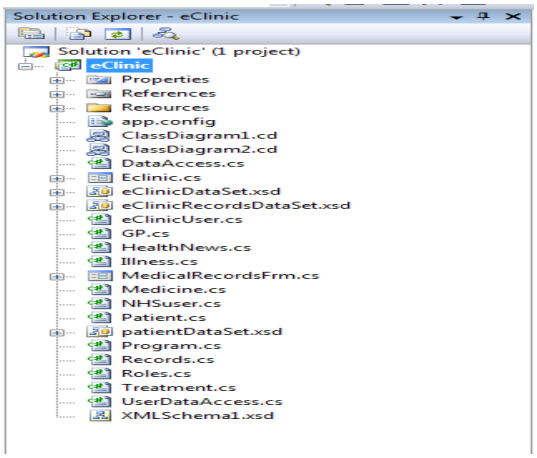

Fig. 4. E-clinic project solutions.

```
POST /eClinicService/eClinicService.asmx HTTP/1.1
Host: localhost
Content-Type: application/soap+xml; charset=utf-8
Content-Length: length

<?xml version="1.0" encoding="utf-8"?>
<soap12:Envelopexmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap12="http://www.w3.org/2003/05/soap-envelope">
<soap12:Body>
<MakeBookingxmlns="http://tempuri.org/">
<booking>
<BookingID>int</BookingID>
<PatientName>string</PatientName>
<DoctorsName>string</DoctorsName>
<DateBooked>dateTime</DateBooked>
<Place>string</Place>
<Date>string</Date>
</booking>
</MakeBooking>
</soap12:Body>
</soap12:Envelope>
```

Fig. 5. The request

```
HTTP/1.1 200 OK
Content-Type: application/soap+xml; charset=utf-8
Content-Length: length

<?xml version="1.0" encoding="utf-8"?>
<soap12:Envelopexmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:soap12="http://www.w3.org/2003/05/soap-envelope">
<soap12:Body>
<MakeBookingResponsexmlns="http://tempuri.org/">
<MakeBookingResult>int</MakeBookingResult>
</MakeBookingResponse>
</soap12:Body>
</soap12:Envelope>
```

Fig. 6. The response

The core functionality of the system is handled by the eClinic web service. All the client components access the web service to get all services. For example, if the user needs to make a booking with a consultant the client can simply log onto the web application or the mobile application and place the booking via the web service. The booking functionality is implemented as follows to communicate via SOAP 1.2 as in

Fig. 5 and 6 which show requesting and responding.

VI. Discussion

Initially the system is introduced to a few number of people and a couple of institutes and deployed to be used by these limited number of users. The main objective here is to make sure that the system satisfies the requirements as expected. All the users of the system are required to have an account on the system and will have to enter a username and password to login to the system. Web client is expected to be used by both patients and doctors. As an example, patients enter the day to day updates on their situation to the system via web client and doctors can check the updates of their patients. Mobile client is intended to be used to make instant updates of information. Functionalities of the mobile application have some limitations because it runs on a mobile phone or a PDA which has limited resources when compared to a desktop application.

E-Clinic is proof of concept developed to provide a facility for patients, doctors, Institutes and other relevant parties to collaboratively perform healthcare activities. Lack of access to medical information is the major issue in the health care industry at present and it is addressed by eClinic in a Technological approach. Manipulating Electronic Patient Records is one of the major functionalities performed by eClinic. Electronic Patient Records was emerging technology a couple of decades ago but now it is a widely used technology to keep patient records. eClinic provides global access to health information via the World Wide Web and internet which enables stake holders of the system to be enriched with accurate, up to date, reliable information in real time.

The system is developed using the latest software development technologies and methodologies enforcing dynamic expansion of the system while it is being used. It is ready to add new features in the future as the industry evolves. The accessibility to the system is increased by implementing several client components and users can use those components as required. Since the system is dealing with highly sensitive data, the integrity and the security of data is of high concern and necessary security features are implemented along with the system development. To have the system at the expected level, the whole process of system development went through several important phases such as requirement gathering, system analysis, system design, system implementation and testing. These phases have been discussed in detail in the above sections.

VII. Conclusion

With the rapid development of technology and the health care sector, collaborative and integrated health care systems are required to help management and administrative activities of information in health care services and also, surveys indicate that the majority of patients are willing to use new technologies to deal with health care services. In fact, implementing such comprehensive health care systems contributes more than by widening the capabilities of health care system in the country since there are many other aspects that are influenced by the implementation. For example, in the education sector, students and teachers will consider eClinic as a valuable asset of information to conduct their lessons. And also for the research community, eClinic will provide actual, statistical data to conduct their research. Also for the business sector, as they can use eClinic to market their valuable products. For the smooth expansion of eClinic through various regions, bilingualism is an essential which should be implemented as a future improvement.

References

[1] N. K. Janjua, M. Hussain, M. Afzal, and H. F. Ahmad, "Digital Health Care Ecosystem: Soa Compliant Hl7 Based Health Care Information Interchange," *Digital Ecosystems And Technologies*, Dest '09. 3rd Ieee in *Proc. of International Conference On Anonymous*, pp. 329-334, 2009.

[2] M. Hadzic, T. Dillon, and E. Chang, "Use Of Digital Ecosystem And Ontology Technology For Standardization Of Medical Records," in *Proc. of Digital Ecosystems And Technologies Conference, Dest '07. Inaugural Ieee-Ies, Anonymous*, pp. 595-601, 2007.

[3] Paragon Corporation. (2003). Calling Webservices From Asp.Net: Example Google Web Service. [Online]. Available: http://www.paragoncorporation.com/articledetail.aspx?articleid=13.

[4] A. Al-Ajlan, *Service Oriented Computing For Dynamic Virtual Learning Environments (Moodle)*, Strl. Leicester, UK, De Montfort. Phd Thesis, pp. 328, 2008.

[5] K. Aldrawiesh and F. Siewe *et al*., "An Observation Model To Detect Security Violations In Web Services Environment," in *Proceedings of the 2011 International Conference On Intelligent Semantic Web-Services And Applications. Amman*, Jordan, Acm, pp. 1-6, 2011.

[6] D. Booth, H. Haas, F. Mccabe, E. Newcomer, M. Champion, C. Ferris, and D. Orchard. (2004). Web Services Architecture. [Online]. Available: http://www.w3.org/tr/ws-arch/.

[7] S. Chou, W. Chang, C. Cheng, J. Jehng, and C. Chang, "An Information Retrieval System For Medical Records & Documents," in *Proc. 30th Annual International Conference of the Ieee, Anonymous Engineering on Medicine And Biology Society*, pp. 1474-1477, 2008.

[8] R. S. Kazemzadeh and K. Sartipi, "Interoperability Of Data And Knowledge in Distributed Health Care Systems," in *Proc. 13th Ieee International Workshop on Anonymous Software Technology and Engineering Practice*, 2005, pp. 230-240.

[9] P. J. Lees, C. E. Chronaki, E. N. Simantirakis, S. G. Kostomanolakis, S. C. Orphanoudakis, and P. E. Vardas, "Remote Access To Medical Records Via The Internet: Feasibility, Security And Multilingual Considerations," *Computers in Cardiology Anonymous*, pp. 89-92.

[10] R. S. Kazemzadeh and K. SARTIPI, "Interoperability of Data and Knowledge in Distributed Health Care Systems," in *Proc. 13th IEEE International Workshop on Anonymous of Software Technology and Engineering Practice*, 2005, pp. 230-240.

Khalid Aldrawiesh is working with Ministry of Education at National Center for Educational Information in Information. He received his MSc in IT in 2006 and then got Ph.D. in 2012 in Computer Science.