# Cloud Modeling and Electronic Medical Record Mining: An Integrated Approach to Improve Healthcare System

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# DECLARATION

We hereby declare that this thesis is based on the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

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# CERTIFICATE

This is to certify that the thesis entitled **Cloud Modeling and Electronic Medical Record Mining: An Integrated Approach to Improve Healthcare System** has been prepared and submitted by **Sumon Biswas**, **Anisuzzaman** and **Tanjina Akhter** in partial fulfilment of the requirement for the degree of Bachelor of Science (honors) in Information Technology on January 12, 2015.

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# ABSTRACT

Healthcare system can be enhanced vastly with the use of modern information technology. Still now in under-developed and developing countries, traditional paper based system is being used in healthcare. Although very few organizations use computer based system, they could not establish a ubiquitous network among patients, physicians and government. Cloud computing is the emerging technology which can be used to develop a heterogeneous network to improve the whole system. In this article, a three tier cloud based application eHealth Cloud has been proposed which will involve different parties to improve old-fashioned healthcare system. RIA (Rich Internet Application) based client, SimpleDB based server and a logic layer have been designed to build an easily accessible network. As a part of this system, one desktop application has been developed for the doctors and it is being used. Besides, smartphones are becoming popular everywhere now-a days. Using web services, android applications have been also developed for doctors as well as patients to make existing doctor-patient communication easier. Improvement of human computer interaction is very important to get better performance from this network. The research also proposes user stereotype modelling based on different contexts to improve healthcare application user interfaces. In addition, by using the eHealth Cloud, enormous electronic medical record (EMR) will be stored everyday. This huge size of data can lead us with new research opportunities. Data mining from the large amount of EMR has been proposed. The process of data mining, a standard for exchanging data and a mining model is described. Finally, the challenges and future research options are directed.

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# LIST OF ABBREVIATIONS

**RIA** Rich Internet Application

**EMR** Electronic Medical Record

**REST** REpresentational State Transfer

**IaaS** Infrastructure as a Service

**PaaS** Platform as a Service

**SaaS** Software as a Service

**SOA** Service Oriented Architecture

**URI** Universal Resource Identifier

**HTTP** Hypertext Transfer Protocol

**API** Application Programming Interface

**SMS** Short Message Service

**GPRS** General Packet Radio Service

**HCI** Human Computer Interaction

**ABE** Attribute Based Encryption

**TPD** Trusted Privacy Domains

**ORAP** Online Referral and Appointment Planner

**QoS** Quality of Service

# CHAPTER I

# Introduction

## 1.1 Overview

The healthcare system in the developing and under developed countries like Bangladesh, India, Myanmar did not come up with the power of information technology yet. In those countries, the medical services are not well furnished and integrated. Some private clinics and organizations are using computer based information system to keep track of their patients but no proper method is being followed for data sharing. Other than the hospitals, there are a lot of private practitioner doctors who give treatment in Bangladesh. So, the existing desktop based technology cannot adopt here. In this paper, a model "eHealth Cloud" has been proposed to build a common platform for the betterment of healthcare system. A patient centered framework has been designed where every patient as well as physician are registered. No doctor has to deploy his/her own information system. Rather he/she will just sign in to eHealth Cloud and become part of large healthcare network. Government ministry will take care of the rules and regulations. While treating a patient, the doctor will be responsible for patient's electronic medical records and other entries. Thus, all medical treatment will come under one umbrella.

Existing paper based system cannot accomplish us with modern medical facilities. The main problems are:

- No electronic medical data is stored for further use
- Doctors are not able to view patient's previous medical history
- Finding appropriate doctor and getting appointment
- Analyzing large amount of EMR data

- No heterogeneous communication possible among interested groups (e.g., doctors, patients, pharmaceuticals, health insurance companies etc.).

Many countries and healthcare providers are using EMR system to store health records for more efficiency, better patient care, patient safety and cost cutting [1] [2] [3]. Prospective benefits can come out from patient's basic information, diagnosis, lab tests, images, medical histories and prescription. Cloud computing is the comprehensive solution for storing the enormous data consistently and lowering the management cost [4] [5] [6]. Here, a three tier architecture for eHealth Cloud has been proposed

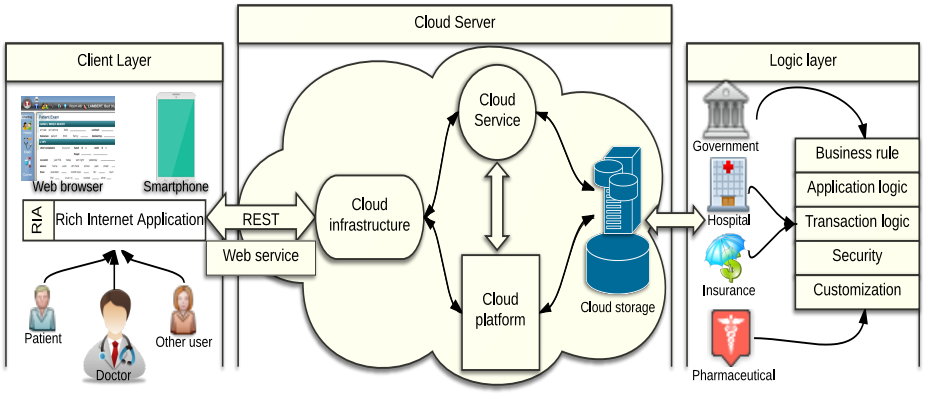


Figure 1.1: Three tier eHealth Cloud model

with proper functionality segmentation which is depicted in figure 1.1. First, RIA based client tier enables the users to interact with the system. RIA with script codes implement rich UI presentation for web clients. Since, smartphones are becoming popular and available everywhere, there are smartphone application which can interact with cloud. Second, the cloud server is simplified which maintains the database via Amazon's SimpleDB. Besides, it will provide the platform for government and third parties to integrate their services with the system. REST (REpresentational State Transfer) is used to establish the interface between RIA client and cloud server. The processor intensive jobs are offloaded to the cloud to reduce pressure on client devices. Third, logic layer resides between client and server that implements rules for the entire system. Web services, application logic, transaction logic, data security and other functionality rules are maintained from this layer. The government ministry will control this layer from top level with its own application. The third parties associated with healthcare like insurance, pharmaceuticals are also attached with the cloud via this layer. Here, the third party affiliations are preserved and updated

by the administrator. In chapter 2, the used technologies to build the network are described and in chapter 3, the implementation of application architecture has been outlined along with the developed desktop based application.

Human are somehow resistive to new technologies in sensitive issues. Specifically, the senior doctors don't want to use applications in their medical profession. The human-application interaction plays a vital role in this regard. An approach has been taken to analyze the user stereotypes and how they react in using mobile applications in their work. Chapter 4 describes those issues and based on different contexts and work environment. In the end chapter 4, the development process of two android applications is described. One is doctor-side application to maintain his/her profile and manage patient scheduling. Another one is patient side application through which the patient will be able to find any doctor and get appointment directly.

Important piece of medical data can be extracted from the cloud repository which has a far reaching value for improvement of healthcare system. Prediction of serious diseases, epidemics can be made by mining and statistical research on EMR [7] [8]. From the relational database, hidden patterns can be found by mining. This will open a great area of research [9]. In chapter 5, the data mining process and mining model using the EMR has been described. This huge amount of data storage and transfer raise challenges in the present context where the internet availability and speed comes into account. Chapter 6 describes the challenges in present context including data security and maintenance.

## 1.2 Objectives

Main objective of this article is to build a ubiquitous network which can connect doctors, general people, medical agencies and government. Eliminating the existing procedure, this article proposed cloud computing to acquire heterogeneity among the parties. Rich internet application has been proposed and one desktop application with two android applications has been developed. Further aim was to improve mobile user interface and human interaction with the applications. Large amount of medical data can be gathered and important decision can be made through data mining.

# CHAPTER II

# Cloud Computing and Other Technologies

Web is the most powerful platform today. Internet based web applications are being built with the use of modern cloud computing. To build a three tier eHealth Cloud, cloud computing has been incorporated with RIA, web services, REST and SimpleDB.

## 2.1 Cloud Computing

Cloud computing is becoming an easy solution for delivering complex service and data interchange method over the internet. Already it attracted worldwide attention providing services like Gmail, Google Docs, Dropbox etc. Fast data access over a ubiquitous network and cost effectiveness made cloud computing one of the most growing internet technology. It has been developed as an extension of grid computing where resources and services overlay on the hardware infrastructure. Generally, cloud computing applications can be developed using internet technologies i.e. HTML, CSS, PHP, AJAX, .Net, SOAP etc. In the third world countries like Bangladesh, there are several limitations (e.g., establishment, availability, communication) for the standalone existing applications where the huge population is lagging behind with technologies. Cloud computing can solve these problems as well as encourage people to involved with the system. Proposed cloud computing model enables appropriate and on-demand access to a pool of computing resources (e.g., application, service, storage). The access is easy, fast and requires minimum management effort [10] so that the model is very useful in the country like Bangladesh. Cloud computing is categorized into three according to the service it provides: infrastructure, platform, software.

**1. Infrastructure as a Service (IaaS):** IaaS uses virtualization technology which allows the cloud to deliver multiple virtual machine on the demand of user. The user gets the machine as his/her own and install OS or other application as needed. Different virtual machines run on the cloud infrastructure simultaneously with abstraction. Users can extend or reduce the usable resources (storage, processor) which eliminate the buying cost [11] which can be useful to support a large population.

**2. Platform as a Service (PaaS):** Users can easily use resources and develop their own application on the service provider's platform. With the use of PaaS, the facilities of IaaS can be utilized without installing OS or maintaining the infrastructure. The users can use the given platform tools (e.g., Apache Server, MySQL Server) provided by the CSP [12] [13].

**3. Software as a Service (SaaS):** Users don't need to install or develop any application to use this kind of cloud service. The users have no control on the underlying infrastructure. They only customize and use provided software services as by their requirements. The privileges of SaaS are the flexibility of the cloud and dramatically lower cost [14] [15].

The basic advantages of cloud computing are:

- Resources are scalable and charges on current use
- Best use of resources
- Users need not to know the internal structure of infrastructure
- Cost efficient
- Fault tolerance and data recovery management is easy
- Processing intensive jobs can be offloaded to the cloud so that users need not highly configured machine.

## 2.2 Service Oriented Architecture (SOA)

A service is a set of business functions and functionality that connect with applications via interfaces. In computing, service means information or functionality which serves the applications. The services do not interact with human rather servers and applications. However, SOAP is the protocol for traditional SOA which is not web oriented. Whereas, REST is the competing technology to use for web based systems. Therefore, in this proposed model, REST has been used as the service oriented architecture for eHealth Cloud.

## 2.3 Representational State Transfer (REST)

Representational State Transfer (REST) is a software architecture for distributed systems like web [16]. The World Wide Web (WWW) has changed and adopted new features with the evolvement of Web 2.0. Internet connectivity is now spreading everywhere through broadband, Wi-Fi, mobile-internet and rural areas are also connected via WWW. REST is designed for Rich Internet Application (RIA) on Web 2.0. REST has gained popularity for its simple interface and light weighted behavior. All the data and functionalities in REST are considered as resources. The resources are identified by Universal Resource Identifier (URI) thorough which well-defined operations are performed to establish a stateless communication protocol such as HTTP. Data exchange is made easy with XML or JSON with an architectural design of client server paradigm without additional messaging layer. The rich clients interacts simply with the server via HTTP which eliminates the use of SOAP. RESTful applications are high performance for its adaptability with other web 2.0 components. In this eHealth Cloud architecture, REST has been used to maintain a persistent communication between the RIA client and SimpleDB based cloud server. eHealth Cloud will deliver APIs to third parties to retrieve and update EMR via REST.

## 2.4 SimpleDB Cloud

SimpleDB is a cloud database services provided by Amazon. Web apps can store data, run query or process data on SimpleDB. The facility is: there is no burden of schema maintenance, indexing or other administrative operation on data. It is done automatically. The developers only use the cloud platform for database management and pay on exactly how much they use. Any core data operation such as querying on structured data can be performed via web. REST is used for the data access on SimpleDB. It reduces complexity and APIs can be used to access on database from different applications.

# CHAPTER III

# Three Tier Cloud Architecture Implementation

Traditional cloud application development methods are complex regarding design and architectural segmentation. The main reasons are:

- inappropriate cloud architecture
- Computation is not performed in the appropriate machine so that system becomes inefficient
- Application logic is entered on the client side
- No top level administration control over system
- Technology features are not fully utilized.

Addressing these problems a three tier architecture for healthcare system has been proposed. Since, the healthcare in third world countries is still a legacy, government ministry involvement and proper functionality segmentation is needed to bring the whole system under a single umbrella. Computational burden from the client side have been offloaded to the server so that less powerful machine (e.g., tablet PC, smartphone) can run application modules.

eHealth Cloud architecture proposes patient centered framework where every patient will have account with his/her basic information. The registered doctors will have also accounts on eHealth Cloud. While giving treatment to any patient, the registered doctor will open patient's account if he/she has no account. Thus, gradually everyone will have account. Doctor will access the patient's history through patient identification number. The client tier provides a rich UI for the users (doctor, patient) to interact with the systems whereas the logic tier implements rules for applications and provides UI for administrators (i.e., government ministry, hospitals). Both the

two tiers will offload their computing burden as well as data to the cloud layer. The different types of applications for different users are shown in figure 3.1. Both web browsers and smartphones will be used for accessing the eHealth Cloud. SimpleDB

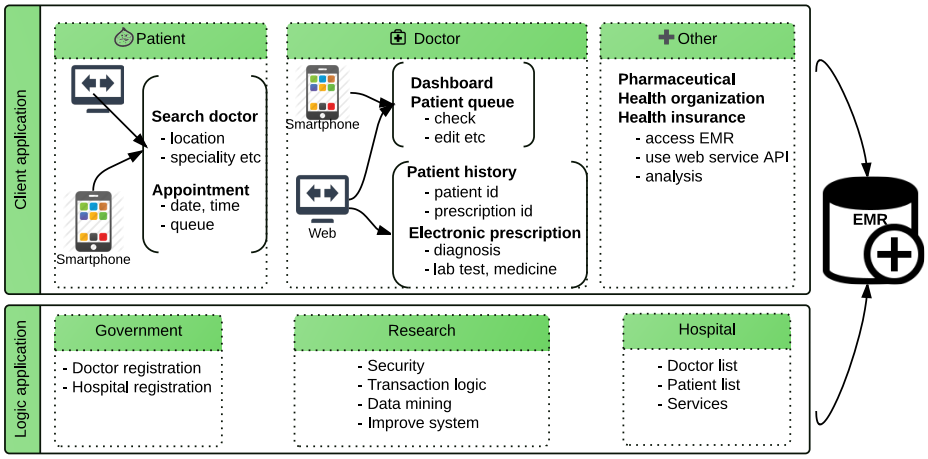


Figure 3.1: Categories of application for users and administrators

database is responsible for storing and manage large amount of electronic medical records (EMR) in eHealth Cloud. The communication between the cloud layer and other two layers are established through REST. Web service APIs are used to access cloud resource and operate on them. In the client layer, the basic functionalities are handled where the logic layer performs administrative and research functions. The layers are connected to EMR database which becomes rich day by day.

## 3.1 Patient Side Application

The patients need to find appropriate doctor, take appointment and get the medical services. There will be registered doctors enlisted with doctor code and doctor's details. From there, the patient will apply for appointment. If the doctor's patient queue is not full, then the patient will get appointment. Since mobile phone is the easiest and must have device in rural areas, the appointment system can be handled through mobile phone SMS shown in figure 3.2. The web application of eHealth Cloud will give different interfaces for doctors and patients. Every patient will login to the system with his/her patient ID. He/she can see his/her previously taken medical services.

The patients are also able to use their patient ID to purchase medicine or taking any medical services from hospitals or medical centers. If the medical center is

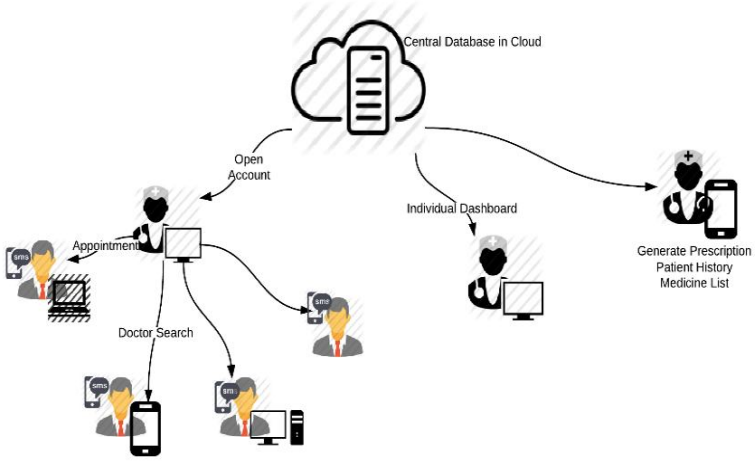


Figure 3.2: General view of doc-patient interaction with cloud

government allowed, then they can access the EMR and see medicine list, medical history, lab tests etc. This central EMR can be a ubiquitous application database which will bring a great change in healthcare.

## 3.2 Doctor Side Application

The government registered doctors will sign in to the web application and get their own dashboard. The dashboard contains the doctor's basic information with his/her qualification, institution, specialty and schedule. For a particular patient, the doctor will check the patient has a patient ID or not. If the patient is a new one to treat the doctor opens an account and proceed. Otherwise, the doctor goes to the patient's details and previous treatment information with the patient id. Figure 3.3 depicts the sequence diagram of doctor-patient interaction in eHealth Cloud. It's possible to ensure PC for every government registered doctor and through this all patients are becoming the part of the system as well.

Electronic prescription is the most important part of doctor side application for go green march. The prescription contains the diagnosis, current health condition, lab tests and medicine list which will make a huge amount of data repository in the cloud. EMR repository will store all data for administrational purpose. Figure 3.4 shows a prescription generating window.

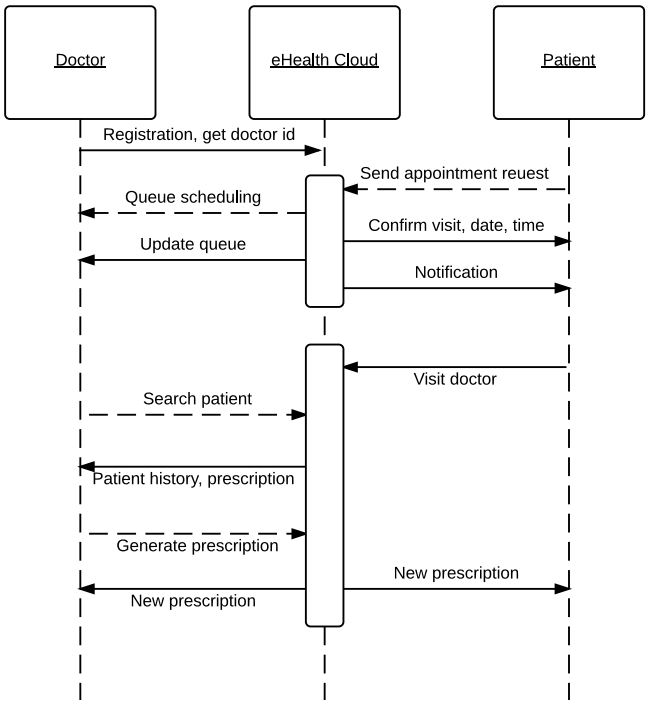


Figure 3.3: eHealth Cloud sequence diagram

## 3.3 Administrative Application

Administrational applications are the most important part in implementation and maintenance. In third world countries' present context, government hospitals, private clinics and a lot of private practitioners give treatment without keeping any proper record. So, the system has been designed in such an administrative manner that government health ministry controls the system from top level. The web application logic layer gives interface for government. The government ministry gives accessibility to the doctors and third parties to access EMR. The research with the EMR is maintained and performed by the administrational layer application. Different complex queries can be performed which will search and show structured data from SimpleDB.

## 3.4 Application Development

The aim was to produce a demo system and deploy on doctors' computer. So, a windows application software has been built which will be installed on doctors' computer. This software is a standalone one and can be maintained by one single doctor.

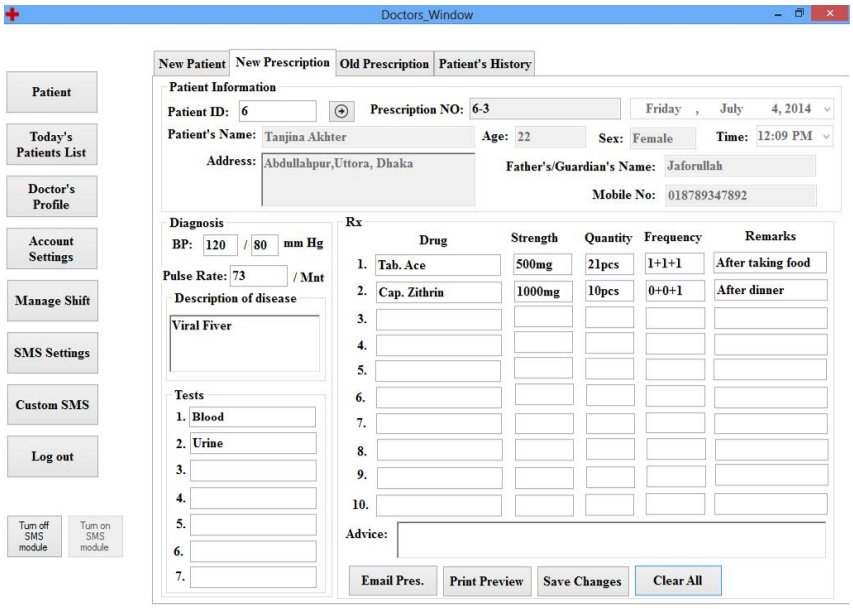


Figure 3.4: Electronic prescription generation window

The doctor will enter every patient's information and generate prescription using this software. Then the prescription can be printed and handed over to patient. One copy electronic prescription will be sent patient's email address as well. The appointment system will be maintained by the system using SMS. Two basic operation are handled by the software:

1. Electronic prescription module
2. Patient scheduling and queue management using SMS

### 3.4.1 Electronic Prescription Module

This module makes the whole prescription generating system easier. The doctor can use the prescription module on the software to diagnosis and prescribe patients. A large medicine table is included so that while writing medicine the software will suggest matching medicine. The prescription is saved and can be printed. One copy is mailed to patient's email address. The can view any patient's previous all prescription entering the patient id. The features are:

- Electronic prescription handling
- Medicine suggestion
- Store all prescription

- Print prescription
- Email prescription.

### 3.4.2 Patient's Scheduling and Queue Management Using SMS

Short message service (SMS) is the most easy and convenient way for the patients to make appointment. The patient will write a keyword, his/her age and name and sent to the doctor's number. The scheduling system will keep track of every SMS and send a confirmation to the patient specifying the date and time. A patient calendar is maintained by the scheduling system to find empty time space for appointment. A GPRS modem is used to receive and send reply for the message. The doctor will be able to send a custom SMS to the patients using the system. A sequence diagram has been shown in the figure 6 below to describe the interaction.

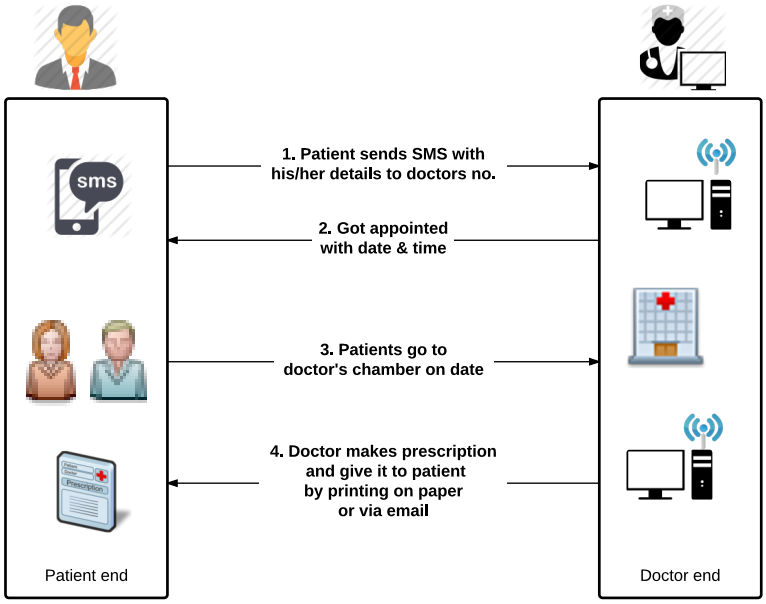


Figure 3.5: Interaction between doctor and patient

Features of this module are:

- Male appointment sending SMS
- Reply sending date and time to patients
- The system maintains the patient list and calendar
- Any greeting or emergency message can be sent to the patients.

### 3.4.3 Used Tools and Technologies

This is a windows based application developed on .Net Platform. The windows form is built on Visual Studio 2012. SQL Server 2008 is used for database support. Here are the technology specifications:

1. Visual Studio 2012
2. .Net 4.5
3. C#
4. SQL Server 2008.

**1. AT Command:** AT commands are used to control GSM or GPRS modems. This command can be executed by the modems to perform particular tasks like sending SMS to a number, receiving and save message to SIM memory, deleting SMS etc. Actually, it performs operation on the SIM which is mounted on the modem. The command can connect modems to specific ports of the desktop computer and perform tasks. C# language was used to manipulate the AT commands.

**2. Crystal report SAP:** There are different crystal reporting system which can be installed on Visual Studio to provide report querying from database. RDLC, SAP are mostly used. Electronic prescription reporting is provided by SAP Crystal Report 13. The SAP Crystal Report allows one to generate prescription, save as PDF format, and print report.

## 3.5 Case Study

Suppose, in the district of Netrokona, an eye specialist named Dr. Atik Hasan uses the software to maintain patients and prescribe medicine. He installed the software on his PC and connected a GPRS modem to integrate SMS gateway for patient scheduling. He enters his profile, speciality, visiting time and time needed for a patient in the software and proceeds. Figure 3.6-3.9 are those user interfaces for a doctor to set up his/her profile.

### 3.5.1 Case 1

Suppose, a man named Ruhul Amin who is a Govt. officer want to visit an eye specialist for major problem occurred in his eyes recently. He has less time in his hand to find a doctor and visit him. The procedure he has to follow is, he has to


Figure 3.6: Login form for doctor

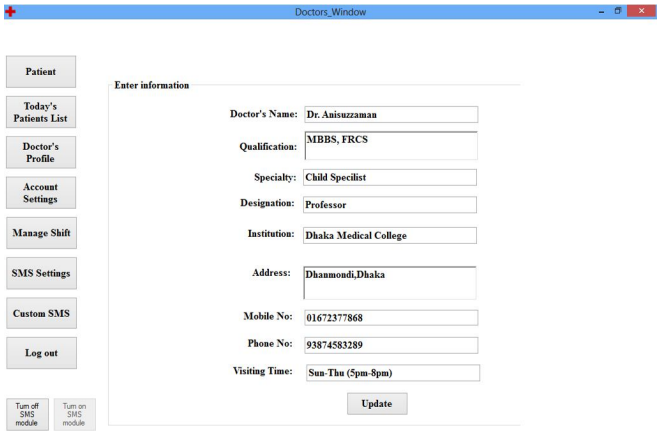


Figure 3.7: Edit doctor's information form

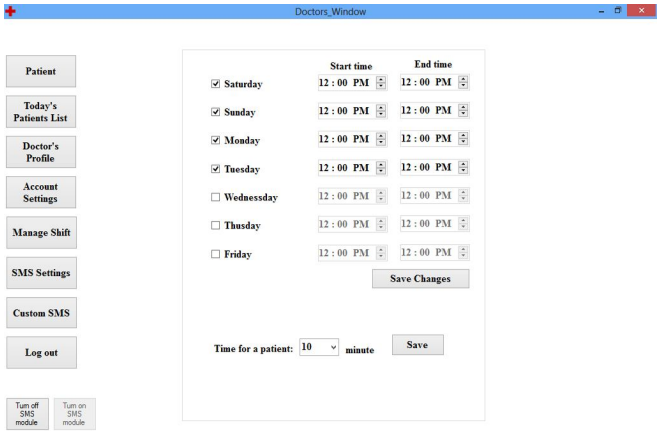


Figure 3.8: Doctor's shift management

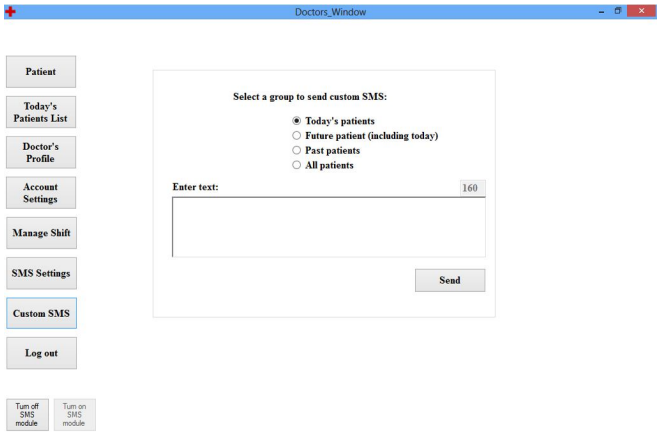


Figure 3.9: Sending custom SMS to patients

go to local hospital for doctor's information or listens to someone for it, go to the doctor's chamber for the appointment and go to doctor for the treatment. The doctor also has no facilities like check patient's previous data, patient's digital information storage for further use.

But using the software, Mr. Ruhul Amin will collect the doctor's mobile no and send an SMS for getting appointment. Instantly, he gets the appointment by the automated queue management system. On the date he visits the doctor. The doctor first, checks that he is a new patient for him. So, he opens a new account for the patient where patient's all basic information is stored. Then the doctor prescribe medicine, print prescription, handover the hardcopy as well as an email to patient's address. The application interfaces are shown in figure 11-14.

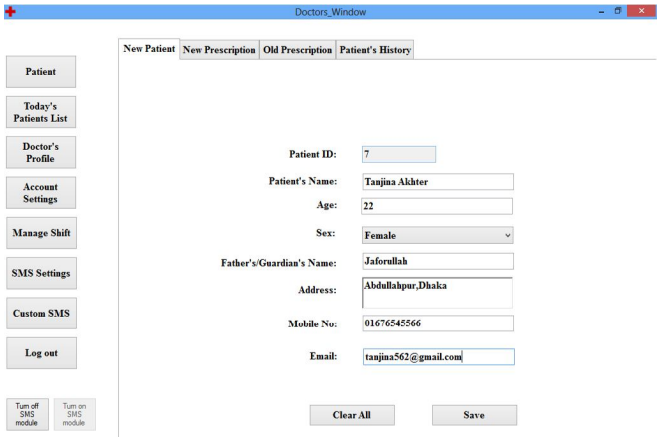


Figure 3.10: New patient entry

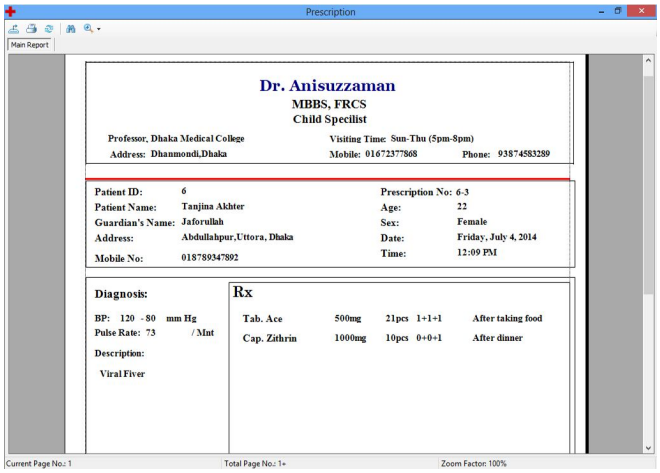


Figure 3.11: Prescription printing screen

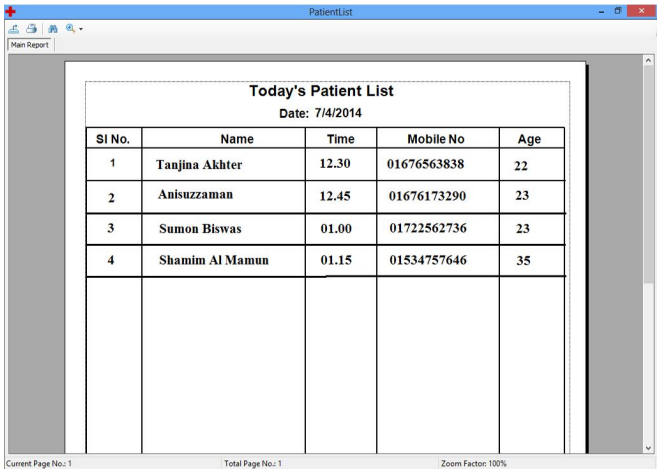


Figure 3.12: Everyday's patient list

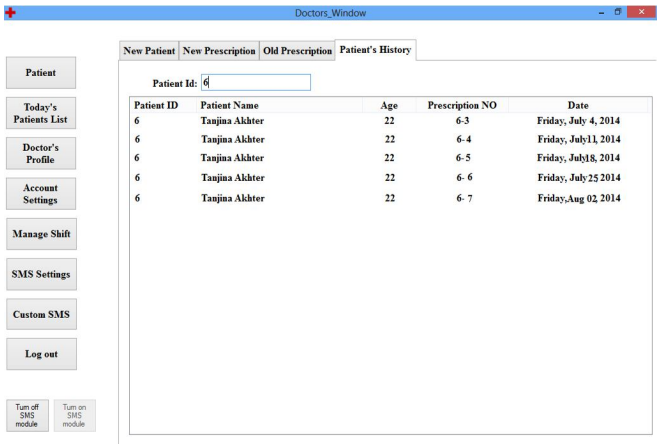


Figure 3.13: One patient's previous prescriptions

### 3.5.2 Case 2

Suppose, Mrs. Tahmina Akhter is a school teacher who remains busy all day with students. She got infected by throat infection for heavy work and wanted to visit the doctor Dr. Ahmed Kader whom she visited previously for typhoid. So, she sends an SMS and gets appointment easily. On the visiting date, she goes to the doctor and doctor asks her patient id. With the patient id doctor gets all information of her and got the list of medicine prescribed before as well as the other prescription. From the history the doctor gets the idea to prescribe this time.

# CHAPTER IV

# Characterizing Context and User Stereotype for Mobile User Interaction

For the last decade, the mobile computing technology has been growing very fast and pervasive way through the smartphone apps and web. The proposed healthcare system tries to improve the sector using the cloud computing technology by the mobile users so that the actors can get services from anywhere. In contrast to traditional desktop based applications, this applications will be much helpful for the physicians, hospitals, government and other people. However, the medical professional do not tend to adopt newer technologies quickly because they are very aware of the risk or uncertainty in medical treatment. Still a gradual shift is occurring in healthcare to adopt technologies and medical professional are being interested in using mobile applications.

Since, the mobile technologies (e.g., smartphone app, SMS, MMS) can bring revolutionary change by data, voice or imagery communication in healthcare, the adoption of these technologies to the medical professionals and the general people is more important. Therefore, human computer interaction (HCI) is very important issue while building the applications. The developed desktop application shows us that, one of the usability challenges for using healthcare applications in hospital context is errors in data while generating or retrieving information from the system. The reasons are: 1) inappropriate human computer interfaces regarding the user and his/her context, 2) number of steps to retrieve information. The proposed model of "eHealth Cloud" consists of both computer and mobile based applications which are connected to the central cloud. Desktop based applications are easy to design and maintain for its stationary nature. Unlike desktop applications, the mobile applications need more consideration from HCI perspective. This section of the research conducts with the MUI design modifications based on the context it is used. The adoption of MUI

sources, like sensors, features, widgets in recording and accessing information depends on the context and user stereotype.

In this Chapter, investigation of the use of smartphone and different user stereotypes in hospital environment is done. This stereotypes can play an important role in designing the proper MUI because various categories of doctors based on age, domain experience, smartphone experience need different UI for better performance. A User stereotype model has been proposed that can categorize the doctors. This research introduces characterization of context modelling that is related to the users of the smartphones. Last section of this chapter describes the implementation details of the developed android applications named "Doctor's Window" and "Patient's Window" for the user groups doctors and patients respectively. Here the experience of using these applications in real life have been analyzed which is very important for the research.

## 4.1 Stereotyping Users

Several techniques proposed by Human Computer Interaction (HCI) researchers exist to understand the users and their need. Persona [17], archetype [18], user profile [19] are some techniques. All of them have some strengths and limitations. This research uses stereotype based user model because this is the natural categorization of people [20]. Creating stereotypes is an inherent activity of human that is used to generate knowledge internally [21]. For example, when we meet people we compare them with similarities and dissimilarities with ourselves and others. The goal is to provide appropriate MUI for a particular stereotype user. So, users should be categorizes in some groups. The aim is to maximize the difference between two stereotypes as well as minimizing the distances between users of same group.

## 4.2 Proposed Stereotype Model

For stereotyping is done among the doctors of Bangladesh. Here, the following characteristics have been considered:

- User age group or gender
- Experience in his/her domain
- User behavior regarding mobile application adoption

- User preferences

Figure 4.1 shows that junior doctors are expert in using smartphone while they have a little experience in their domain [22] . In contrast, the senior doctors are experienced in their domain whereas they are novice in mobile application using.

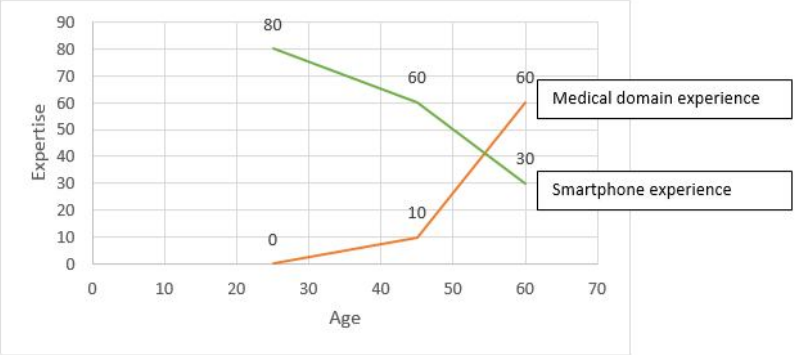


Figure 4.1: Comparison of smartphone and domain expertise among doctors of different ages

### 4.2.1 Stereotype 1: Junior Doctors

Junior doctors belong to the 25 to 34 year old age group and having very little experience in medical practice. They are very friendly with their smartphones and familiar with most of the feature. They spend more time with their smartphones. They like to play and maintain lifestyle with it. The featured apps like map, GPS, social networking is used by them. These junior doctors are tolerable to newer applications. They want to maintain the scheduling of patients, electronic medical recording, getting information regarding patients and medicines by their mobile phones. Almost all the input and output features are used by them in all situation. They are also quick in taking action with their smartphone in a correct way.

### 4.2.2 Stereotype 2: Intermediate doctors

Intermediate doctors are in the 35 to 45 year old age group. They have at least 10 year experience as a medical professional. They have all basic knowledge about smartphone platform and how it is used. But they are somehow resistant to newer applications. They do not want to use smartphones in dealing with sensitive medical data. However, this doctors want easier and not multi-functioned mobile applications for their use.

### 4.2.3 Stereotype 3: Experienced Doctors

Doctors belonging to this group are above 45 year old age. They have vast experience in their medical profession and have a little knowledge about smartphone platform. Though some of them use smartphones, they do not want to use the applications in their professional work. They don not spend much time with. Some of them refers to use IS by other assistants rather than use themselves. However, a few of them are interested in using mobile application but not in handling sensitive medical information.

## 4.3 Characterizing Context

In information system design, context is comprise of the environmental parameters which are responsible for achieving goals in software engineering. The design of MUI depends much on the context. For example, it is important to know when the application is used and in which location. There are various way to input data in the application. In all contexts typing the data may not be efficient. Voice or image input can be necessary in some conditions. Here, assumption is a hospital environment and a doctor is giving treatment to the patient using smartphone application.

Table 1 shows the different methods based on different context environment. This comparison is for stereotype 1 that is junior doctor. Various tables can be built for other stereotypes as well. The selection rule depends on the context variables. For example,

IF [C1] is a match, Then ADAPT MUI features which belong to Method 1 ELSE IF [C2] is a match, Then ADAPT MUI features which belong to Method 2

## 4.4 Android Applications

Among smartphones, android is the most popular and available platform. In Bangladesh, it has also spread a lot in cities and villages. There are many android phones and tablets of different configuration and price in market. So, for doctors and patients of all categories, android will be the best option. In figure 4.2, the application structure has been depicted. Both the android apps connect to the central app server via internet. HTTP request is made for particular information. The server script is run and query is generated for the database. Then the database is updates or send response to the app server which in turn formats the response and send the data in JSON format. This JSON data is received by the application and parsed to display

information in the app screen. These two android apps are developed for maintaining the appointment scheduling easier and quick for both the doctor and the patient:

1. "Doctor's Window""
2. "Patient's Window""

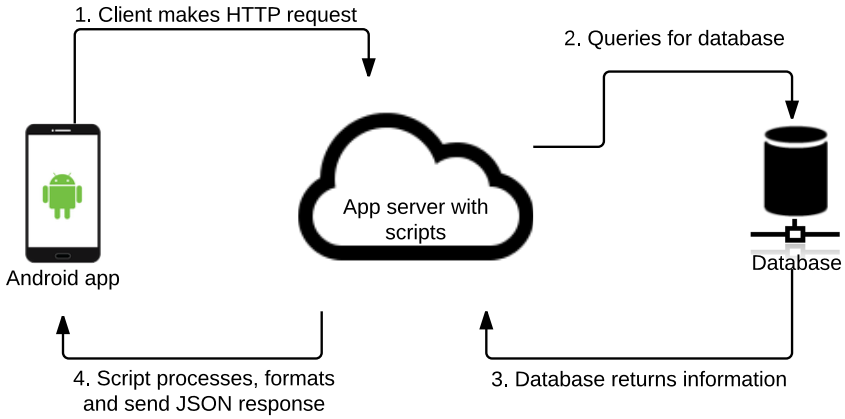


Figure 4.2: Android application interaction with server

### 4.4.1 Doctor's Window

This application runs on doctor's mobile android phone or tab. Every doctor has create account with his/her email and user ID. When the doctor created an account with the system, he/she is taken to the profile update form. Then the doctor enters his/her name, designation, specialty, institution, address, contact number and the visiting time to complete the profile. Once profile is completed he/she can login to the app and see his own patient's list by date.

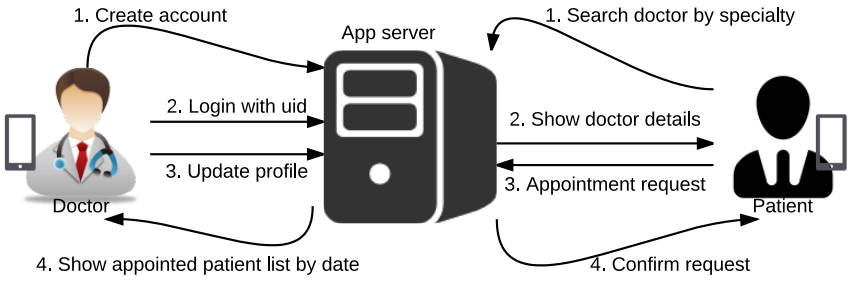


Figure 4.3: Application activities

### 4.4.2 Patient's Window

This application runs on the client's smart devices to connect the desired doctor. No login or registration is required for this app. Anyone using this app will easily find different categories of specialty. Then he/she will be able to find doctors from different localities. The patient will choose doctor and see doctor's detail information. Then he/she will click the "Get Appointment" button to seek for appointment. An automated scheduling system will run on the app server based on the doctor's predefined time. This will check for free space and make the patient known about the appointment date and time. Eventually, the app will notify the patient before the appointment. Only one has to enter name, age and phone number for seeking appointment. Figure 4.3 depicts the activities done by both the applications.

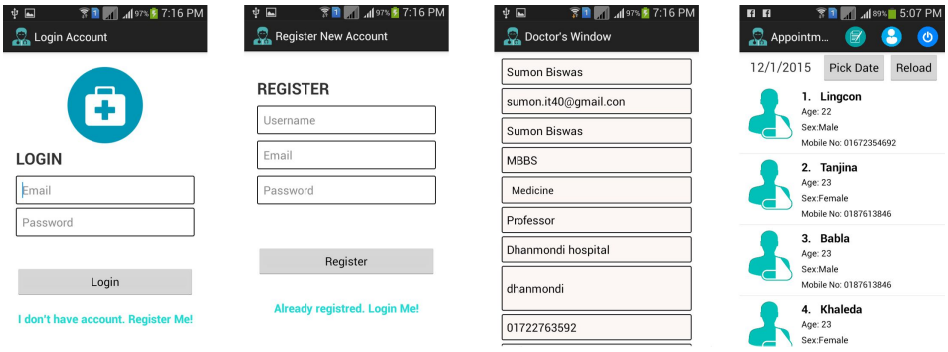


Figure 4.4: Android application interface for doctors

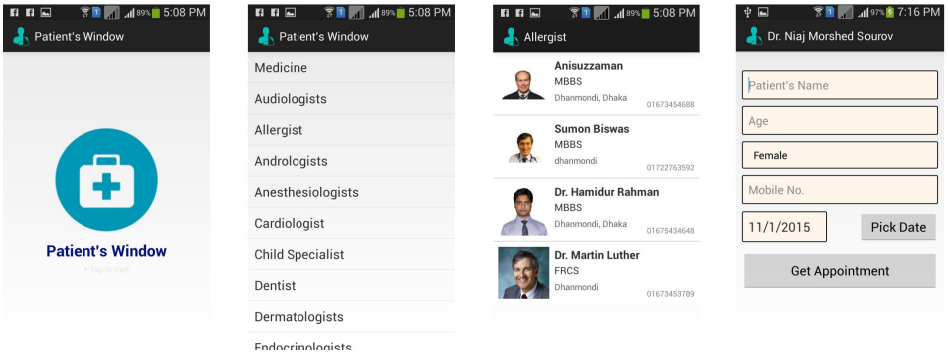


Figure 4.5: Android application interaction for patients

# CHAPTER V

# EMR Mining

Data mining is the method of analyzing large set of data and find hidden pattern from them to generate useful decisions. Today is the age of information. Everyday enormous data is generating from which valuable information can be extracted. Summarizing data from different perspectives, a particular field can be improved a lot. Data mining software helps us to find correlations or patterns among dozens of fields in large relational database. eHealth Cloud will generate large amounts data of patients, doctors, hospitals, disease, diagnosis, medicine, lab tests etc. This large amount EMR will be a key resource to be analyzed and processed for knowledge extraction and enabling decision support regarding cost, benefit, feedback. In this section, a data exchange standard has been proposed through which a proper EMR would be built. And then, the method of mining has been showed and finally a data mining model has been described for healthcare.

## 5.1 Standard Data Exchange Method

This study proposes Health Level International (HL7) which is a widely accepted method for implementing EMR. Several nationwide organization adopted HL7 to set standard for managing, integrating and exchanging electronic medical record in healthcare applications [23]. Different users and applications use HL7 web service

to interchange documents in a well-defined format so that the sharing of healthcare information becomes efficient [24] shown in Figure 5.1. EMR creates a service layer in the eHealth Cloud that serves medical information according to accessibility. The health organizations will be able to build communication based network using HL7. This service oriented strategy makes EMR enriched and usable simultaneously.

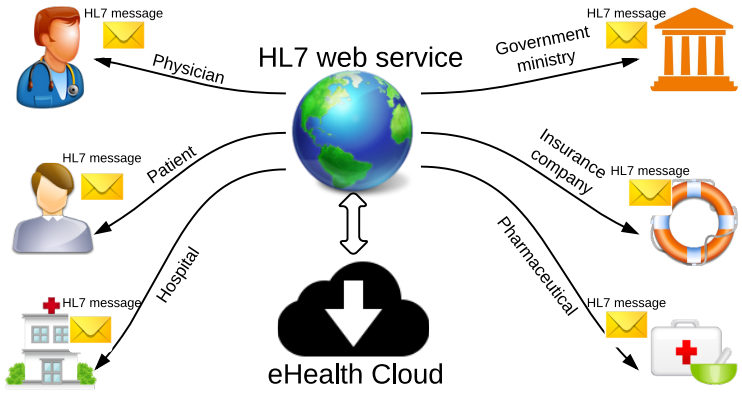


Figure 5.1: HL7 web services

## 5.2 Data Mining Method

Data mining is an algorithmic way to find and extract information from raw data. Generally large database cannot give us useful information but when we look deeply and analyze it, there can be something valuable. Suppose, we have seen x (set of independent variables) and observed y (dependent variables); then we can calculate y = f(x). Data mining can tell us about the nature of f. Here, x = symptoms or tests result, y = diseases; or x = treatments, y = symptoms. Then question is, how is x related to y? What function describes the relationship between x and y? Hence, f(x,y) = score, or $f(x|y) = Pr(x|y)$. Data mining does not directly explain why but shows the previous results probability to make decision. It helps physicians or patients to figure out historical background of a particular disease and make a decision. Besides, the government can take step to for a regional or seasonal disease.

Kuttikrishnan et al. proposed a model form data mining to assist physicians at the point of healthcare [25] depicted in figure 5.2. Neural network technique is used for this model. The knowledge base is the eHealth Cloud database. An inference engine is needed to combine the rules and patient's data. The system to user communication helps to build the mechanism of mining. The large number of data create neural network which works on the basis of artificial intelligence. Several layers including input layer, output layer and undefined hidden layers build the neural network. First,

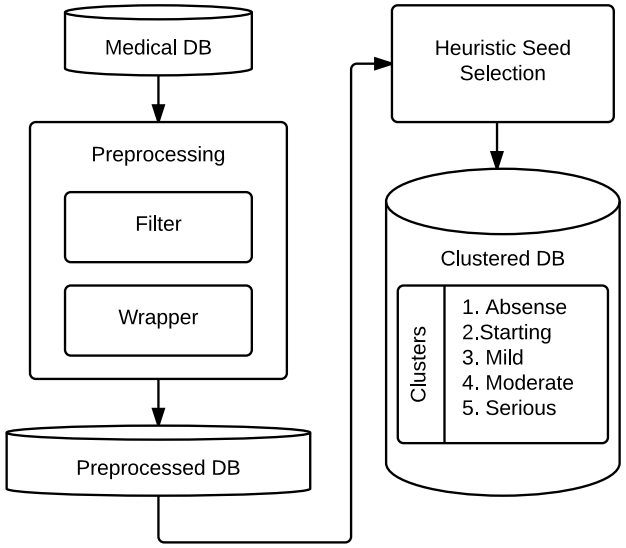


Figure 5.2: Kuttikrishnan et al model block diagram

at the preprocessing and symptom identification stage, text to XML conversion and indexing are done. Then, the feature selection, ranking and pattern mining are done. Afterwards, the symptom and model based dependencies are identified. Then the aggregation of symptoms are made. Finally the model based comparisons and comment classification are done. The dominant and unique feature is identified to make important decision.

## 5.3 Security and Privacy

The creation and maintenance of EMR in eHealth Cloud should preserve authenticity, privacy and integrity. All data storage, transmission and access should be secured. Security arrangement will be accomplished based on the country, culture and social aspects along with intrinsic cloud security offerings. One way to deal with the risks is to allow the patients for selective sharing of their EMR data [26]. In lieu of encrypting data by cloud, the patients will generate their decryption key using attribute based encryption (ABE) for authorized users. Though this method does not address privacy exposure to the cloud, the computation overhead and privacy expertise is required by the patients which is difficult. A technical solution described in [27] proposes transferring medical data to mobile storage which takes away security control from the user end and cloud as well. The approach is to construct trusted privacy domains (TPD). The data communication between cloud and any other parties will be supervised by the TPD. A secured gateway in TPD will automatically encrypts data. While storing data in cloud or any external storage, TPD ensures the data privacy. Another way proposed in [28] is to take security measure while data generating in the doctor's end. EMR leaves the physician's end with encryption and signing. The online referral and appointment planner (ORAP) transfers information to other users. Since the patient's end is not considered as a secure environment, in this model the patients can not access data from their home. However, ORAP model does not secure patient centric functions and only secures the transfer of EMR.

# CHAPTER VI

# Challenges and Future Work

## 6.1 Challenges

**1. Security:** Multiple cloud providers as well as many healthcare organizations will take part in eHealth Cloud. Different parties will interact with different resource pool. Therefore, a proper security mechanism is a challenge to maintain data persistence, integrity, confidentiality and availability.

**2. Data management:** A lot of structured and non-structured data will generate continuously in eHealth Cloud. Database should be replicated to different locations and geographical distances for higher reliability and better access. All data should be error free because it matters a lot to the users of it. In spite of any hardware or software failure data should be persistence constantly.

**3. Scalability:** Always the users and connecting devices are increasing. So the system should be able to scale itself to the requirements so that no failure is occurred in case of traffic. Moreover, there may open new window to be added to the system for better service.

**4. User experience and usability:** People of various walks of life are the users of eHealth Cloud. Different kind of specialists, people from various educational background, cities, and towns will come under the umbrella. So, proper and adequate pre-implementation training along with post implementation training is important.

**5. Maintainability:** A large scale system development is not completely finished. Unlike a single organization system, this is difficult to maintain different parts and mechanisms. Cloud resources and services must be designed for reliability and quick maintenance. To provide error free services to lot of people and different organizations, perfect testing models should be developed for reducing maintenance time.

**6. Flexibility and interoperability:** Organizations and people will expect various functions, operations and services. So, the Quality of Service (Qos) requirements will have to be maintained. Adding new services to the system should be flexible and require minimum effort and cost. Along with the quality the cloud service providers will agree on some open protocol and framework for secure information exchange. Easy data migration and a good degree of interoperability between local and external clouds is necessary without having to worry about underlying structure.

**7. Legislations and data ownership:** There is no clear laws and guidelines for using clinical data in business or e-context right now. Therefore, the stakeholders in eHealth Cloud will face problems for policies to establish ubiquitous network from social and ethical view. Besides, though patient's record is an exclusive property of patient, the physician, the hospital, and patient's insurer can also claim that. Patients data classification and sharing among different parties arises challenge.

## 6.2 Future Work

Theoretical and applied research can be performed for reaching higher optimization. In future, this model can be incorporated with other domain like education, finance. The third party services like map, GPS can be included in the system. Wireless sensor network in the healthcare organization can be made with the help of eHealth Cloud. Moreover, this model of eHealth Cloud should be more accurate with proper security mechanism.

# CHAPTER VII

# Conclusion

eHealth Cloud can change the existing healthcare system to a new dimension. Cloud computing gives us the opportunity to bring all doctors and patient in the network. The enhanced communication and automation will make the desired healthcare for the government. The conventional thinking of treatment can be fully changed by analyzing the EMR in a broad sense. The position of general people will be strengthened by bringing the healthcare in hand. Data mining technology will make the condition easier to protect ourselves from diseases, epidemics and unusual deaths. Government along with its people and physicians will improve the whole healthcare system using eHealth Cloud.

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