PERSONAL HEALTH RECORD SYSTEM AND INTEGRATION TECHNIQUES WITH VARIOUS ELECTRONIC MEDICAL RECORD SYSTEMS

by

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Electronic Medical Record Systems

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ABSTRACT

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In order to improve the quality of care, there is urgent need to involve patients in their own healthcare. So to make patient centered health care system Personal Health Records are proposed as viable solution.

This research discusses the importance of a Patient Centric Health Record system. Such systems can empower patients to participate in improving health care quality. It would also provide an economically viable solution to the need for better healthcare without escalating costs by avoiding duplication. The proposed system is Web-based; therefore it has high accessibility and availability. The cloud computing based architecture is used which will allow consumers to address the challenge of sharing medical data.

PHR would provide a complete and accurate summary of the health and medical history of an individual by gathering data from many sources. This would make information accessible online to anyone who has the necessary electronic credentials to view the information.

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INTRODUCTION

1.1 Context and Motivation

Health care is an information-intensive business. It generates huge volumes of data from sources like hospitals, primary care agencies, clinics, and laboratories. In spite of decades of experience in the application of Information Technology (IT) in other fields majority of healthcare data continues to be processed manually.

There are some specific challenges in application of IT in health care. Key challenges are issues related to privacy, security, complexity of medical data and absence of unique national patient identifier in many countries. General lack of awareness of the benefits and risks of information technology are also the major ones [9].

Information is central to healthcare. Knowing individual's family background, history of diagnoses, test results and medications is essential. This would allow care providers to manage patient's health, assessing problems and preventing medical error. Today individual's medical information is scattered among many sources and health care providers. The data is stored in individual memories, on scraps of paper and in spreadsheets on personal computers. Some doctors and hospitals keep computerized medical records but most personal health information is stored in thick paper files.

There is no coordinated and standardized system which provides a secure way to integrate an individual's health information in one place. This makes it difficult for care providers to have a centralized and holistic view of the patient information.

Integrating all data into a structured information system will increase the effectiveness of healthcare management. Moreover allowing patients to access their own medical records will encourage patients to be involved in their own healthcare. This would also strengthen the patient - care provider relationship. Such a system will also provide cost benefits .In the current state of health records a visit to a new doctor means new forms to complete, new tests to run and new conversations being made. This naturally results in higher cost to the patients, insurance companies and government.

In an integrated health record system duplication of records can be avoided which can lower the overall cost of healthcare. For abomination reasons healthcare institutions around the world are encouraged to develop the Electronic Health Record (EHR) systems. For patient centric use Personal Health Record (PHR) systems are proposed. PHR would track all EHRs from various encounters with a variety of health professionals. PHR can be seen as one of the means that can empower patients in their own healthcare. It is noted that consumers that are well informed about their illnesses tend to understand and follow instructions and ask more insightful questions [41].

Electronic Medical Record (EMR) is a computerized medical record created in an organization that delivers care. EMR tend to be a part of a local stand-alone health information system that allows storage, retrieval and manipulation of records. It is the basic building block and source of information that feeds the EHR. The EHR is the longitudinal record made possible by RHIO's (Regional Health Information

organizations) and provides interoperability across care delivery organizations. PHR is the record owned, accessed, and managed by the consumer [42]. The interdependencies are clear. Without linkages to the EMR, the PHR depends on the consumer to manually input vital data like laboratory results. Without an EHR, the PHR cannot accept information from multiple providers.

A PHR is typically a health record that is initiated and maintained by an individual. An ideal PHR would provide a complete and accurate summary of the health history of an individual by gathering data from many sources. PHR makes this information accessible online to anyone who has the necessary credentials to view the information.

Developing a cloud computing based web enabled PHR system present very attractive yet difficult research problem. Such a system can be used by patients to collect and manage their health information. It can also allow various authorized users to securely access patient records from any location. This presents a very good example of effective use of Information Technology (IT) in the field of Health Care.

1.2 Problem Description

Electronic PHR are increasingly recognized and used as a tool to address various challenges. Challenges which originate from the scattered and incompatible personal health information that exists in the contemporary health care system. However, there has been the lack of enthusiasm and adoption of PHR systems. Following are the major challenges which need to be addressed associated with the PHR system adoption.

1. A major challenge that patients face in healthcare today is the lack of access to their complete health information. Individual moves, travel, switch health insurance carriers and get their care from different providers. Also their medical records are distributed across multiple sites where they have received care. Ideally patients should have comprehensive and updated data of their health information. So that such information can be used & made available to any provider that they wish to see [1, 2].

2. System Integration has been always the most critical issue for the development of information systems in healthcare industry. Medical Information Systems (MIS) are heterogeneous in nature. They pose a severe challenge in their interoperability [3, 4]. A large number of healthcare applications are isolated and do not communicate with each other. Therefore integration of existing information systems represents one of the most urgent priorities of healthcare information systems [5].

3. Barrier to the use of EHR system by an elderly population has always been a great challenge. Majority of the Elderly and disabled patients could not create and maintain the PHR system independently. This may be due to cognitive & physical impairments or health literacy [6].

4. Nursing is an essential part of healthcare and has been documented in health records. It is logical that nursing perspective can be applied to compose a part of the PHR content. There has been no PHR that encompasses nursing care elements. So there exist opportunity to include nursing in the PHR system which can contribute to consumer health in an innovative way [7].

5. Imaging serves as a tenet of evidence-based medical practice and it contains important data in patient healthcare. Imaging also plays an emergent role in expanding the understanding of normal and diseased states. With the growing size effective management of DICOM (Digital Imaging and Communications in Medicine) imaging data is now a paramount necessity [43]. Unlike standard medical data images pose additional and distinctive management challenges. Systems are required so that patient can store and share the large imaging file effectively with different care providers without losing the quality.
6. Making information understandable to consumers is a thorny issue. There is no single standard language for health professionals. There exists wide variability in the terminology used by professionals. This makes it difficult to translate health information in ways that consumers can understand. Clinicians rely on the granularity of the term in its entirety to diagnose and treat patients. At the same time patients need everyday language to understand the ramifications of their health condition [11].

1.3 Thesis Contribution

This is an interdisciplinary area of research with interest in health care, health care standards and use of IT. The contribution of this thesis can be summarized as follows:

1. Goal of this research is to develop a model based PHR system framework with web based image viewer.
2. The research also proposes a process of specifying integration with multi tier applications in healthcare domain.

3. Effort is made to develop a user friendly interface for patients to maintain their health care information themselves.
4. Integration of the web based user interface with open source PACS (picture archiving and communication server). This would help in storage, retrieval, management, distribution, and presentation of DICOM images [44].
5. Integration of web based open source image viewer to provide patients facility to share medical imaging information effectively with their care providers.
6. Use cases of the proposed system for the patient and care providers have been defined.

1.4 Thesis Outline

This chapter gives the general overview on the importance of electronic health care and patient centric PHR system. It also describes various challenges faced by researches in developing computer based health care systems.

The rest of the thesis is organized as follows:

Chapter 2 discusses the evolution of computerized health record system in health care industry. It also explains the various disadvantages caused by traditional paper based health records. Section describes the various health care systems such as EHR, EMR and PHR. Importance of integrating the various systems is also discussed keeping in mind the current state of art technology.

Chapter 3 discusses the framework for proposed PHR system. The overall architecture is divided into three layers: 1. PHR system user interface (client layer), 2. Application and business logic layer (middle layer) to serve users requests and 3. Database layer which consist of MS SQL 2008 and DCM4CHE PACS server. The architecture strictly follows Java Enterprise Edition's benchmark model of 3 tier architecture. This chapter also covers the security aspects and patient and CDO centric use case for the proposed PHR system.

Chapter 4 provides overview of system in terms of functionality. Screen shot of system are provided to describe various screens in web enabled health record system. The user interface can be enhanced to include customized names of an individual.

CHAPTER 2

BACKGROUND AND RELATED WORK

2.1 Introduction

Healthcare system improvement is one of the topmost agenda for any society. The overall improvement of healthcare system requires streamlining of number of processes and practices. These improvements and changes are required to better control the rising cost of healthcare provision as well as to provide accessible quality healthcare to all citizens. Thus, to provide proper medical care for patients it is required to standardize storage, maintenance and accessibility of health records.

The adoption of e-health initiatives promises to revolutionize healthcare by reducing errors and costs while improving quality of care. It also empowers consumers to understand their healthcare needs, hence enabling them to make informed decisions on their healthcare. Among these initiatives are e-prescribing, provider-controlled EHRs, telemedicine, and consumer-centric PHRs [9].

Although technological advancements in science have greatly improved medical care in recent decades, improvements in the management of patient information have been deficient [45]. Most industries have plunged into data automation but health care organizations have lagged in moving patients medical records from paper to computers [46].

Patient records appear in a variety of forms, for example as paper records, microfilm, monitor strip, optical disk, computer card, tape etc. They are created and used most frequently in health care system such as physician or dentist offices, hospitals, nursing homes, and public health clinics [47]. However many healthcare institutions continue to rely on paper-based medical records as primary source of patient medical and demographic information.

The need to examine and manage health needs of patients has dramatically increased the demand for IT systems for capturing patient's clinical data. Substantial improvements in patient care can be realized through the use of electronic healthcare systems. These systems provide the ability to capture, organize, and present relevant clinical information in a manner superior to the physical records currently in use. In addition unlike the paper-based record EMR allow all caregivers to access patient records concurrently.

2.2 Inadequacy of Traditional Paper Records

When considering patient records the starting point is paper record since it has many advantages. It is familiar, portable, and can be easily browsed or scanned. However in the climate of modern health care delivery it has a number of major shortcomings.

Paper-based medical record is inadequate for meeting the needs of modern health care system. It originated in the nineteenth century as a highly personalized "lab notebook" that clinicians used. They used it to record their observations and plans so that they could be reminded of pertinent details before the patient's next visit.

While most health care institutions employ information systems to manage some aspects of patient care, the systems are often disjointed. Many times each department in a hospital has its own information system. In such cases communication between departments is reduced to printing the information from one system and sending that output to other department. Ultimately these paper records are transferred to patient's medical record. Delayed or inappropriate patient treatment is often due to miscommunication, lost or destroyed records, and overall inefficiency of paper based systems [45].

Difficulty in obtaining information about a specific patient is a frustrating, but common occurrence for practitioners. With increasing pressures to enhance clinical productivity, practitioners are starting to clamor for more reliable systems. Systems which can provide facile, intuitive access to the information they need when they see their patients.

Generally the patient's record are scattered among various care providers. Sharing and managing those paper records is a big challenge for the patients. Also it is not feasible for frequent moving patients to move with all of their medical records. Paper-based records are difficult to locate, update, and share with others. Paper-based PHR can be portable if the consumer carries it all the time. Otherwise, the access to this data is limited within the consumer's local area [10]. The health information is usually not kept up-to-date and possibly out-of-sync with health data from other sources.

Substantial improvements in patient care can be realized through the use of computerized version of healthcare records. So the key notion is that at heart of the evolving health care lays the medical record in a new incarnation. The record that is electronic, accessible, confidential, secure and acceptable to clinicians as well as patients [8].

There is an urgent need for the system which can provide the ability to capture, organize, and present relevant clinical information in better way.

EMR offers the hope for such improved access to patient-specific information. It provides major benefit for the quality of care for the patients. The concept of EMR is not new. Rudiments of it have been presented in paper records for decades. In addition unlike paper-based record EMRs allow all caregivers to access the patient record at the same time [12, 13].

2.3 Development of Computerized Health Record

The idea of computerizing health care record has been around since the early 1960s when hospitals first started using computers [48]. Initially computing systems in hospitals and throughout health care system focused on supporting financial processes. Hence there was a need to record basic data about patients, in order to ensure they were correctly billed for the treatment they received. Since these systems already stored such basic patient data, it was natural to extend them to include more clinically relevant data.

At the same time hospital laboratories were becoming increasingly computerized. Patient's test results were available in electronic form and could be integrated with basic demographic information [48]. Hospitals can integrate the basic patient data gathered for financial purposes and test result data produced for operation of clinical laboratory. However it is not the appropriate way to achieve the computerized record. Health care records are much more than simply arbitrary collections of patient data. The data in a record is structured for example chronologically, by source, by problem etc [15].

Advantages of electronic health care record over its paper-based counterpart are clear. It is always available, information can be easily transferred. Also it can support different views of the record for nurses, doctors and patients. Electronic record can also be linked to evidence based guidelines to provide decision support.

A major challenge that patients face in the current healthcare system is lack of access to their complete health information. There is need to consolidate patient's health information at one place. This would make information available to patients and health care providers with whom patients wish to consult [14]. Even before EMRs became available there was interest in encouraging patients to review their health information. With the development of EMRs and IT it becomes more feasible to provide patients control and access to their health information. Compared with written health records kept in localized storage patients can retrieve update and share their health information at their own convenience. This obviously will increase the awareness, compliance and management of their medical conditions and healthcare. EHR systems can also provide additional functionality such as interactive alerts to clinicians, interactive flow sheets, and simple order sets. All of which can not be done with paper-based systems.

2.3.1 Electronic Health Record

An EHR is an electronic version of a patient's medical history. It is maintained by the care provider over time. It generally includes key administrative clinical data relevant to patients. The data includes demographics, progress notes, problems, past medical history, immunizations, laboratory data and radiology reports. EHR automates access to

information and has the potential to streamline clinician's workflow. EHR also has the ability to support other care-related activities directly or indirectly through various interfaces.

EHRs are the inevitable next step in continued progress of healthcare that can strengthen the relationship between patients and clinicians. Availability of data in timely manner will enable providers to make better decisions and provide better care [49].

Implementation of EHR helps in lessening patient sufferance due to medical errors and inability of analysts to assess quality [16]. Improved usage of EHR is achieved if presentation on screen or on paper is not just longitudinal but hierarchically ordered and layered.

The area of study in EHRs is quite vast and there are various standards, practices and protocols for maintenance. Some of the studies and approaches regarding EHR maintenance are mentioned here that have been used as background study material for this paper. Dong et al. [34] have published an analysis and design of standard EHR. This report analyzes the various aspects of electronic records and their designs to present an approach for a standardized EHR. Kwak [35] had published a survey report on standards of EHR that are prevalent in different countries and regions. Bhatti et al. [36] have discussed an approach for engineering a policy based EHRs database. Covvey et al. **Error! Reference source not found.** have discussed a formal structure of EHR for specifying the content and quality of health records. Hoerbst & Ammenwerth [38] have described and structural model for the quality requirements of health records. In their paper they have discussed the state of the art and first concepts of the quality requirements of EHR. Having defined and basic nature, content, quality, structures and

formalization processes of EHR it is necessary for IT solutions to find ways of secured access and maintenance of health records. Wimalasiri et al. [40] have discussed the security requirements and privacy issues of health records vis-à-vis the specific requirements of EHR itself. They have discussed the security measures and issues of web services and SOA that could be used for accessing health records. Katehakis et al. [39] have described an approach of delivering integrated health records based on SOA.

EHRs provide access to novel amounts of clinical data for research that can accelerate level of knowledge of medical practices. These benefits will work only if EHR systems are interoperable and wide spread so that various systems can easily share information.

EHR provides the essential infrastructure required for effective use of new healthcare modalities and IT tools. Modalities related to integrated care, evidenced-based medicine, computer-based decision support, care planning and pathways, and outcomes analysis.

2.3.2 Electronic Medical Record

An EMR is a computerized legal medical record created in an organization that delivers care [17]. EMR is a tool that helps clinicians to manage all aspects of patient care. Generally EMR application environment are composed of various components. Components related to clinical data repository and decision support, order entry and pharmacy and clinical documentation support are main ones. It is used by healthcare practitioners to document, monitor, and manage health care delivery within a care delivery organization (CDO). The data in the EMR is the legal record of what happened to the patient during their encounter at the CDO. EMRs tend to be a part of a local stand-

alone health information system that allows storage, retrieval and manipulation of records.

In US most states require physical records be held for a minimum of seven years [16]. The costs of storage media such as paper and imaging films are very high compared to EMR. When paper records are stored in different locations collating them to a single location for review is time consuming and complicated. The process can be simplified with electronic records. This is particularly true in the case of person-centered records which are impractical to maintain if not electronic. Handwritten paper medical records can be associated with poor legibility, which can contribute to medical errors [18]. Electronic records help with the standardization of forms, terminology and abbreviations, and data input. Digitization of forms facilitates the collection of data for epidemiology and clinical studies.

EMRs may include access to PHR which makes individual notes from an EMR readily visible and accessible for the patients. A major concern is adequate confidentiality of individual records being managed electronically. There are many standards relating to specific aspects of EMRs. Some of these include:

a) XML: A document format allowing easy interoperability [50].

b) HL7: HL7 and its members provide a framework (and related standards) for exchange, integration, sharing, and retrieval of electronic health information. It is basically a messages format for interchange between different record systems [26].

c) HIPPA: Health Insurance Portability and Accountability Act (HIPAA) protects the privacy of individually identifiable health information. HIPAA Security Rule sets the

national standards for security of electronic protected health information. To analyze patient safety events and improve patient safety there are set of Patient Safety Rule [51].

d) DICOM: DICOM is a standard for handling, storing, printing, and transmitting information in medical imaging. It includes a file format definition and a network communications protocol. Communication protocol is an application protocol that uses TCP/IP to communicate between systems. DICOM files can be exchanged between two entities that are capable of receiving image and patient data in DICOM format.

2.3.3 Personal Health Record

Focus of healthcare has recently been shifted from healthcare provider's paternalistic approach to consumer oriented approach. There are several efforts in such direction. Microsoft and Google's open source health initiatives are just two examples of big corporation's future interest in this domain.

PHR is a concept that has been developing over several years. Early form of PHR used to be paper-based records. They pose problems due to the lack of availability of paper based medical records and lack of data transferability. Moving these records into an electronic format has been proposed as a way to solve some of these problems. As a result the focus on PHRs has increased over the past several years with more than 200 systems available in 2006 [19]. Effective use of IT is a key focal point for improving healthcare in terms of patient safety, quality outcomes, and economic efficiency.

PHR is an Internet-based set of tools. It allows people to access and coordinate their lifelong health information and make it available to those who need it. PHRs offer an integrated and comprehensive view of health information. Information includes data which people generate themselves such as symptoms and medication or from doctors such as diagnoses and test results. Information from pharmacies and insurance companies are also included.

Individuals access their PHRs via internet using state-of-the-art security and privacy controls at any time and from any location. Family members, doctors or nurses can see portions of a PHR when necessary. In case of any crisis situation emergency service providers can retrieve vital information from the PHR systems. Patients can use their PHR as a communications tool to send emails and share information to doctors, receive test results and access online self-help tools. PHR connects each of us to the incredible potential of modern health care and gives us control over our own information.

PHR is a single person-centered system and is not limited to a single organization or a single health care provider. EMRs usually contain a health history, doctor's notes laboratory and radiology results. They are generally owned by and limited to the information collected by one doctor or hospital. EMRs can supply information to PHRs. On the other hand PHR can also capture information from many EMRs and directly from patients.

In today's world Patients want to be more involved in their healthcare. One survey indicated 90 percent want to be an active and involved partner with their physician. On the other hand only 9 percent want their physician to manage their care and make decisions for them. [20]. More than half (52 percent) want to make final treatment

decisions for themselves or a family member, and 38 percent want to make the decision together with their physician [21]. Sixty percent of Americans said they favored creation of a secure online PHR service for their own use. They believed PHRs could improve safety and offer convenience. Some 69 percent of respondents said they would use it to check for mistakes in their medical records. 68 percent said they would use PHRs to check and fill prescriptions. Another 58 percent said they would use PHRs to get results over the Internet. 57 percent would turn to PHRs to conduct secure and private e-mail communication with their physicians [11].

Common contents of existing PHRs are clinical encounter related to health conditions entered by individual users. It includes medical diagnoses, medications, laboratory results, allergies, immunizations, visits, and treatments. Accumulation of such information helps in avoiding duplicate or unnecessary tests. It also provides benefits in better comparison with existing data from earlier examinations and excluding ineffective treatments. Assembly of such information can also increase patient compliance with clinical care processes and further reduce length of stay in hospitals.

Few studies have explored the nurse's role in the development and expansion of PHRs. Nurses historically have taken and recorded a patient's health history at admission to hospital or care facility. A new model asking completion of this aspect of nursing might replace this admission work thus saving time [22]. Nurses could then review this information and focus on the present health concern rather than spend time entering data. In addition, the patient's complete health history in this new model of the PHR includes education. Individuals can take guidance and get to know about their condition(s) prior to admission and provides additional information after discharge.

PHR can take many forms and each of these manifestations carries with it different implications for implementation policy and use. A well-designed PHR enables individuals or their authorized representatives to control personal health information. It also supports them in managing their health and well being and enhances their interactions with health care professionals. PHR provides an integrated view of information such as individual's health status, medical and treatment history and communications with health care providers. In order to accomplish PHR as described above, it must reflect the following attributes:

1 Each Person controls their own PHR:

Individual PHR users decide which parts of their PHR can be accessed, by whom and for how long. The patient owns his PHR and can designate others (family, caregivers, and clinicians) to manage it for them. Individual users can enter their own information and they may authorize others to add specific types of data into their PHRs. User can expect that systems that help them manage their PHR will use state of art security measures to prevent any unauthorized access to their data.

2 PHRs contain information from one's entire lifetime and all health care providers:

PHR should be a portable record. The system should aggregates and integrates information from multiple health care professionals, systems and patient directly. Unlike many EMRs that often only contain episodic and illness-related information. PHR contains an ongoing, longitudinal and life-long record of information that bridges both wellness and illness.

3 PHRs are accessible from any place at any time:

Using PHR individual users and other care provides can access up-to-date health information at the point of time.

4 PHRs are private and secure:

New federal regulations under the HIPAA affirm the right of individuals to control access to their personal health information. Patients may wish to grant full unfettered access for providers with whom they have an ongoing relationship.

5 PHRs are transparent:

Individuals should be able to see who entered each piece of data where it was transferred from and who has viewed it. Each piece of information that is added to the PHR should be attributable to its source.

6 PHRs permit easy exchange of information:

Exchange of information with other health information systems and health professionals is essential. The user should be able to transfer information between their PHR and other online record systems. Other systems may be within health plans, doctor's offices and hospital systems. Standards play an essential role in facilitating the secure interaction between PHRs and other systems.

2.4 Integrating Various Systems

Immense advances in IT have allowed many business sectors to explore the advantages of worldwide interconnected systems. Health care professionals should be able to access

the complete medical record of the patient even if it is distributed among several remote units.

The integration of healthcare software systems has remained one of the most prominent issues in healthcare software development [23]. Changing work in healthcare e.g. to support patient-centered care and regional healthcare networks requires integrating health information systems. Many workflows in the healthcare facilities involve more than one application [24]. At the same time the application architectures for new systems in healthcare are evolving towards use of web enabled, distributed and component and service based systems. Many systems have been built and acquired from heterogeneous sources during a long period of time. These systems have differences in implementation technologies and architectures [25]. In these legacy systems the heterogeneous environment and an increasing pressure to introduce new software rapidly add even more pressure on systems integration. Furthermore, there are many complementary and also overlapping technologies and standards available for integration.

Many efforts have been made on integrating heterogeneous systems in hospitals. Healthcare industry has developed several standards through which relevant data can be transferred among different information systems. These standards are Health Language Seven (HL7), Electronic data Interchange (EDI) X12 Version 4010, HIPAA, DICOM, and Integrating Healthcare Enterprise (IHE) among others [27]. All these standards are currently being widely used in healthcare industry. According to Open Source Clinical Research Group HL7 is the most widely used messaging standard. The proposed solution will be able to integrate all medical information systems that are in compliance with HL7 standard.

Standardized interfaces are available to many healthcares. "Object Oriented Services" such as CORBA med (Common Object Request Broker Architecture in Medicine) which realizes the share of common functionalities like access control among different systems. Others, like DICOM, HL7 and the initiative of IHE [28] specify guidelines or standards for exchanging messages among different systems. It makes different systems work in harmony and implement the workflow integration [29].

Broker based embedded device facilitated communication between HIS, RIS and PACS by integrating HL7 with DICOM. Broker accepts HL7 messages from RIS translated and map the data to produce DICOM messages for transmission to PACS. However the Broker system posed a challenge since it allowed RIS information to flow only in one direction resulting in the duplication of databases.

IHE initiative jointly established by Hospital Information Management Systems Society (HIMSS) and the Radiological Society of North America (RSNA) later addressed this issue by allowing the integration of clinical information within a healthcare delivery network. Later a consolidated solution with RIS/PACS/HIS integration was offered by healthcare companies. This was a major step towards successful integration of patient records within a network [30]. Assurance of consumer control of privacy is essential to the acceptance and adoption of PHRs. With appropriate access controls, patients can allow portions of PHR to be made available to family members, various care providers, and others.

2.5 Summary

In this chapter we explained the evolution of computerized health record system in health care industry. Then we explained various disadvantages caused by traditional paper based health records. The section also lists various electronics health records systems such as EHR, EMR and PHRS and their relationship. The importance of integrating the various systems is also discussed keeping in mind the current state of art technology.

CHAPTER 3

A FRAMEWORK FOR PERSONAL HEALTH RECORD SYSTEM

3.1 Introduction

The goals of the proposed PHR System are collecting, organizing, storing, and sharing an individual's personal health information. PHR System is a web-based repository that provides users a facility to log their medical information. The information consists of general information (e.g., date of birth, address, emergency contact), insurance, primary CDO's contact information, family health history, past surgeries, allergies, medications, laboratory tests, and social history. Patients can also upload their health related documents and medical imaging data such as XRAY, MRI, and CT scan etc. Patients can fill out information in any order they choose and over as many sessions as needed. This system creates duplication of records.

The proposed system is implemented based on the three tier architecture as shown in fig 1. Database tier comprises of databases that include data, metadata and enterprise management rules. In our system this tier includes all databases concerning the DICOM information. The user is not in direct contact with the data storage level. Every user has to retrieve the required data through the middle tier. This method is used to preserve data security and integrity. The end-user has no knowledge of the underlining processes cooperating in order to render data to him.

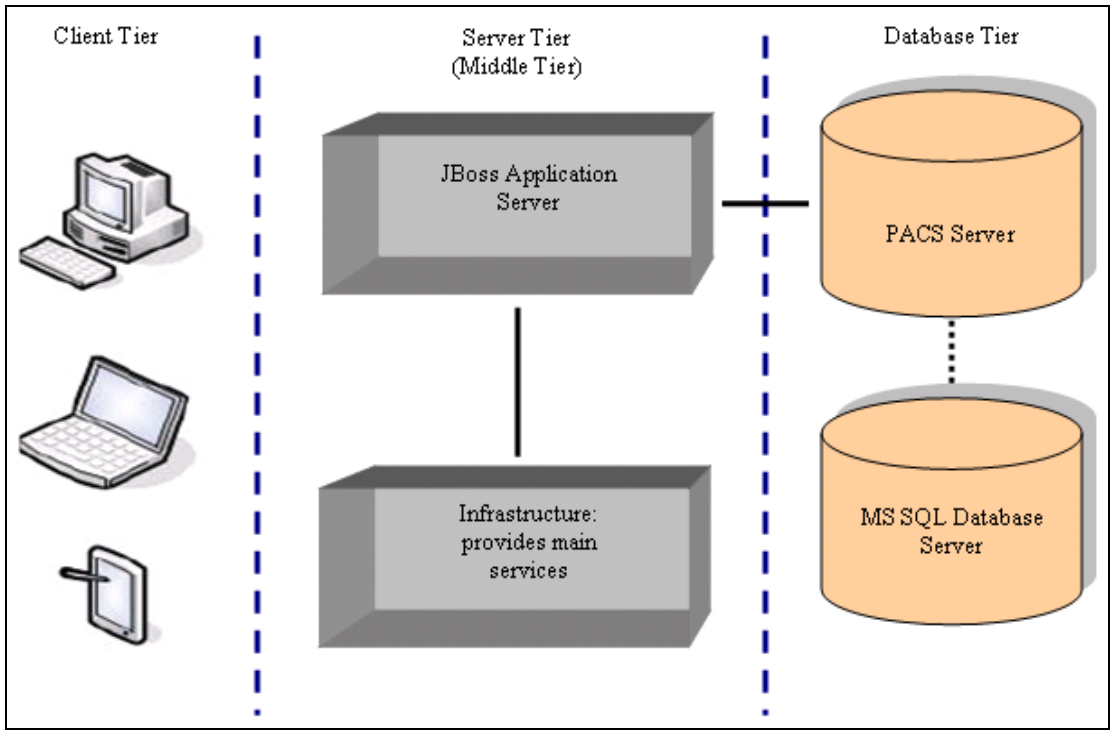

Figure 1 Three tier architecture

PACS Server which implements the database tier accepts images or studies from the modality or from the clients and has the role of the DICOM Service Provider.

Server (or middle) tier consists of the Application Server for formalizing application and web services. This tier processes the service requests coming from the client tier. Service of a client tier request may demand access or change of the database tier's data. Server tier is the most important and complicated part of this architecture providing the technology for web application's development. It improves the performance, scalability and availability of frequently used web sites.

JBoss application server is chosen as it is a Java EE certified platform for developing and deploying enterprise Java Web applications. JBoss Application Server provides full range of Java EE 5 features as well as extended enterprise services including clustering,

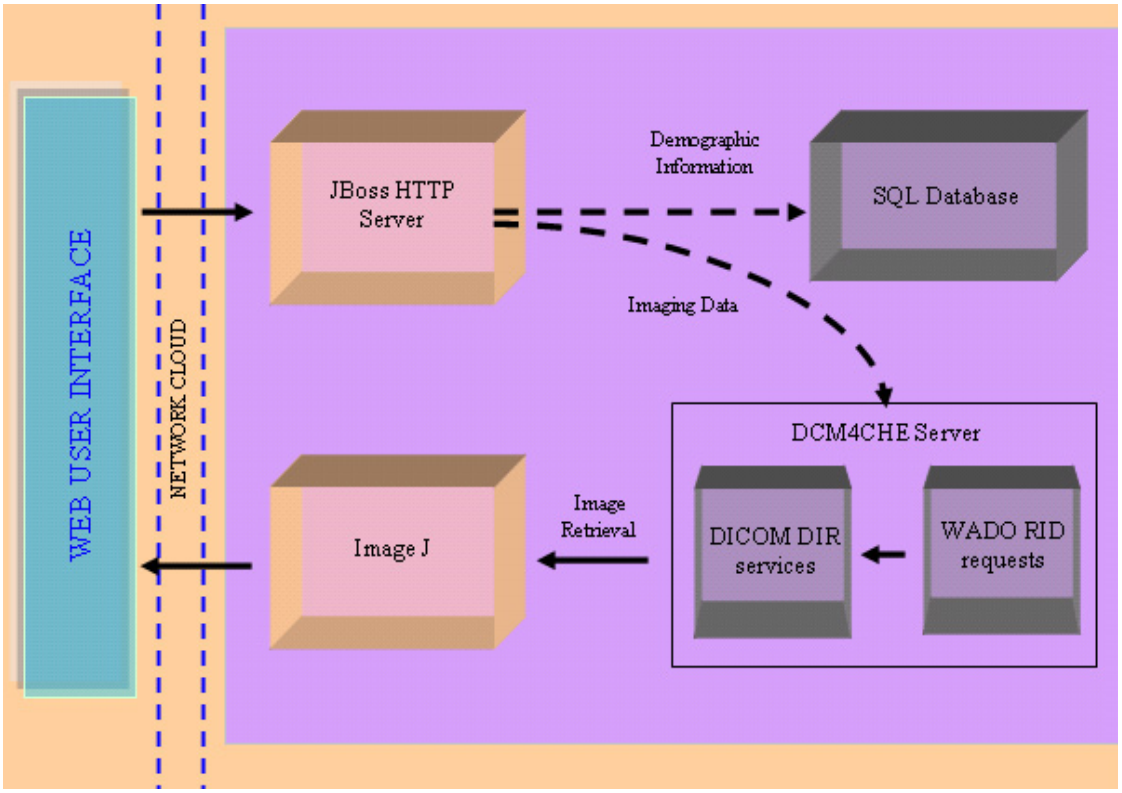

Figure 2 Proposed Personal Health Record System Architecture

caching, and persistence. User interface of the system is designed using Java EE web technology. The system also integrate and uses two open source products; DCM4CHE as PACS server and Image J as medical imaging web viewer. System strictly complies with HIPAA. To provide reliability, scalability and security the entire system is hosted on a cloud computing environment.

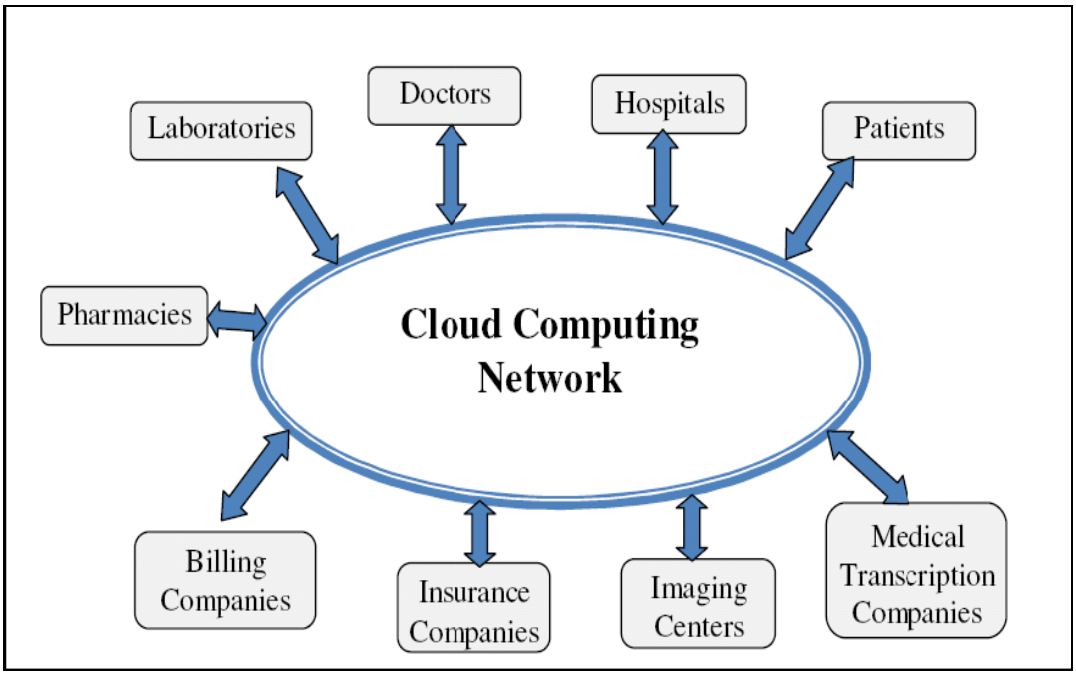

Figure 3 Interaction of various CDO's and Patient with the cloud computing network

3.2 System Description and Architecture

Architecture of the proposed PHR system is shown in Fig. 2. It is a web application that runs on J2EE platform. The technology is chosen for its platform independent features and availability of rich web application framework library. Application could be deployed on cloud computing network such as Amazon EC2. Application deployed on the cloud infrastructure delivers reliable, scalable and secure software as a service over internet. This kind of scheme eliminates the need to install and run the application on customer's own computers and simplifying maintenance and support. Cloud computing infrastructure for the proposed system is shown in fig 3. The system comprises of following major components:

a) PHR web based user interface

b) Server side component

c) DCM4CHE – PACS

d) Image J

e) Security

3.2.1 Web Based User Interface

The user interface layer for PHR system is based on J2EE a platform for web applications hosted by JBOSS Application server. The user interface is divided into role-specific pages (system administrator, patient, CDO, researchers and insurance providers). Figure 4 lists the identified prospective functions and the requirement with respect to each function for the web based user interface [31].

Function	Requirements
Providing Web-based access to personal medical information	■ Secure password-protected patient access ■ Capacity to provide authorized provider access ■ Capacity to provide directed emergency access
Providing an organized summary of personal medical information for presentation to health care providers	■ Accurate entry of past and current medical conditions, including information about diagnosis and treatment ■ Accurate entry of past and current medications, including information about indication, dose, frequency, and duration ■ Verification of laboratory test results ■ Verification of diagnostic study results ■ Verification of immunizations, including information about dates and sequences
Serving as a portal to patient-specific consumer-level health care information	■ Accurate entry of medical conditions ■ Accurate entry of medications ■ Capacity to provide links to consumer health care information
Providing interpretive information about laboratory test and diagnostic study results	■ Accurate entry of medical conditions ■ Accurate entry of medications ■ Verification of laboratory test results ■ Verification of diagnostic study results ■ Capacity to interpret laboratory test and diagnostic study results
Serving as a database of information for patient-specific self-monitoring and disease management	■ Accurate entry of medical conditions ■ Accurate entry of medications ■ Verification of monitoring study results ■ Capacity to interpret monitoring study results ■ Capacity to provide evaluation and treatment recommendations ■ Capacity to provide secure communication between patients and providers

Figure 4 Function and requirement for the web based UI [32]

3.2.2 Server Side Component

MS SQL 2008 database is used to collect and store information. This will allow users to retrieve, add, update or remove information in an automatic fashion. Patients can store the general demographic information along with other health related data. Data such as Insurance provider details, frequent CDO visit logs and prescription, lab reports etc. In the business logic of application database programs are designed for users so that they can add or delete any information needed. The structure of a database is tabular.

3.2.3 DCM4CHE – PACS

DCM4CHE server is a collection of open source applications and utilities for healthcare enterprise. These applications have been developed in the Java programming language for performance and portability, supporting deployment on JDK 1.4 and up. Also contained within the dcm4che project is dcm4chee. Dcm4chee is an Image Manager/Image Archive (according to IHE). Application contains DICOM, HL7 services and interfaces that are required to provide storage, retrieval, and workflow to a healthcare environment. Dcm4chee is pre-packaged and deployed within JBoss application server. By taking advantage of many JBoss features (JMS, EJB, Servlet Engine, etc.) and assuming role of several IHE actors for sake of interoperability. Application provides many robust and scalable services.

Dcm4Chee server contains various applications which provide wide range of services to the user. The overall system architecture of the Dcm4chee server is described in fig 5.

The main services which Dcm4Chee provides are:

a) DICOM Server:

This server sends incoming requests to registered DICOM services. It provides many different services most of which involve transmission of data over a network such as storage, querying lists of images or other such objects and then retrieves them from a PACS, printing etc.

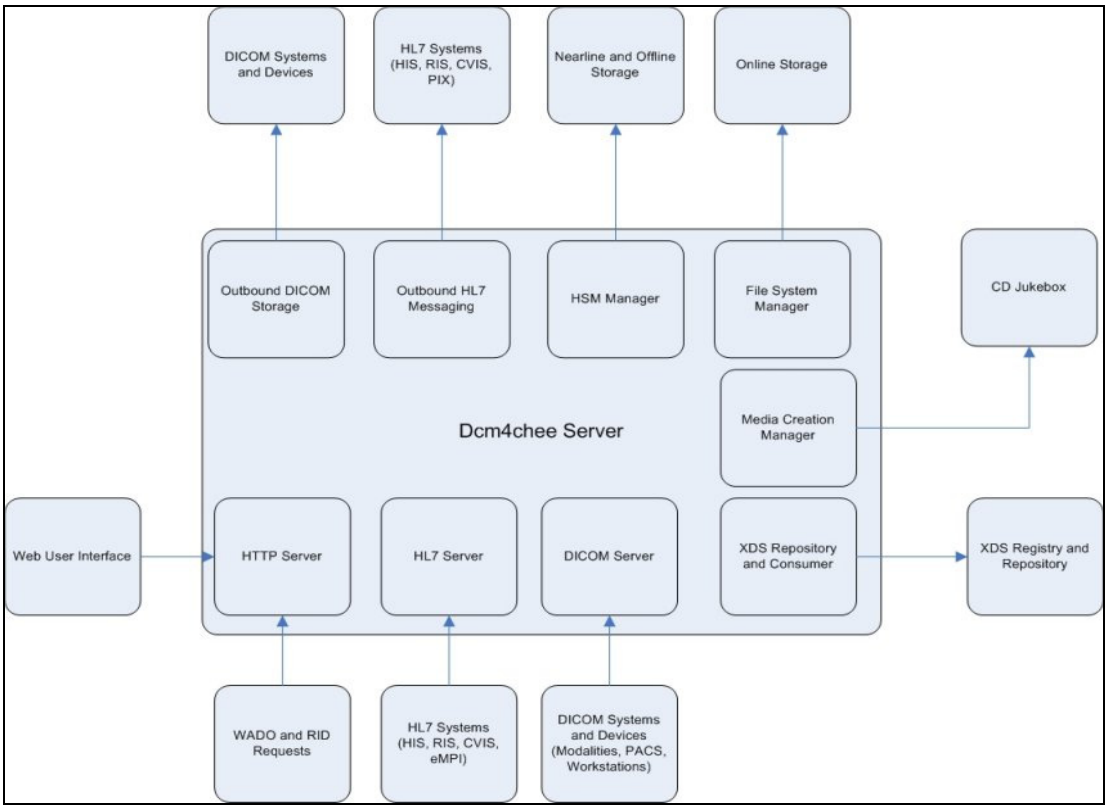

Figure 5 System architecture of the Dcm4chee Server [52]

b) HL7 Server:

This server dispatches incoming HL7 messages to registered HL7 services. The HL7 server automates the development of systems called collaboration ports. As a result enable interoperation among systems in the healthcare domain. Also interactions defined by the HL7 standard as information exchanges that take place between Application Roles in response to Trigger Events.

c) WADO and RID request:

In web-based PACS design, images are delivered to the client PCs only on demand. Browser does not store the images locally. The Server is able to keep up with "just in

time" delivery of images. This service is able to be provided in high quality, when there is a broadband network.

DICOM Persistent Object is an instance of a data object that has been allocated a unique identifier in the format specified for SOP (Service Object Pair) Instance UID. Within the DICOM Standard, a DICOM Persistent Object is referred to as a Composite SOP Instance. Web Access to DICOM Persistent Objects is the Service enabling Web Client System to retrieve DICOM Persistent Objects. These objects are managed by Web Enabled DICOM Server. HTTP/HTTPS protocol is used for this communication. Fig. 1 shows the Request-Response Model for communication between the Web Enabled DICOM Server and a Web Client System. Query parameters are sent to the Server through the http GET request. Server will respond sending one or more objects in a proper MIME (Multipurpose Internet Mail Extension) type.

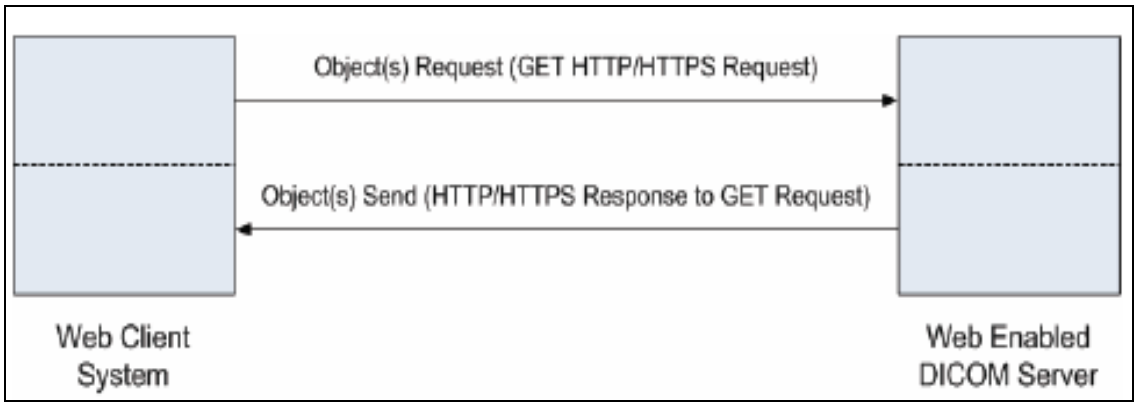

Figure 6 WADO Request – Response Model

3.2.4 Image J

The Web viewer interface used is open source ImageJ which is a Java based image processing program. ImageJ can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can read many image formats including TIFF, GIF, JPEG, BMP, DICOM, FITS and "raw". It supports "stacks", a series of images that share a single window. It is multithreaded so time-consuming operations such as image file reading can be performed in parallel with other operations. It can calculate area and pixel value statistics of user-defined selections. It can measure distances and angles. It can create density histograms and line profile plots. It supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering.

It does geometric transformations such as scaling, rotation and flips. Image can be zoomed up to 32:1 and down to 1:32. All analysis and processing functions are available at any magnification factor. The program supports any number of windows (images) simultaneously, limited only by available memory.

ImageJ was designed with an open architecture that provides extensibility via Java plug-in. Custom acquisition, analysis and processing plug-in can be developed using ImageJ's built in editor and Java compiler. User-written plug-in make it possible to solve almost any image processing or analysis problem. ImageJ can be integrated with a PACS server to read data from a remote server. In our experiments we integrated the ImageJ with Dcm4chee server.

3.2.5 Security

To ensure the security of the data we plan to implement password protected access to the system. Only registered patient's having Single Sign On (SSO) authentication can login in the system. At this point a unique id and a unique password are required for any user to enter the application. On a second layer, a container, responsible for translating user's request in applications logging, accomplishes the whole logical process. Users already registered to the catalogue are authorized to continue navigation inside application platform.

Patients are restricted to viewing and modifying and sharing only their own records. CDO's and other care units can only access those records which are shared with them. Patients can edit the access privileges on their records at the granularity of the categories.

The cloud computing architecture of the Amazon Web Services (AWS) provides a reliable, scalable, and inexpensive computing platform. It can be used to facilitate healthcare customers HIPAA-compliant applications. This platform is built on the same robust technology that Amazon.com uses to run its global web properties. Amazon EC2 offers a flexible computing environment with root access to virtual machines. It also provides ability to scale computing resources up or down depending on demand.

To adhere to HIPAA guidelines customers can create point-in-time snapshots of EBS volumes which are automatically stored in Amazon S3 and are replicated across multiple Availability Zones. These snapshots can be accessed at any time and can protect data for long-term durability.

3.3 System Use Case

One approach to establishing a foundation for evaluating information design in PHRS is "use cases". Use cases categorize and describe discrete functional scenarios and how computer interactions are carried out. Use cases are intended to serve as a framework demonstrating and establishing the relationship between high-level clinical functions and related standards in information design and usability. Figures 7, 8and 9 outline the use of the proposed PHRS.

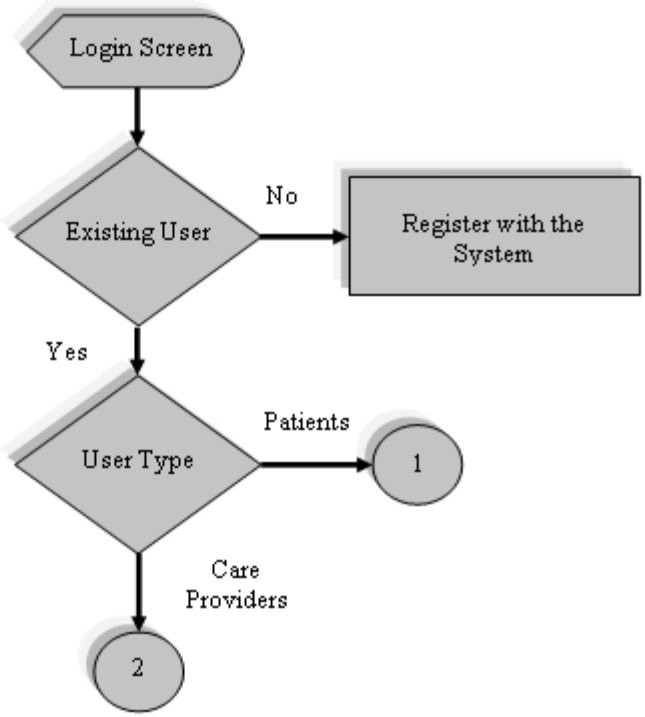

Figure 7 Login Screen Use Case for Proposed system

The UI will benefit from further evaluation using use-cases that represent uses by patients. Findings will help develop a more user-centered PHR system.

User first logs into the web based PHR system (Fig. 7). If user is a first time customer then he/she will have to create a user account in system. Storing/accessing the medical information can only be done after successful user authentication. Once account is created, user can select desired user type and can login into the system. As soon as users logs in the system with user type as Patient they will be first asked to create their profile. Data in the profile comprises of demographic information of the patient and past laboratory results including images MRI, X-rays and other scanned documents. All demographic information entered by the patient will be stored in the SQL database and all imaging data will be processed and stored by Dcm4che server.

Patients can View/Update or Add new information in the exiting profile. Patients can also share medical records and their laboratory test results (including imaging information) with various CDO's and insurance providers by giving access to them. Patients can control data sharing mechanism and can either share complete profile or only selected information with the care provider or insurance provider companies.

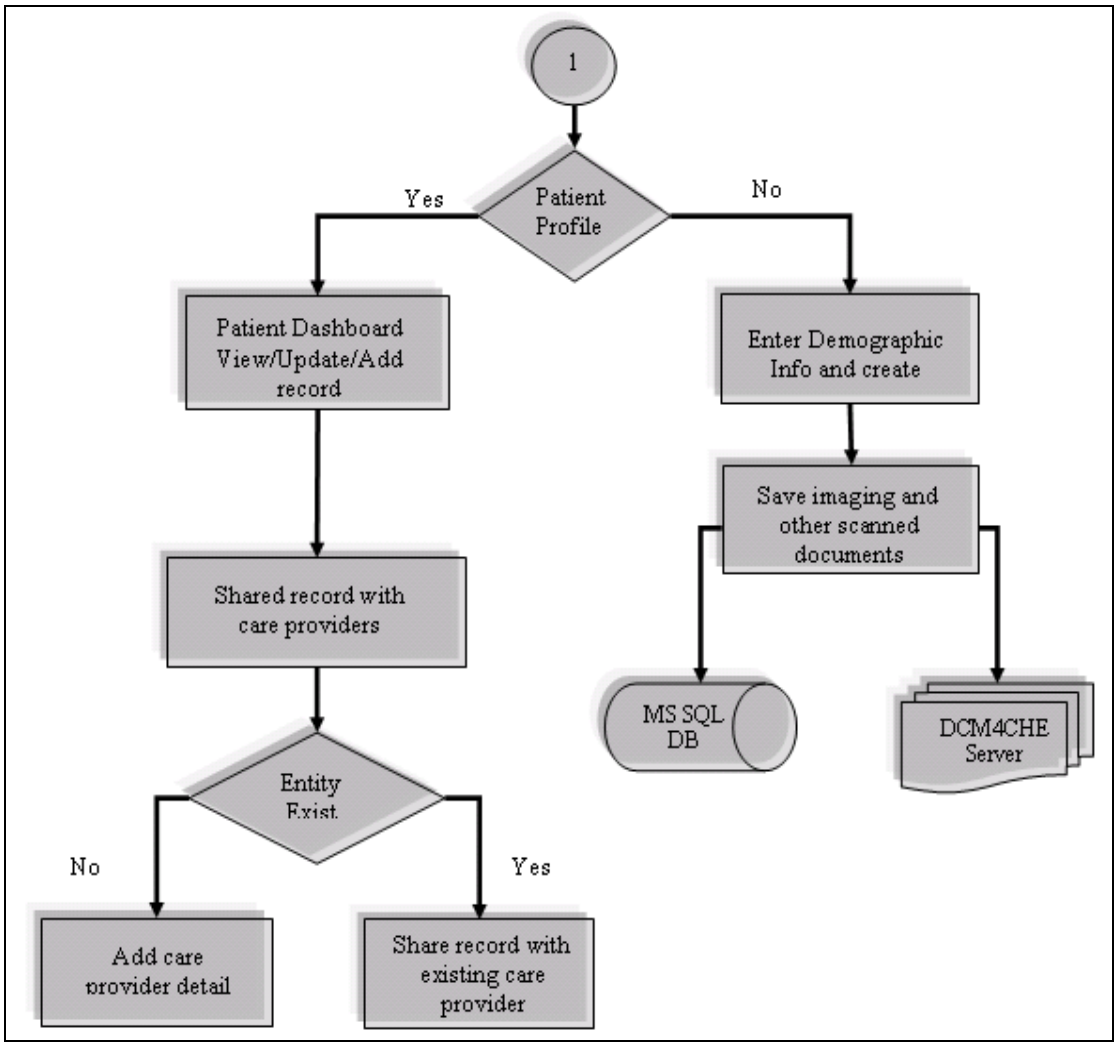

Figure 8 Patient Centric use case for proposed PHRS system

When user shares any information to any of the registered CDO it will be displayed on that particular CDO's dashboard. Any information to the CDO can be shared either in read only mode or with the read/write mode. The patients control the access levels. Once any patient case is displayed in the dashboard they can then examine patient data and can suggests if any medication or radiology is required. Later the details can be stored into the database.

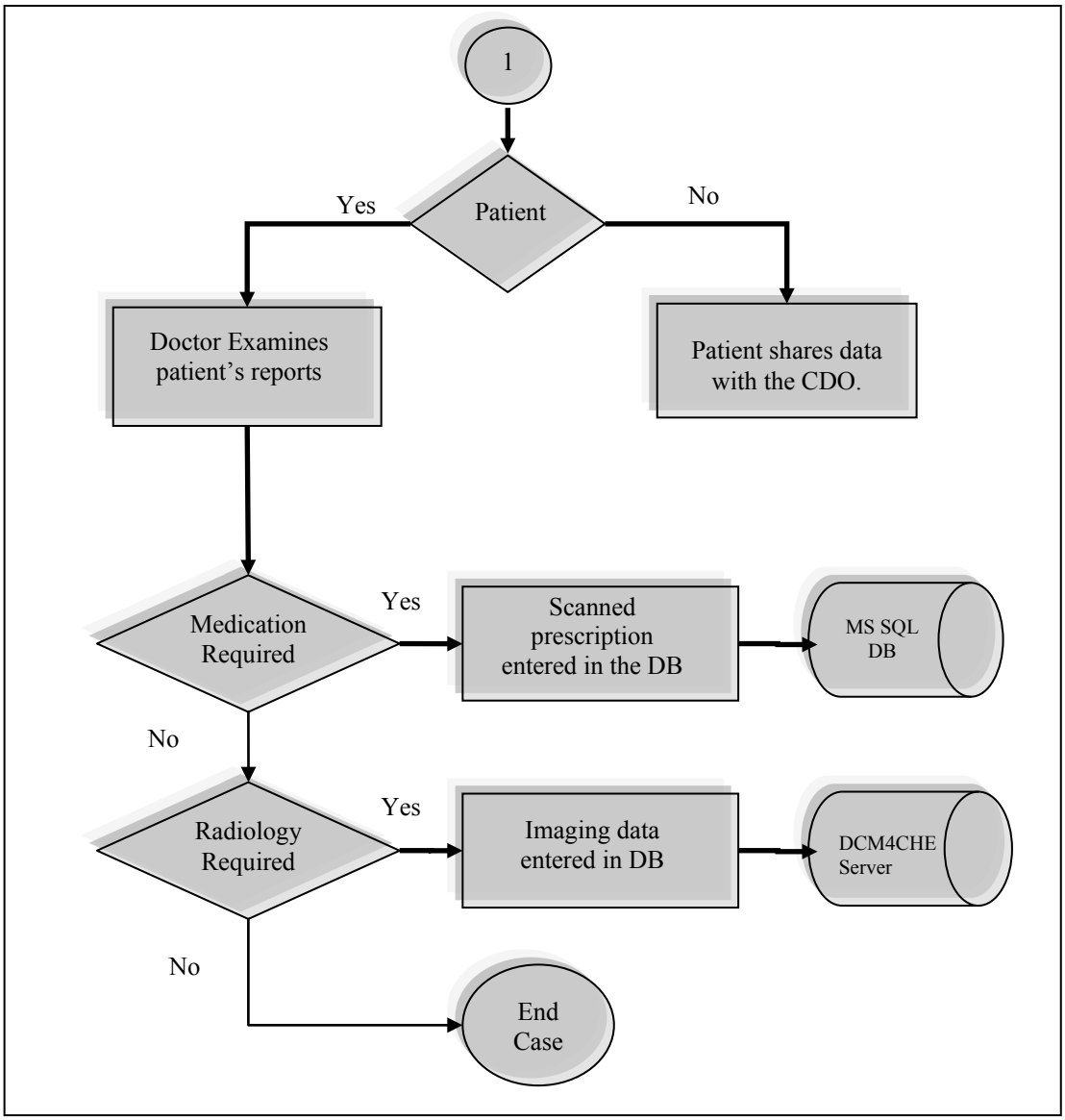

Figure 9 CDO use case for proposed system

3.4 Summary

This chapter discusses the framework for proposed PHR system. The overall architecture is divided into three layers: PHR user interface (client layer), application and business logic layer (middle layer) to serve users requests and database layer which consist of MS SQL 2008 and DCM4CHE PACS server. Architecture strictly follows the Java Enterprise

Edition's benchmark model of 3 tier architecture. Chapter also covers the security aspects and patient and CDO centric use case for proposed PHR system.

CHAPTER 4

CASE STUDY

4.1 Data Generation for Simulation

The proof-of-concept system with respect to the proposed solution has been tested for the primary functionality, workability and feasibility. Some snapshots have been taken for example cases to show the behavior and process flow of the system with various input data and events.

The case studies describe the input data to the system and present some screen-shots from the proof-of-concept system to show how it follows the process flowchart.

4.2 Simulation Results and Analysis:

1) Login Screen for PHR System: This screen will allow users to log into the system. Users who already have account in the system can login by entering username, password & user type. Currently system allows two types of user, Patients, CDO's.

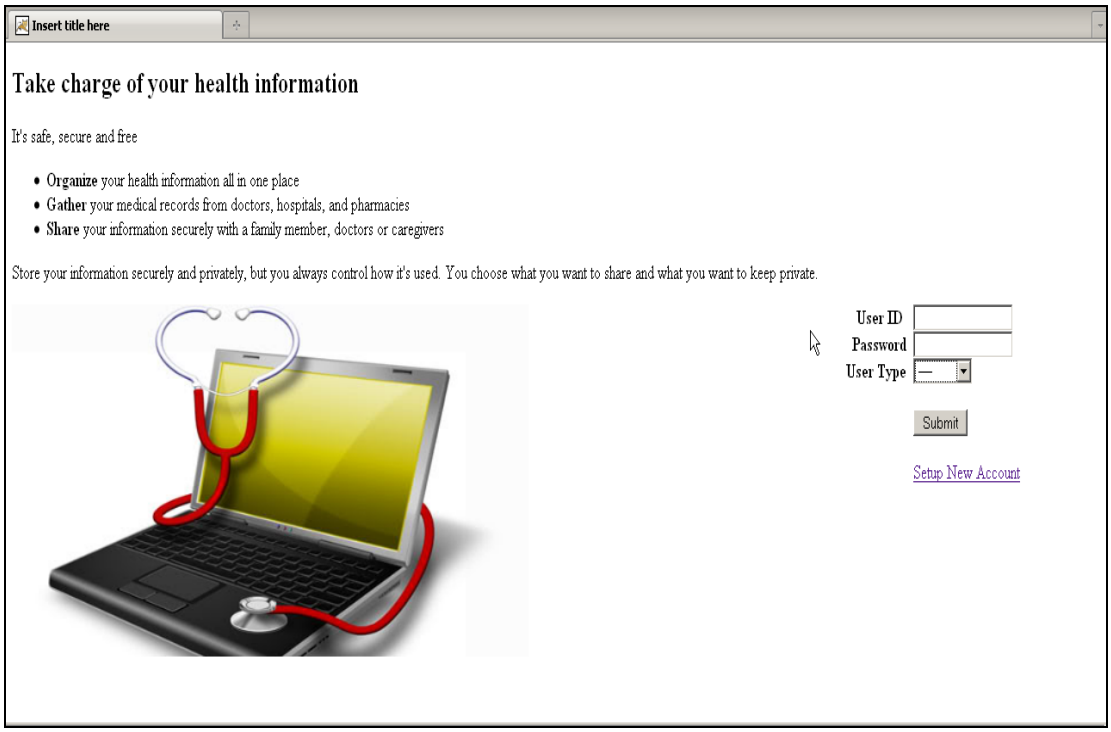

Figure 10 Login Screen for personal Health Record System

2) New User Registration: This screen allows new users to be registered in the system.Demographic information for the user is captured in this screen.

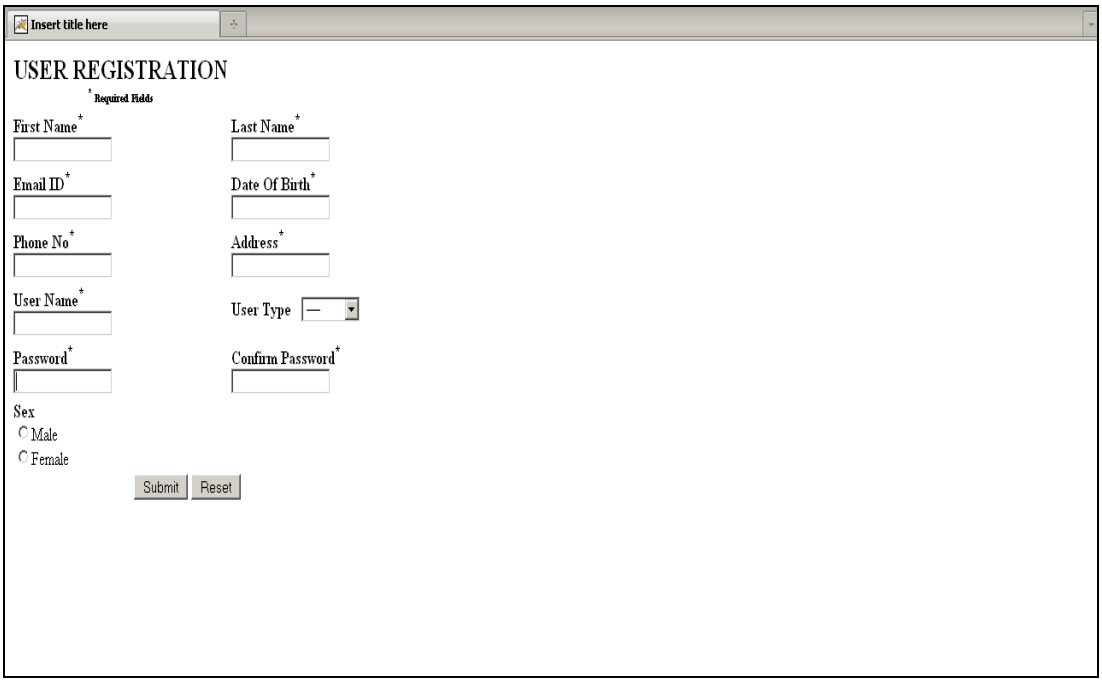

Figure 11 New User Registrations

3) Patient Dashboard: This screen presents the user with links to manage the data. From here user can get access to data in variety of views.

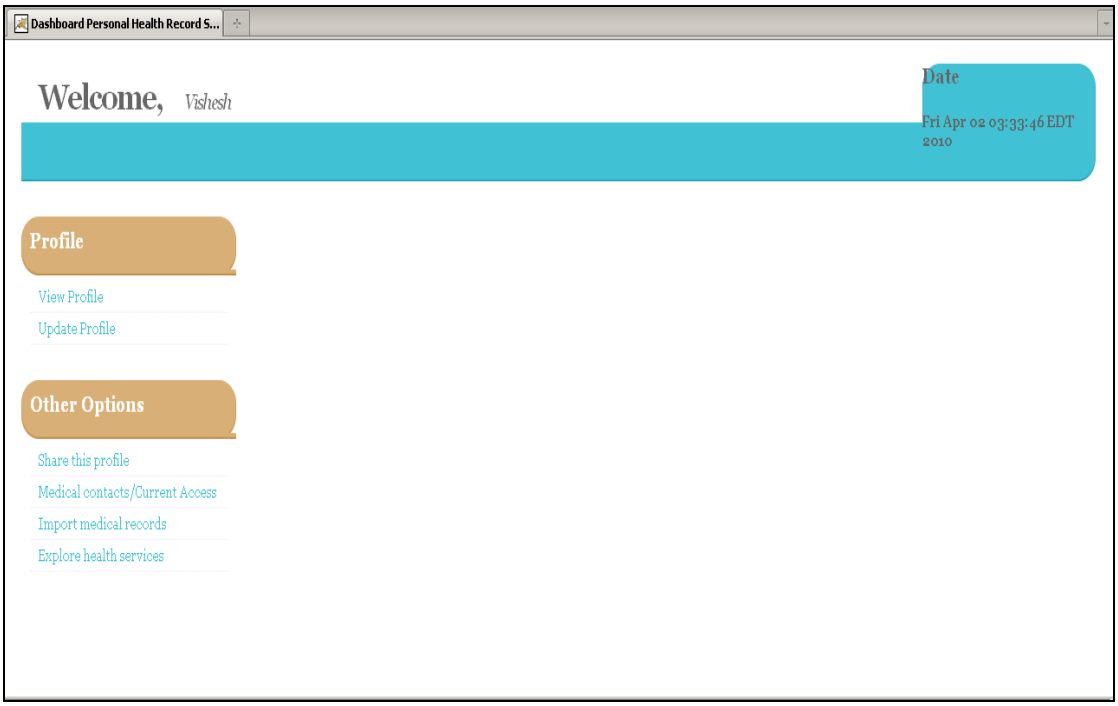

Figure 12 Patient Dashboard

4) Patient clicks to View profile: Patient can view general demographic information and medical data by selecting the view profile option.

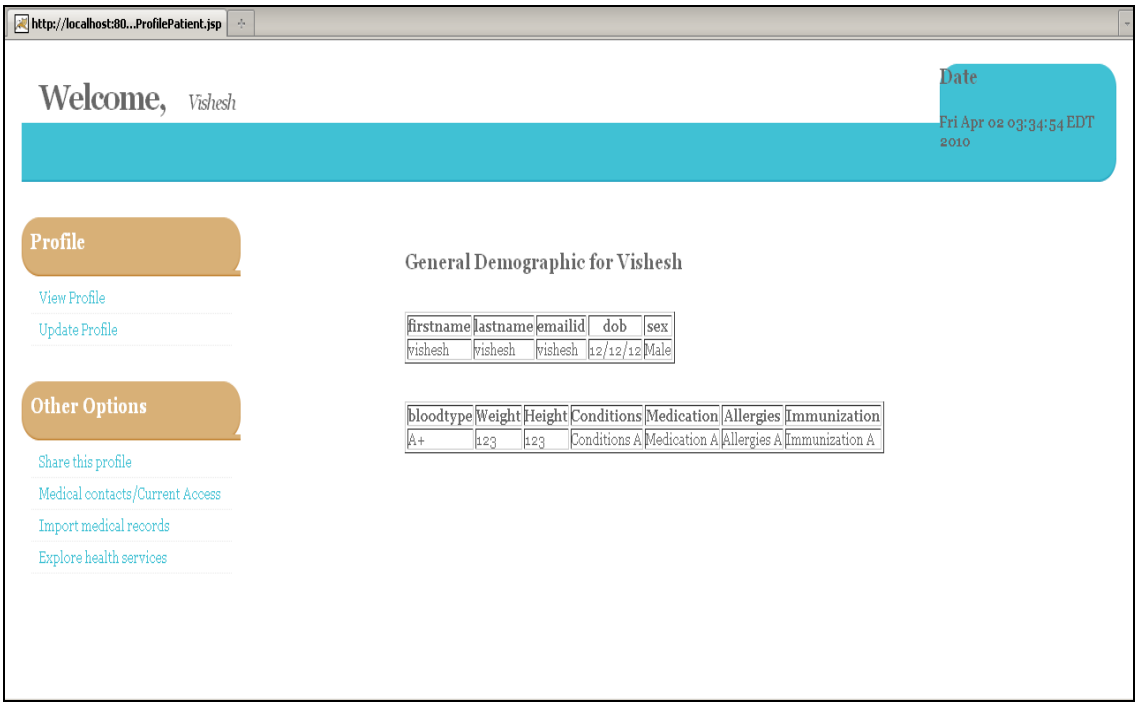

Figure 13 View Profile for Patients

5) Patient Clicks to update the profile: This screen allows user to add/update information present in the system.

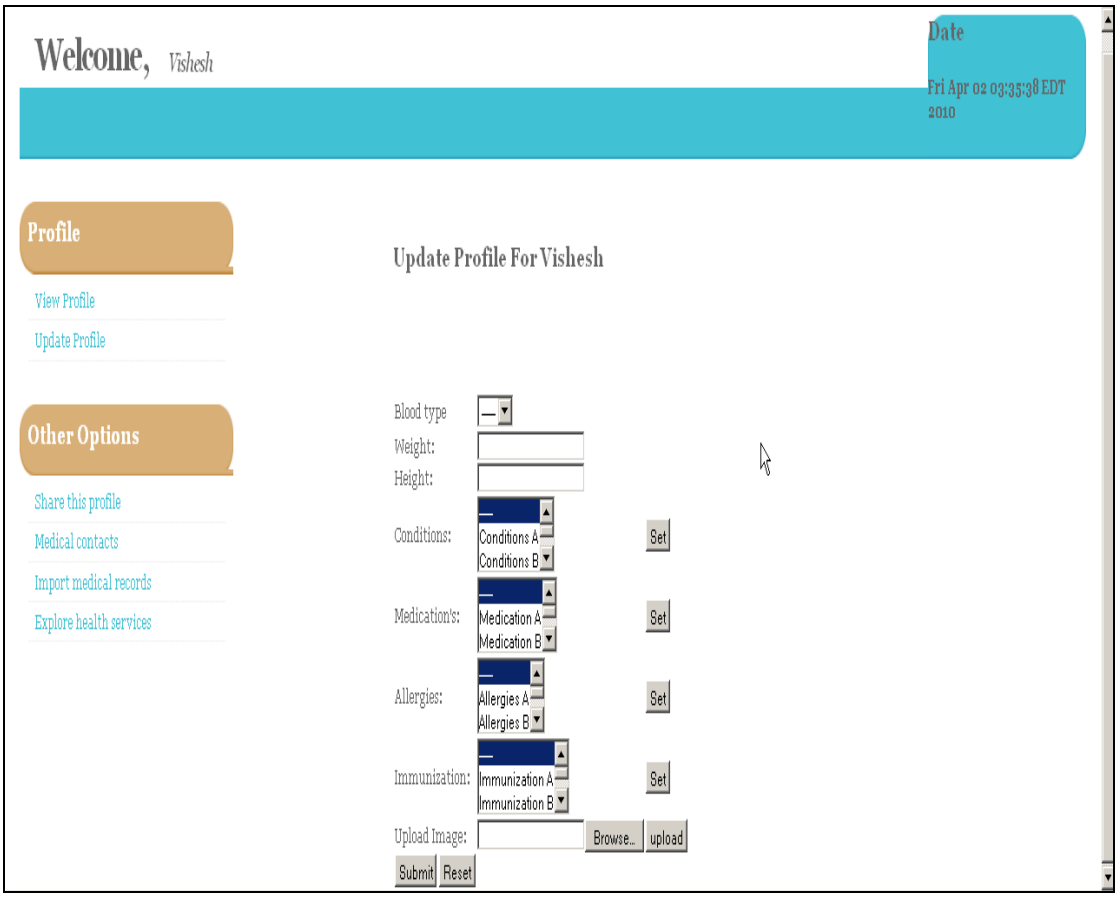

Figure 14 Update profile for patient

6) View CDO list / Share information with selected CDO's: This screen allows user to manager access rights of their medical data. From here user can grant access to various CDO's.

Figure 15 View CDO list / Share information

7) Manage Profile – delete record: This screen allows user to delete records from the system. User can delete demographic as well as medical information.

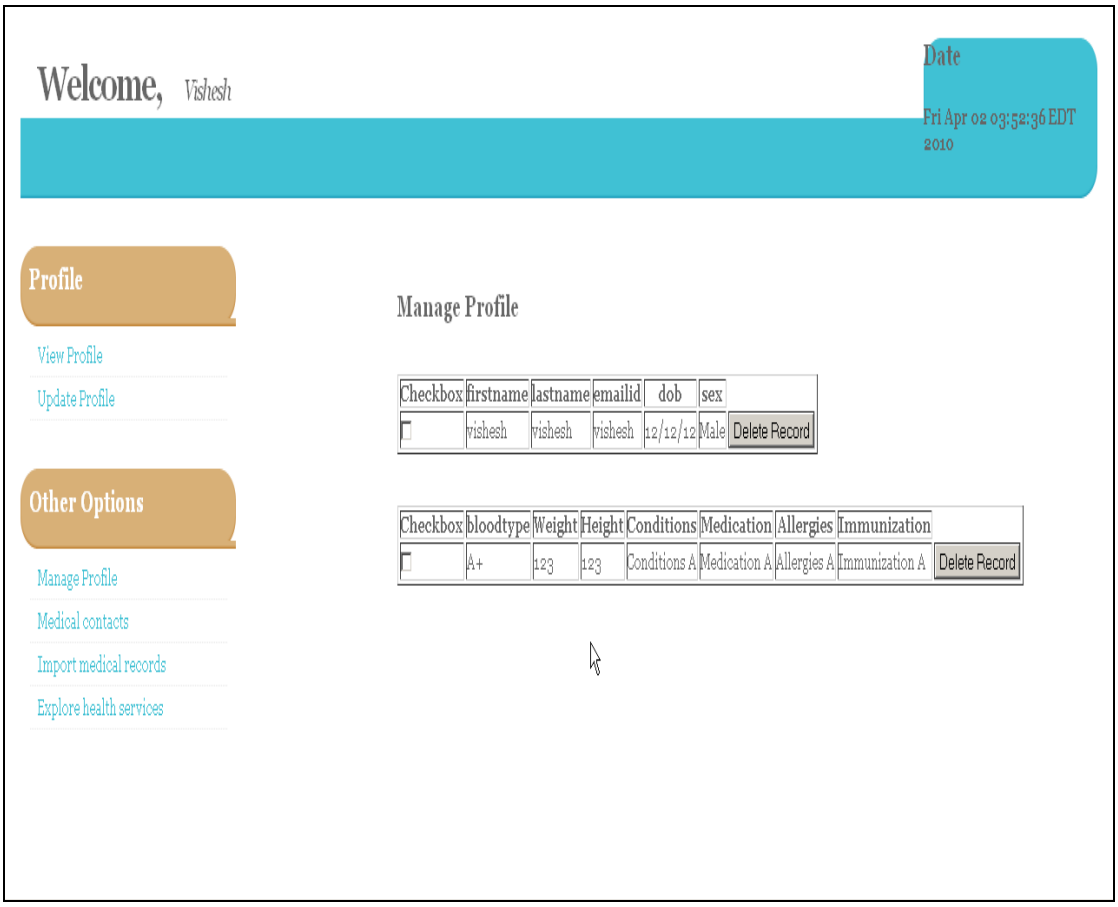

Figure 16 Manage Profile

8) CDO Logs into the system: This screen is the dash board of CDO's. CDO's can view information of all those patients who have given access to them. Along with textual data CDO's also can also view images uploaded by the patients.

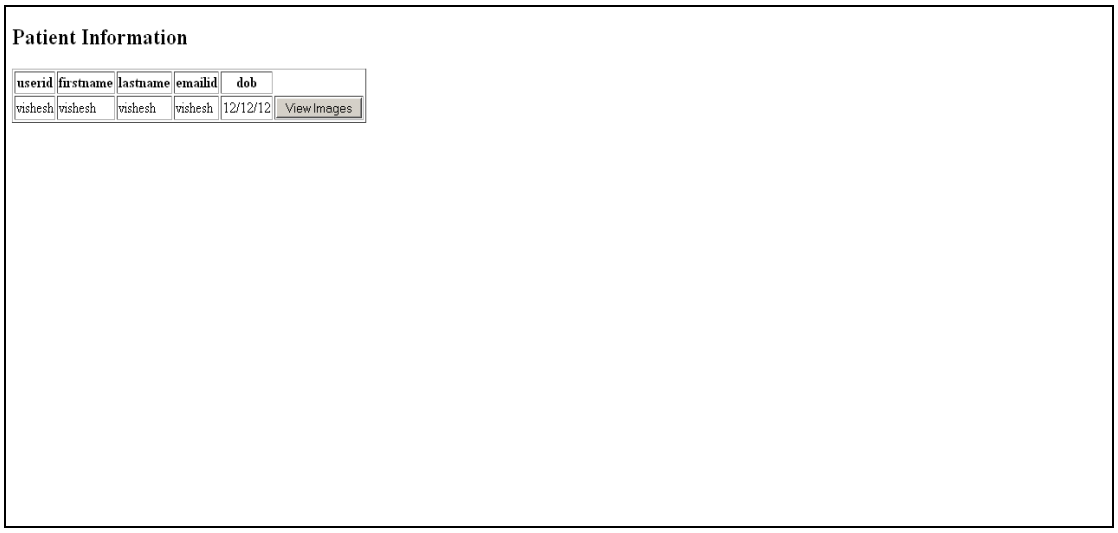

Figure 17 CDO Logs into the system

9) Image J: Application allows doctor to view and manipulate the medical images. Once doctor clicks on View Images button DICOM image of the patient is downloaded through Wado request. Doctor can then view the images by opening it in Image J.

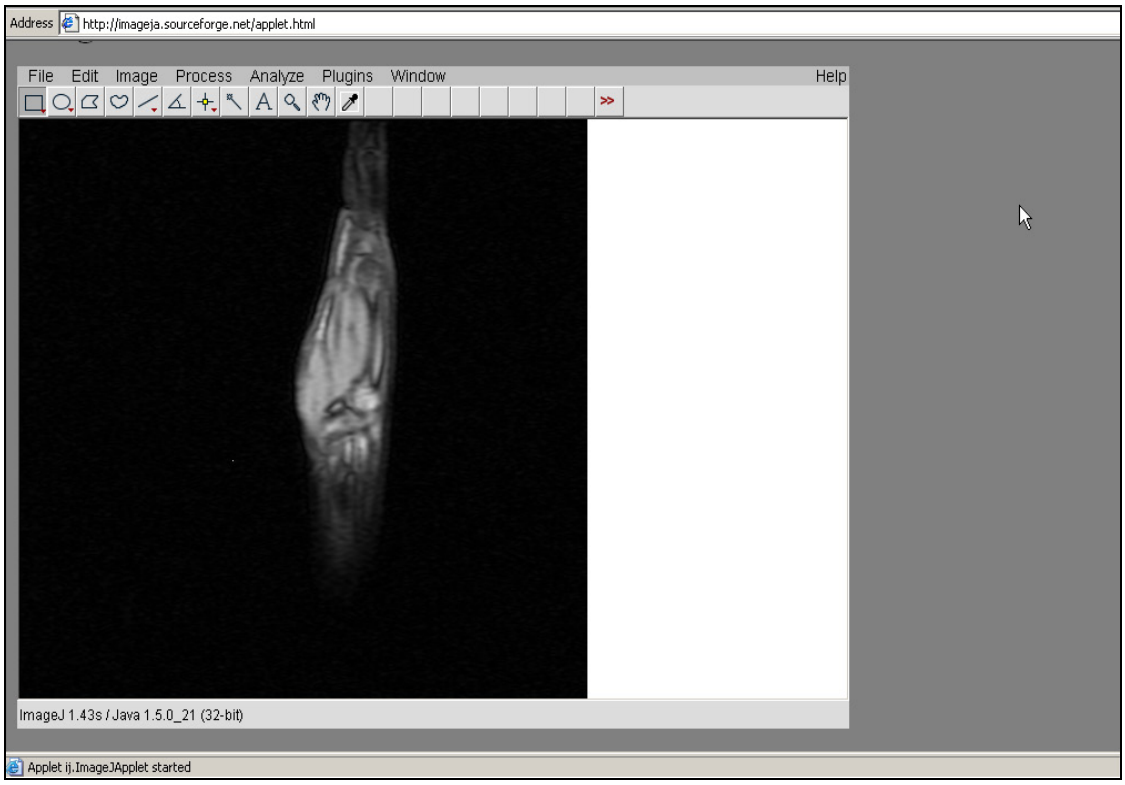

Figure 18 View Image in Image J

4.3 Summary

This chapter provides overview of the system in terms of functionality. Screen shot of the system are provided to describe various screens in web enabled health record system. The user interface can be enhanced to include customized names of an individual.

CHAPTER 5

CONCLUSION AND SUMMARY

5.1 Research Summary

At present most healthcare systems are built for the convenience of healthcare providers. Since the 1990s there has been a growing interest on increasing the involvement of patients in his/her own treatment. It helps in improving the quality of care. One of the means of doing that is to develop software that puts the patient in the centre while allowing the providers to carry on with their normal work habits. Electronic PHR is one possible solution to this challenge.

The concept PHR has traditionally been used to encompass systems that focus on the patients. Patient right includes access to the content in the record and determining who should be able to read and write in it. Additionally PHR offers functions that enable patients to contribute to their records and ensure better communication with healthcare providers. These functions are meant to stimulate patients' awareness and reflection, and finally give a better quality of care.

The inexorable increase in national health expenditures and the desire to improve the quality of health care are driving the widespread adoption of Healthcare Information Technology. Iterative, user-centered design helped improve the patient centric health care, leading us to refine portions of the initial UI before exploring additional features

suggested by the users. The UI will benefit from further evaluation using use-cases that represent uses by our user personas. Our findings will help develop a more user-centered PHR system much needed to empower patients to organize and maintain their health information at their own convenience and help them take control of their own health.

We have proposed a Web-based PHRS that can store data in a cloud-based architecture. The purpose of the proof-of-concept system is to highlight the capability of the functional framework. The prototype design is done with as little complexities as possible. The prototype of the framework presents the concept of the solution and demonstrates the feasibility of the solution. The proposed system provides an avenue to store images such as MRI, CAT, X-Ray and Medical personnel can view images with Image J viewer. A user case is discussed to show the functionality of the system.

Following is a description of how the solution presented in this paper resolves the problem areas identified:

a) The proposed system is web based and is built on J2EE technology which will enable users to access and share the medical health information from any place at any time with desired care provider.

b) Integration of healthcare information systems is a complicated task and full of challenges. This paper made a primary attempt

c) To effectively handle the large volume of medical imaging data system uses the open source DCM4CHE PACS system. PACS replaces hard-copy based means of managing medical images, such as film archives. With the decreasing price of digital storage, PACSs provide a growing cost and space advantage over film archives in

addition to the instant access to prior images at the same institution. Digital copies are referred to as Soft-copy. It expands on the possibilities of conventional systems by providing capabilities of off-site viewing and reporting. PACS provides the electronic platform for radiology images interfacing with other medical automation systems such as Hospital Information Systems (HIS), Electronic Medical Records Systems (EMR), Practice Management Systems, and Radiology Information Systems (RIS).

5.2 Future Work

The current state-of-the-art for PHR is at best characterized as 'beta releases'. They provide selective functionality and their usage footprint is limited As such, they lack the iterative cycle of software refinement on either the back-end databases or the user interface, that are required for the development of more polished systems. Nevertheless, they offer key insights into the process of trying to figure out, how such record systems should work? What information should be contained in them? Who will use them and for what purpose? How the legal and data confidentiality issues surrounding them would be resolved?

One of the goals of PHIMS is to allow patients to share their records with providers of their choice. PHIMS allows patients to maintain a permanent record of their consultations that can be used for future clinic and hospital visits. One of the main barriers to this goal is agreeing upon and implementing universally recognized digital identifiers for patients and providers.

It is clear that PHRs have the potential, if designed appropriately and adopted widely, to reduce costs and simultaneously improve quality and safety of care. This potential has led to enormous public enthusiasm for PHRs and large investment. However, the existing knowledge base that underpins this work is surprisingly limited and most of the fundamental issues remain unresolved.

CHAPTER 6

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