Design and Implementation of Web Based Telemedicine System using Service-Oriented Architecture (SOA)

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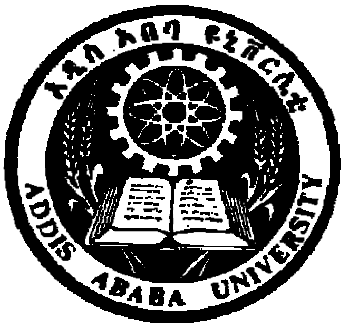

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By

Amanuel Degu

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Amanuel Degu

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Abstract

The advancement of Information and Communication Technology (ICT) has forced its employment in healthcare services. Exchange of medical information from one site over network followed by medical care is improving the quality of healthcare service provision. Teleconsultation as one of applications of telemedicine is used to improve patients' health status by letting health professionals consult specialists.

This project deals with designing a simple store-and-forward telemedicine system operating on the existing network infrastructure. This provides a messaging platform whereby text messages are used to convey patients' case. In addition to the messaging service, the system enables users to share documents. Since there is no a comprehensive mechanism that could help professional refer, this feature of the system is of paramount importance.

The major challenge of using ICT applications in healthcare services is how to integrate different components from various vendors. This project uses the service-oriented architecture implemented using web services to enable seamless integration and easy extensibility of the system.

Chapter 1 Introduction

1.1 Background

In Ethiopia, where the number of health professionals is very small, the quality of health care is undoubtedly low. According to the Federal Ministry of Health (FMOH) report, there are only 2085 physicians throughout the country serving the entire population which is more than 79 million [1]. Patients need to travel long distance to get basic healthcare service. Most of the health professionals in the country are tending to work in urban areas and hence the rural community is suffering a lot in getting better healthcare service.

Like other sub-Saharan Africa nations, the healthcare provision in Ethiopia is characterized by its low level. Moreover, it experiences heavy burden of disease with growing prevalence of communicable infections. According to the recent FMOH Health and health indicator report†, the ministry provides basic health service to only 89.6% (the current strategic plan also aims Millennium Development Goals (MDGs)) of the total population. For the entire nation only 149 hospitals are operating with a very low physician to population ratio, i.e. 1:42,706 (World Health Organization (WHO) standard is 1:10000). In this regard, the ratio of other professionals is also low. As it is shown in the report, the available healthcare services do not provide sufficient medical care to patients.

The quality of healthcare service given exacerbates for the areas on which specialty skill is required. There are only 168 specialists serving the whole country of more than 79 million. And usually in developing countries like Ethiopia physicians or doctors don't like to go to the rural areas. In providing the required level of healthcare service, there has to be a way to deliver it to the underserved communities.

Information and Communication Technology applications are useful in numerous instances to facilitate the developments of various aspects of the society. Information and Communication Technology (ICT) is considered as an enabler for various disciplines. It is applied in different areas and witnessed an effective result. Some of the different aspects whereby ICT provides an option to improvement include:[14]

† Summary of Health Indicators is shown in the annex, [Table 2]

- Facilitating public and private sector activities in areas such as in: Urban and Rural Development, Transport
- Improving the quality of life for citizens such as in: Health, Education, Special Needs, Agriculture
- Facilitating activities in the business sector such as: Manufacturing, Electronic Commerce, Travel and Tourism
- Sharing knowledge and improving access to information

However, the use of ICT in the area of health care is very minimal compared to other disciplines. But nowadays the advancement in Information Technology (IT) and telecommunications is forcing the utilization of ICT in healthcare area. To employ IT in the health sector as well as any other sector in the country, an appropriate infrastructure has to be established. From an interview it is learnt that the Ethiopian Information and Communication Technology Development Agency (EICTDA) is dealing with maintaining and developing ICT in the country. The agency is managing the largest network in the country, Woredanet, connecting over 600 Woredas with an average bandwidth of 512 Kbps to 1Mbps. Moreover, Ethiopian Telecommunication Corporation (ETC) is also striving to realize an Internet with better service delivery. It is trying to make it better in terms of bandwidth as well as services provided through it. ETC provides the Internet service via different alternatives such as satellites, fiber optic cables etc.[21] The ICT infrastructure can be considered to improve medical care delivery. In remote areas where the distance between a patient and a health professional is long, ICT can narrow the gap by enabling to transmit medical information followed by medical care. Telemedicine is a term to describe the delivery of healthcare services where distance is a critical factor using ICT.

Nowadays, due to the advancement of IT equipments and infrastructure the span of usage is expanding. Telemedicine is defined as the use of medical information exchanged from one site to another via electronic communications to improve patients' health status[2]. It may be as simple as two health professionals discussing a case over the telephone, or as sophisticated as using satellite technology to broadcast a consultation between providers at facilities in two countries, using videoconferencing equipment or robotic technology. Telemedicine is meant to make use of ICT infrastructure in providing a better health care service to the community. Telemedicine

now has a potential of bringing improved medical care by bringing the services of those specialists to the underserved urban and rural community[13]. To make telemedicine systems more useful among such a community where there is low usage of the technology, an enhanced user interface that is not complex, efficient to execute, etc need to be developed.

Although, most often telehealth and telemedicine are used interchangeably, there are subtle differences between the terms 'telehealth' and 'telemedicine'. Both involve the use of IT and telecommunications in improving the coverage and quality of healthcare services to the community, telehealth encompasses a broader definition of remote healthcare that does not always involve clinical services[12]. Telehealth refers to a system which enables the clinical management of an individual's condition at a distance or in their own home. For example, the technology can enable a patient to monitor their own vital signs, such as blood pressure, pulse rate, or temperature. Meanwhile, according to World Health Organization, Telemedicine is the practice of medical care using interactive audio visual and data communications. This includes the delivery of medical care, diagnosis, consultation and treatment, as well as health education and the transfer of medical data[3]. But telehealth refer to clinical and non-clinical services such as clinical healthcare, health-related education, training, public health and health administration[15].

In the process of improving healthcare service, telemedicine is applicable in various areas of healthcare. Telemedicine has numerous advantages as leveling of regional differences, improved efficiency of medical care, improved service for patients, and physicians will have greater opportunities to deliver medical care to patient in places where medical care is not otherwise accessible[13]. The different areas on which ICT is used to improve medical care are usually prefixed with the term ‘Tele’. Some of the most common areas on which telemedicine is used are:

- Teleconsultation: The use of information and communications technology to enable clinical consultation between geographically separated individuals such as healthcare professionals and patients and their patients or healthcare professionals engaged in diagnostic, mentoring, or other clinical decision making activities.

- Teleradiology and Telepathology – consultation and reports on radiology services and pathology test results done at remote sites. Radiographic images and pathologic test results are sent to a remote site so that a professional can be consulted.
- Telemonitoring – monitoring patients at remote especially using advanced medical equipments. It uses devices to remotely collect and send data to a monitoring station for interpretation
- Telecardiology – It is the electronic transmission of cardiac data from the patient site to a consulting site for the provision of health care services. Consultations are possible through the transmission of ECG's, laboratory results, ultrasounds, medical history, etc.

Telemedicine works based on the bases of two technology concepts:

1. Real-time (synchronous) telemedicine – Using this technology, the two parties interact in real-time using video conferencing equipment. It might also involve the use of other medical devices such as tele-stethescope and tele-otoscope[‡] to aid in the interactive examination.
2. Store-and-forward (asynchronous) telemedicine – This technology, typically involves the transfer of medical data to a doctor at a different location for diagnosis or consultation offline. It does not require the presence of both parties simultaneously during communication.

In practicing telemedicine the major challenge for its continuity is the level of cost incurred. Although, it varies with different types of telemedicine, there is some inevitable amount of cost to be sustained. The source of it may range from procuring equipments to training and enabling to run. Telemedicine systems are supposed to be very cost effective while improving the quality of health care services.

Amount of cost associated with telemedicine varies depending on whether it is real-time or store-and-forward type. For example advanced digital medical equipments might be necessitated for real-time type so that medical data could be transferred at real-time. While the store-and-forward method requires a simple server to enable two

[‡] These are peripheral devices attached to computers and assisting remote physician gets appropriate data. For instance, tele-stethescope allows the remote physician hears patient's heartbeat and tele-otoscope allows to 'see' inside a patient's ear.

remotely located ends communicate. Additionally, the server stores the messages communicated among participating in a telemedicine scenario.

It is well known that security and privacy concerns related to healthcare data, which is very sensitive by its nature, is hardly to be neglected. Because of the unique combination of patient data, video imaging, and electronic clinical information that is generated between two distant sites during a telemedicine encounter, privacy concerns that normally pertain to patient medical records may be magnified within the telemedicine arena or may be different in character altogether [4]. Patient records when transferred to the remote location should then be very much stringent in protecting their privacy.

Among the most difficult challenges facing organizations making IT investments is deciding whether to purchase everything from a particular vendor, integrate different components from various vendors, or use in-house development. When they are running, organizations experience problems to extend their service, integrate with legacy systems, upgrade their services, etc. In coping with this challenge the industry researchers realize Service Oriented Architecture (SOA).

SOA is an IT architectural style of building reliable distributed systems that deliver functionality as services, which are discovered and used by clients[22]. Services may be individually useful, or they can be integrated to provide higher-level services. Most of these services are made available as web services. A web service is a software interface that describes a collection of operations that can be accessed over the network through standardized eXtensible Markup Language (XML) messaging. Different services in an SOA communicate using Simple Object Access Protocol (SOAP), which is a simple XML based protocol to let applications exchange information over Hypertext Transfer Protocol (HTTP).

A system that uses a web service relies on its Web Service Description Language (WSDL) document. The WSDL document is an XML document specifying location of the service and the operations the service exposes. These services are then published in a Universal Description, Discovery and Integration (UDDI) framework to make them publicly available.

This system provides a communication platform where by professionals can send a message containing a case to a remotely located specialist. The specialist from the specialty center replies on the case. If the case at hand forces to include an image, it can be attached to the message and sent. In this scenario the message can contain a case on any clinical discipline; it can be cardiac, orthopedic, or pathologic case. However, it works on the store-and-forward concept in that the message is accessed later when the remote user log into the system. Hence, using the existing ICT infrastructure in the country allows clinicians to consult remote specialists so that they provide better healthcare service to patients. This system doesn't focus on a specialty area; simply provide a messaging environment to send messages containing any kind of clinical case.

This project considers all these issues to come up with a web based telemedicine system using service oriented architecture (SOA). Different services provided by the system will be made available as web services to be consumed by other web services or systems, if necessary. However, this does not necessarily mean to make all functionality of the system made available as a service. Different functionalities of the system such as getting list of articles and accessing list of messages are exposed as a web service. To avoid vendor lock-in, this architecture, using open standards, will be used. Since communication between different components of the system is done using Simple Object Access Protocol (SOAP) as it can be easily understood by users. The security concerns of healthcare data is managed using different options available in SOA. Security can be implemented through protocols such SSL/TLS or IPSec, or using different security standards in SOA such as WS-Security or even application level security by web servers can be used.

1.2 Problem Statement

As the number of health professionals in the country is very low, the health coverage is limited. Let alone the required number of specialists in different fields, there are no enough number of doctors and nurses as well as other professionals in health institutions. Coupled with other reasons, this compromises the healthcare service quality of the country. Health professionals do not have access to up-to-date medical information. Outside the university or college, where they have attended, there is no a comprehensive choice to get up-to-date resource on health related issues.

Using IT infrastructure, it is possible to create a network of clinicians where they can collaborate to give a better quality healthcare to patients. This will in turn complements the lack of abundant health professionals in the country. Health professionals can then consult another professional or specialist on a remote site for a case. Health professionals working in rural areas can access specialists who are stationed in cities thereby improving the medical care available to the rural and underserved urban communities.

Hence, this project will try to answer the question: How could we develop a simple, effective telemedicine system that improves healthcare provision to the community by providing support to clinicians and letting patients aware of their medication?

1.3 Objectives

Generally, the objective of this project is to design and develop a web based telemedicine system using a web services in SOA.

To achieve the aforementioned objective, the final product has the following specific objectives.

- Display up-to-date medical related news so that clinicians can utilize it to improve the quality of health care services. Up-to-date medical news is collected from the well known websites using syndication technologies.
- To enable document sharing, the system has made different documents, written and/or contributed by other professionals, accessible
- To complement the symptoms observed, it is customary and necessary to prescribe laboratory and other tests. But some may come up with unusual and confusing results. Therefore to get a better interpretation, these results may be sent to a specialist
- Whenever there is a need, it helps in sending x-ray and CT scan images as an attachment to a specialist

1.4 Scope and Limitation

As a store-and-forward telemedicine system, this project serves as a teleconsultation enabler among health professionals. The system allows users to share articles and other

health related documents. They can also use the system to get up-to-date medical news over the net using feeds from different sites.

The scope of this project focuses on the involvement of health professionals; assisting them to consult specialists thereby improving healthcare provision to patients and let them update their medical knowledge by sharing articles as well as providing current news from different websites.

1.5 Application and Contribution

Telemedicine systems are well applicable to any situation whereby healthcare provision is uneven. Different telemedicine approaches can be adopted to deliver better healthcare services. In this case this system can be implemented to provide store-and-forward telemedicine system for the purpose of tele-consultations.

This usage of telemedicine systems is becoming a necessity in countries like Ethiopia where a very few specialist are available and those are found around major cities if not the capital. Hence to deliver better healthcare service to the underserved urban or rural communities, this system contributes a lot. In addition to helping professionals to get consultation on case analysis, it allows them to get up-to-date medical information and news.

1.6 Methodology

To develop the system, a set of methods and techniques are used. Primarily it needs to understand the current endeavors of telemedicine by concerned bodies. To understand the current efforts made regarding telemedicine, documents have been reviewed and interviews are conducted. Basically, the secondary data sources as well as the primary data sources from interviews are used to conduct requirements analysis.

Following the completion of requirements analysis, the system is modeled using UML tools. The system then is developed using object oriented concepts in a tiered architecture. Moreover, to reinforce the different object oriented characteristics (-illities of the system such as scalability, interoperability, etc) some of the more commonly used services are designed using SOA and services realized via web services.

The designed functionalities and services are implemented on the .NET Framework platform using C#. Different pages are developed as ASP.NET web forms and the services are developed as ASP.NET Web Services.

1.7 Document Organization

This project is to develop a web based telemedicine system that is named as Wonfel[§] from now onwards. It is named so because it allows users to share what they know as well as helping each other. A clinician can ask a specialist for consultation via sending message, optionally attaching image files.

This document is then present the project and it is organized in chapters to present different parts of the whole project report. As a project report different sections are presented as follows.

Chapter 1 presents introduction information about the project and background related to healthcare status in the country. An overview of telemedicine and related concepts are presented. This chapter also introduces Service Oriented Architecture (SOA) and related technologies

Chapter 2 describes related literature reviews. Recently, works related to telemedicine are flourishing, partly attributed to the advancement of Information Technology. Hence various works in the area are presented in this chapter.

Chapter 3 deals with the requirement specification and detailed analysis of the system.

Chapter 4 deals with different design issues. It models various aspects of the system design. While chapter 5 presents a prototype of the system, chapter 6 describes the testing strategy carried out on the system.

[§] Wonfel is a term used in rural areas in the North Western Ethiopia – aka Debo in other parts of the country. It is a way farmers cope with their work burden through cooperative task completion. One farmer works for somebody else and the other comes at some other time to help him finish his work.

Chapter 2 Literature Review

In the area of healthcare, following the advancement of IT and telecommunication technology, different works involving information and Communication Technology (ICT) had been developed. But most of them are focusing on a specialized area such as teleradiology, telecardiology, telepathology. The number of specialty and subspecialty areas that use telemedicine increases from time to time. Some of such areas include radiology, dermatology, mental health[2].

Different efforts are made in the Ethiopian context to realize telemedicine in the nation. An attempt to introduce Telemedicine started around 1997 when the Ethiopian Telecommunication Agency recognize telemedicine as one of its services and AAU, Faculty of Medicine attempts to create awareness among stakeholders. To organize telemedicine efforts by these varying bodies, in February 1998, a National Telemedicine Coordinating Committee (NTCC) established[16].

Following International Telecommunication Union's (ITU) commitment to support telemedicine pilot projects in developing countries, NTCC has prepared a project proposal and submit it. The project proposes connecting ten selected sites (hospitals and medical institutions) to the Internet. After 11 months of proposal submission and ITU's promise to provide material and expert support, group of experts came to Ethiopia and visit selected sites. They recommend implementing the pilot project in the following three phases.

- Phase I: Pilot program, involves connecting ten sites
- Phase II: Expanding the telemedicine network to more hospitals and health institutions in the country
- Phase III: Expanding it further to join International Telemedicine Network

The overall network diagram of the pilot project is not fully documented; however, figure 2.1 show how the 9 sites are connected to the central hospital in a kind of star topology. The telemedicine application point of view depicts that the central site is where all the consulting specialists are stationed.

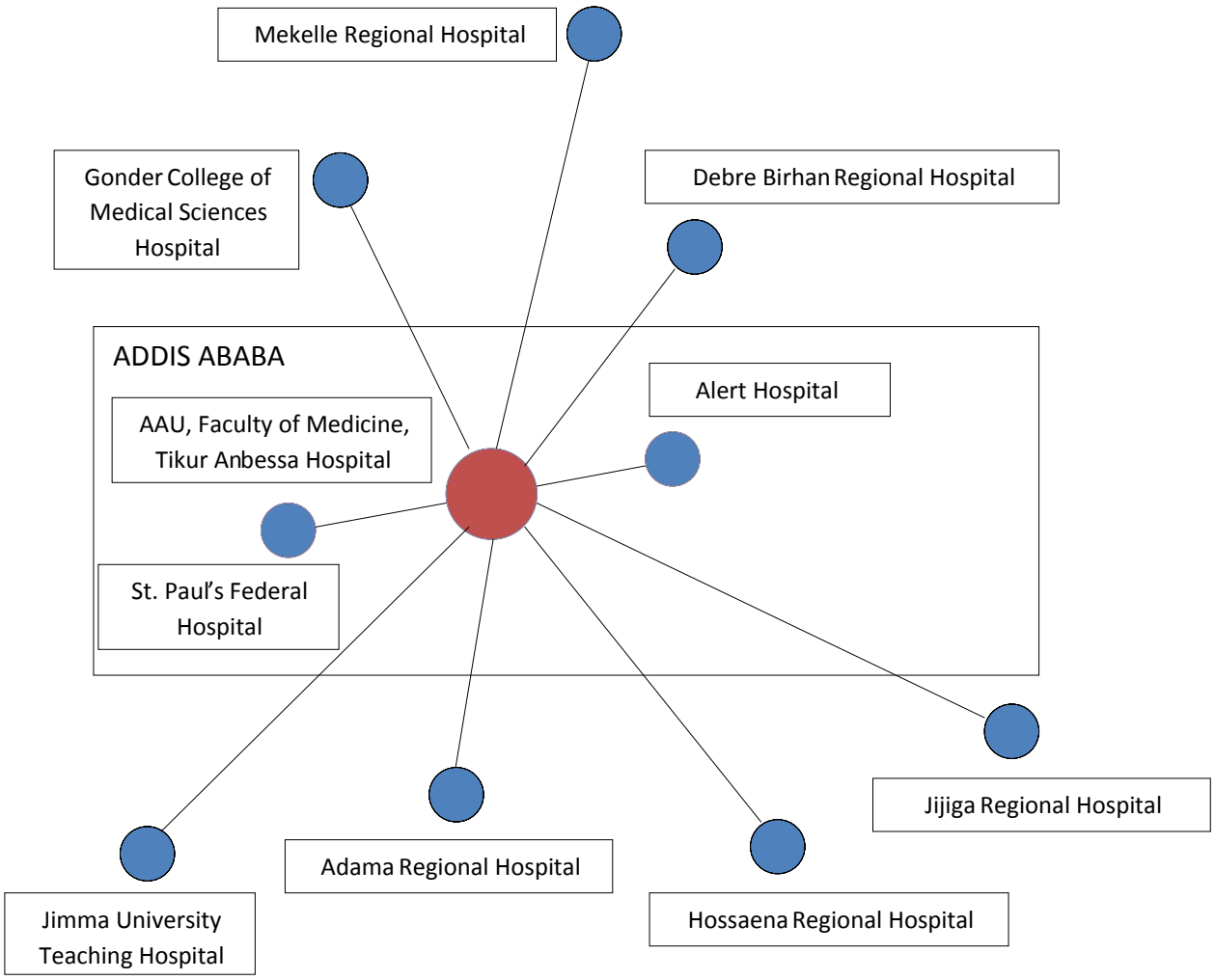

Figure 2.1 Ethiopian Telemedicine System Pilot Project Network Diagram [17]

In this project, it is supposed to practice teleradiology and teledermatology by using Tikur Anbessa, Gonder and Jimma university hospitals as specialty centers for Radiology consultation, and ALERT hospital for dermatologic consultation[17]. But it was learnt that, when it is launched the pilot project was realized only on Alert, Zewditu and St. Paul hospitals with Tikur Anbessa as a central referral hospital.

According to the conceptual network of the existing telemedicine network, as understood by the researchers [16] all the ten sites will have dialup internet connection through the Public Switched Telephone Network (PSTN). Each hospital will be equipped with digital equipments and the national Gateway at the Sululta satellite ground station connects to Intelsat Indian Ocean and Atlantic Ocean regional satellites. While there are no firewall or internetworking devices such as switches involved in the current telemedicine network[11].

According to the researchers[11], Some of the drawbacks of the pilot project are:

1. There is no GUI specific to telemedicine
2. There is no database design considered in the pilot project
3. Expansion of the network as is planned is not visible, because there is no system design
4. It considers the use of e-mail and file attachment
5. Using e-mail, it would be difficult to structure information exchange
6. It would be difficult to secure the patient information system

Hence there was a need for new telemedicine system design that will have its own GUI, database and uses the existing ICT infrastructure for its network connectivity.

Meanwhile, currently a telemedicine system exists in the Jimma hospital as interviewees said. This telemedicine system is using the general purpose email system to communicate. In this setting, the Jimma hospital is serving as a center for the other institutions connected. They have arranged a Gmail group account and using that they communicate with professionals in Mettu and Wolisso hospitals.

Deng and Poole [5], has developed a telemedicine network for learning. Their network is meant to solely educate the users by conceptualizing Telemedicine as an integrated IT enabled healthcare network of collaborative relationships. Although most current research on telemedicine focuses on the technology that makes the interaction possible without physical presence, but largely ignores the social/organizational effects of telemedicine that may stem from its integrative functions. Telemedicine will tend to evolve from point-to-point connections toward more coordinated, integrated and interoperable networks. Healthcare is a knowledge-based industry, characterized by an exponentially expanding knowledge base, increased uncertainty and equivocality, time compression and severe cost constraints. So individual and organizational learning that promotes knowledge creation, acquisitions, transfer and sharing is of critical importance.

In addition to the flexibility of IT, there are three properties of telemedicine networks influencing learning. This includes density of the telemedicine network, strength of the network tie, and network diversity. The density, which is the extent to which the members of the network are interconnected, positively affects the acquisition and

transfer and sharing of medical knowledge. The more strong ties in telemedicine network, the more effective the learning process concerning how to collaborate effectively via telemedicine. In contrast, the weak ties enable the effective detection an exploration of novel opportunities and innovative ideas. Meanwhile, the diversity of the network ties provides the opportunity to access and combine information from qualitatively different sources, thus enabling learning through novel integration of relevant information and knowledge.

Shaikh and Misbahuddin's [6] work on a telemedicine system that focuses on a specialty area. They design a system for Tele-Wound™ application, with a target audience confined to leg ulcer patients. The pictures of infected areas will be fetched through camera by a nurse in their location. These pictures are sent into the application server with little description of the patient. The system utilizes telecommunication and internet technology and their major component/modules are more dependent on those technologies.

Tele-Wound™ has two parts, the doctor's end and the patient's (nurse's) end. Communication between these two ends is completed by sending MMS and emails through mobile network.

The architecture, which is developed based on SOA, communicates with web services. It assures the availability of medical data from the other sources. Specialists in the doctor's end need to have internet access and browser so that they can help out patients from anywhere.

Another related work on telemedicine is by Sridhar and Kankaraj [7] in the Raja Rajewsri Engineering College. This project is used in hospitals to constantly monitor patients in the intensive care unit for their temperature, saline status, and ECG. It involves sensors to measure all these parameters and transfer it to the computer, so that the patient condition can be analyzed by doctors in any part of the hospital. These readings are stored in a relational database system created using Microsoft Access. The aim of this project is to utilize computer systems as access terminals for general enquiry and patient monitoring services. Mobile phones are also used to send short messages to doctors, if patient is in distress. Authorized users can view the patient's monitored physiological parameters on access terminals.

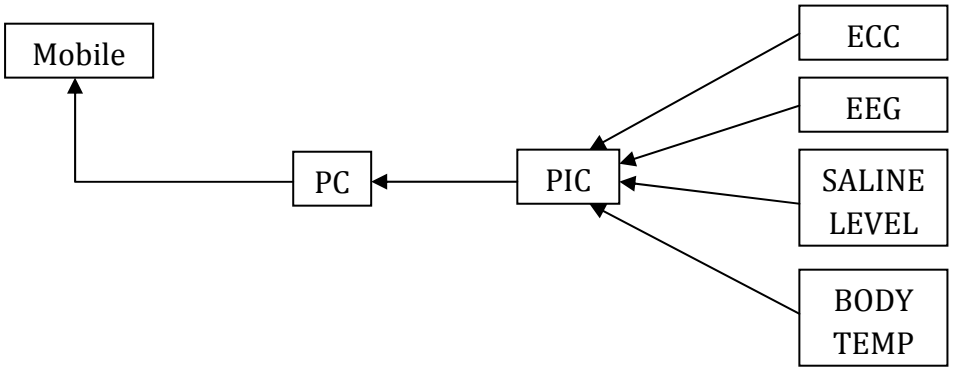

Figure 2.2 System Diagram [7]

The system consists of database server, access terminals, complete body scanning kit and the mobile phone. The access terminal communicates with the database server, which stores information and responds to the users' request, using its front end via Open Database Connectivity (ODBC). The mobile phone receives short messages alerting of the patients are in an emergency situation.

Figure 2.2 shows the architecture of the systems with its different components. The figure depicts the Peripheral Interface Controller (PIC) microcontroller used to interface with the PC using RS322 port of the computer. This module is responsible for communication with and control of the patient monitoring devices. The software module records the result of the hardware readings and sends it to the doctors.

A System design by Kart et al [8] based on SOA tries to minimize human error by automating data entry and sending data over a network. The system has three layers as shown in figure 2.3.

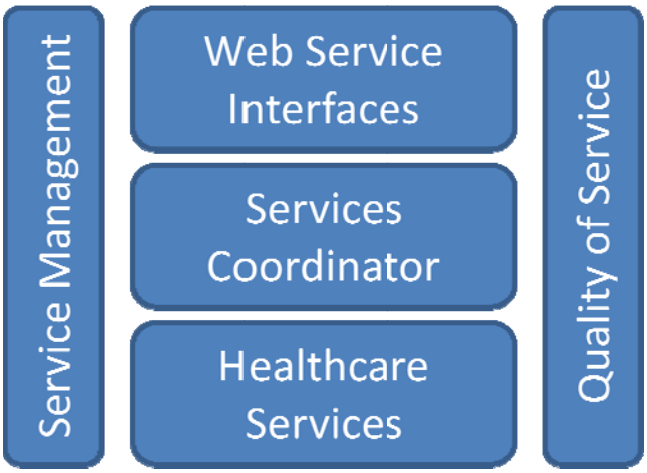

Figure 2.3 e-Healthcare layers [8]

The web service interfaces layer describe the web services interfaces, while the services coordinator controls the flow of message between the web services layer and the bottom layer, the healthcare services layer, which provide core healthcare services. The other components in the system: Service Management and Quality of Service are maintained using the underlying platform. Basically the whole system has two major modules; the clinic module and the pharmacy module. The clinic module maintains information related to patients for physicians. The clinic module sends prescriptions from the physician to the desired pharmacies over the Internet using the Web Services provided. They focus on the pharmacy prescription in that when the doctor wrote new prescription, the clinic module communicates with the pharmacy module over the Internet, thus by avoiding human intervention. Moreover, a pharmacy in the vicinity will be located using Yahoo!LocalSearch and the patient will get minimal difficulty in getting the prescribed medicine. The Pharmacy module provides services to the pharmacist, patients and devices used at the pharmacy. Moreover, it keeps a record of the patient's prescriptions for the pharmacist's and the patient's reference.

Another work by Omar and Taleb Bendiab [9] has outlined the use of Grid computing for e-health support services. They envisage an e-health monitoring system, using sensors and actuators. The framework is in charge of collecting information from the patients' side and providing it to the health system according to the policy which is provided by the health consumer (hospital for instance). The remote e-health monitoring system for tracking patients to improve remote monitoring healthcare and care provision uses a number of components.

The study in [10] proposes a system to give remote diagnosis and consultation services. Additionally, the system helps physicians to make selection of remote physician for particular consultation.

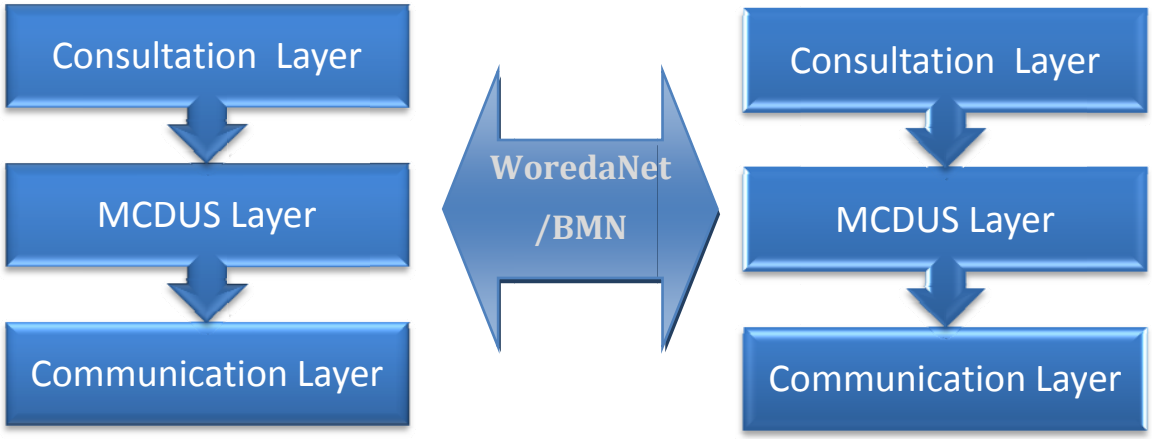

Figure 2.4 Three Layered Architecture of the National Telemedicine System [10]

In designing the system, the author has used layered architecture shown in figure 2.4; so that the design complexity is simplified. Communication between distant units is carried out using the existing network infrastructures (WoredaNet and Broadband Multimedia Network). The system has a model to help physicians' select remote physician. The goal of Multi-criteria doctor's unit selection (MCDUS) model is to locate potential specialists or physicians for a consultation request. This selection improves healthcare by providing remote medical services at an appropriate time.

Chapter 3 Requirements Analysis

When a system is developed, there are expected level of capabilities. These are functionalities expected by users of the system. Different requirements of a system are elicited by observation and interviewing users.

The Ministry of Health is implementing a telemedicine system, making the Jimma hospital as a focal point. Other sites are communicating with the center via the general purpose email system. This system serves as an environment to provide tele-consultation services.

This chapter focuses on the requirement analysis of the proposed system called Wonfel. The proposed system is a store-and-forward telemedicine system. Wonfel is used as an environment where by users can collaborate via sending messages. It could be applicable for all clinical areas; it is not tied to a specialized clinical discipline. Moreover, Wonfel provide a way to share documents and to view up-to-date health related news on the internet. The chapter discusses functional and nonfunctional requirements, the system model and associated concepts.

3.1 Functional Requirements

Functional requirements describe the interactions between the system and its environment independent of its implementation. The environment includes users and any other system that interacts with the system. This describes these interactions without considering any implementation details.

Wonfel is a web based telemedicine system that enables users to collaborate to improve healthcare provision. To structure service provision, users who are using the system must be determined. Hence, before using the system, users need to get registered and logged into the system. However, the profile they provide is kept secured to ensure their privacy. When required, though, it provides them a mechanism to modify their profiles and change password.

As a store-and-forward telemedicine system, it facilitates communication among users via the messaging environment. The system allows major messaging functionalities

such as sending, deleting, forwarding and replying messages. The content of the message is the case to be consulted. It also gives a way to send images as an attachment.

Additionally, when users need information related to health, Wonfel is able to share documents among users and display recent news online. Displaying health related news from the Internet allow users know the current medical information. For example, when there are new outbreaks worldwide, new medical findings, etc. users get informed. The display of health related news is possible if there is internet connection, of course. However, it enables to make documents written and/or contributed by specialists or other users for that matter accessible so that others can get it. Articles written by professionals will be made available after their approval by administrators. Almost all health professionals don't have the choice to have books and/or articles so that they can refer. When they want to refresh their knowledge or analyze a case, they may be short of any reference materials. Wonfel provide a way to alleviate these problems by making articles and/or eBooks, which are uploaded by users, available to others so as they are able to download it.

3.2 Non-functional Requirements

Non-functional requirements describe requirements of the system that are user-considerate but not directly related to the functional behavior of the system. Usually, these are constraints of the system to improve quality of service.

3.2.1 User Interface

The usability of a system is highly affected by the way its user interface is designed. In this case simplicity is a key characteristic of a user interface. To complement the low level of information technology usage in the country, the system needs to have a simple and attractive interface. Making the system web based put any user familiar with internet at ease in using the system. Since it uses familiar links to work with different components of the system, it makes users comfortable in using it.

3.2.2 Availability

Any system needs to be available whenever it is required to make use of. However, the development of systems related to healthcare heightens this requirement. Wonfel is expected to be available at any time when professionals need to use the system.

3.2.3 Performance

Since it is a web based system, it runs on any system capable of running web browsers. Although clients can run on a PC, the server should be a powerful computer which is capable of handling requests even during high traffic times. Wonfel is designed to run on the existing network infrastructure, hence, the bandwidth vis-à-vis the data transferred should be considered so as not to thwart system performance.

3.2.4 Security

Security and privacy issues in healthcare data are very sensitive, exceptionally to other forms of data. The data transferred to a remote site should be secure and users should have access to part of data they are supposed to.

3.2.5 Scalability

This project considers currently available health institutions and level of professionals in the country. But the numbers of healthcare providers as well as professionals are increasing. Therefore the system should scale up to accommodate this increasing need without a noticeable performance downgrading. Though, the architecture used allows seamless scalability, the network infrastructure should also accommodate. Along with the scalability issue, the system allows easy extensibility. It is simple to add services or integrate with other systems.

In addition to using a tiered architecture, to further simplify scalability, Wonfel allows other systems, to consume the common services. It expose functionalities such as getting list of messages and authentication as a web service so that they can use them as part of another system.

3.3 System Model

System modeling is a tool used to understand the system; the model is then used for an analysis of the system[19]. Models are developed to represent the system view under consideration and to explain the behavior of various components of the system.

Different components in the system are described using UML tools. These tools are used to model these components of the system so as to better understand it and its requirements. This part of the document present the model diagrams of Wonfel.

3.3.1 Actors

An actor is a person, organization, or external system that plays a role in one or more interactions with your system[18].

In Wonfel, there are about five groups of users. As shown in table 1, the administrator is one type of user of the system and it is basically set to administer the system. The Administrator is responsible to register institutions as a user of the system. These institutions could then be able to register their health professionals as member users. These members can be either clinicians or specialists. The actual messaging task is carried out between these two user groups.

When the administrator has made the institution inactive, it is not possible to register member users and members of that inactive institution can't log in either.

Some of the functionalities in Wonfel are exposed as web services. Hence, external systems can possibly be users. These external systems access services; however, their request should be completed if they are authenticated.

Table 1 List of Actors

Actor Name	Description
Administrator	Performs all administrative related tasks. It may inactive or delete institutions, approve or remove uploaded articles
Institution	A health institution registered as a user via the administrator. It could add member users to the system
Clinician	A health professional that is a member of an institution. S/he is able to consult a specialist on the other end by way of sending messages
Specialist	A health professional that is a member of an institution. S/he resides in the Telemedicine specialty center and responds to case requests.
External Systems	Other applications and systems can access functionalities that are exposed as services. These are available as web services.

3.3.2 Use Case Model

A system comprises of functions, features, etc with specific outputs contributing to the system goal. These functions are initiated by users that can be inside or outside the system. Use case diagrams describe these behavioral requirements of the system as it is

appeared by an outside user. The use case diagram is followed by a description of each use case given separately in a use case description.

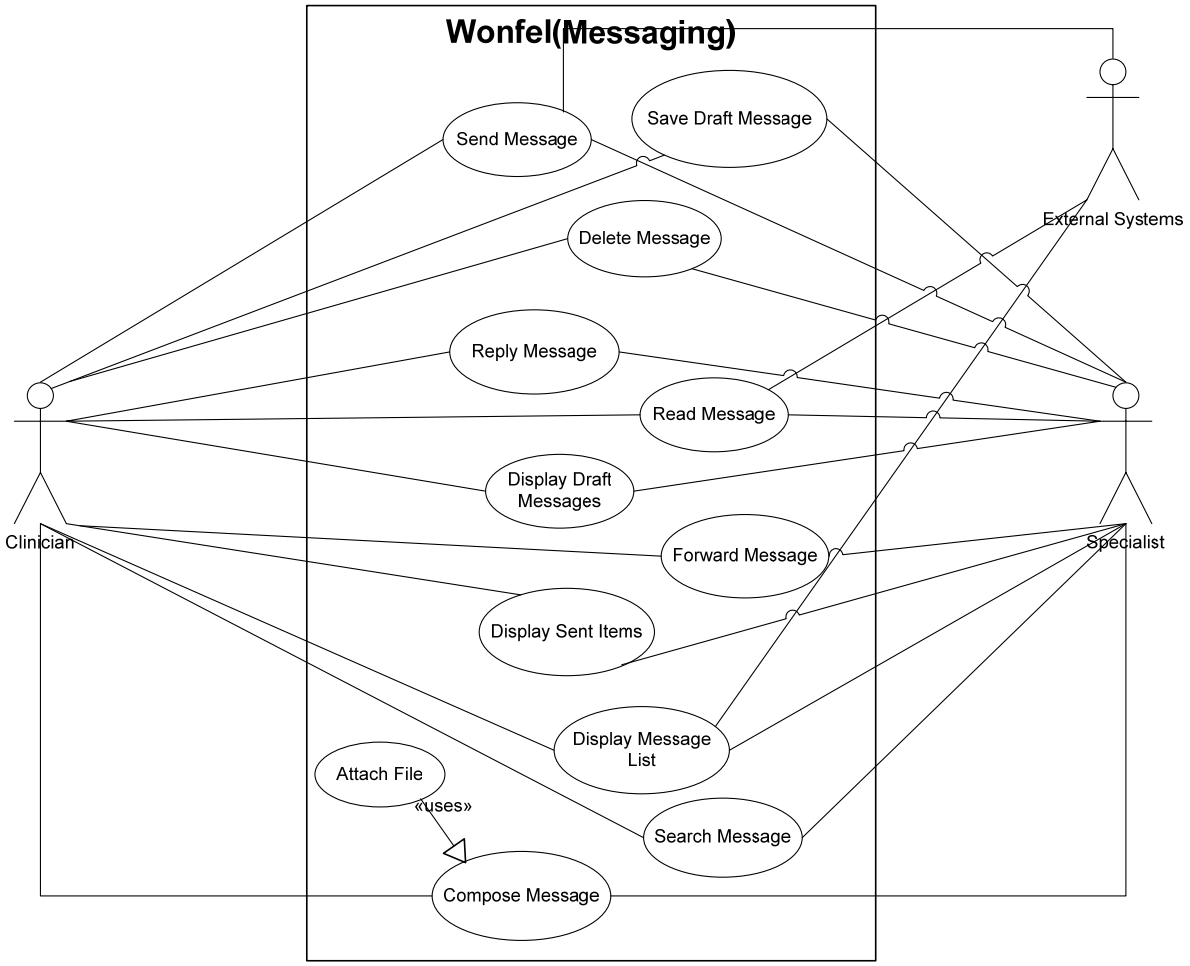

Figure 3.1 Use Case Diagram for messaging component

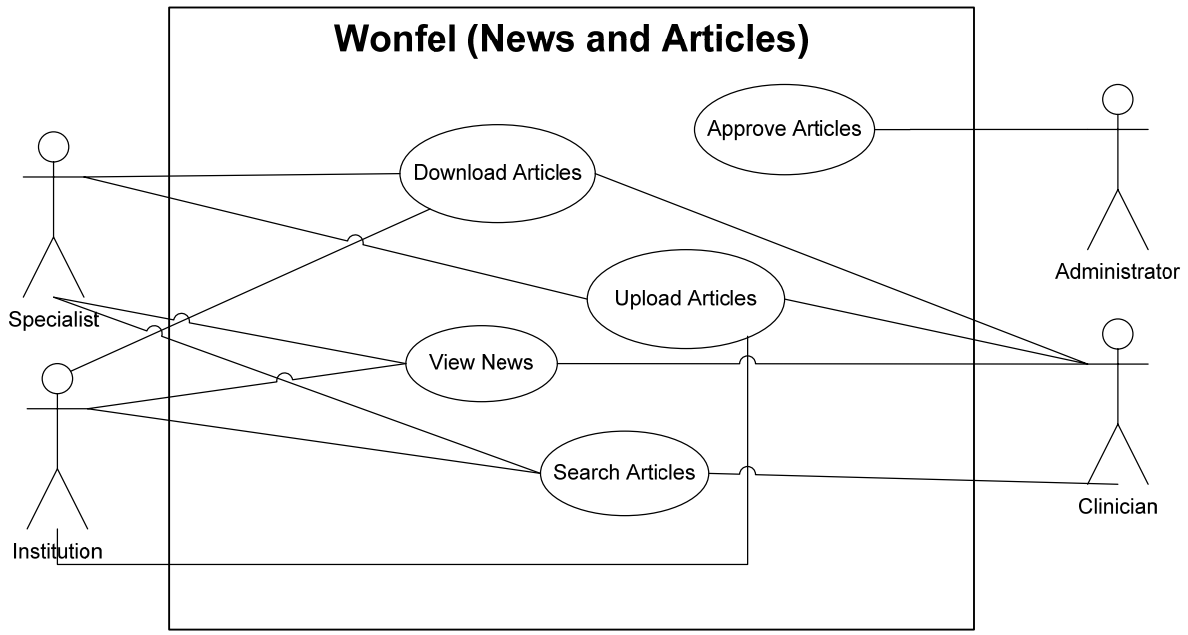

Figure 3.2 Use Case Diagram for News and Articles Component

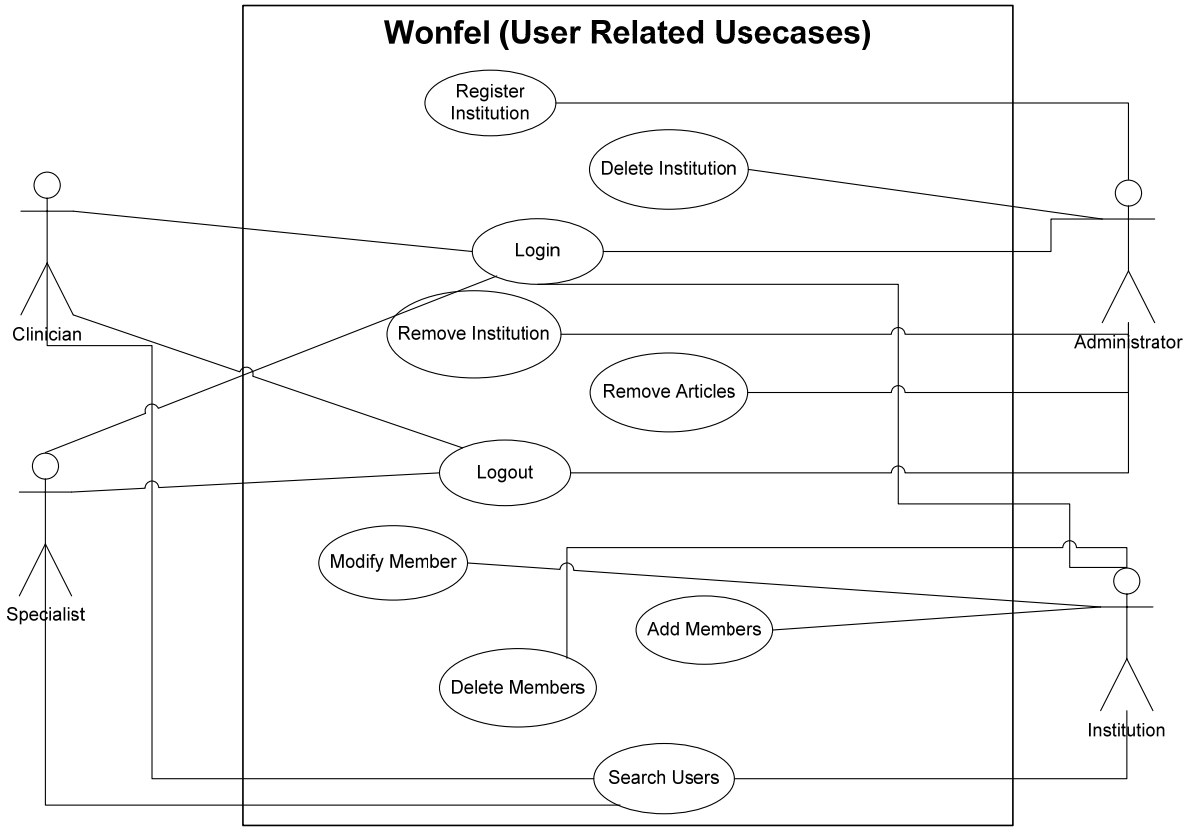

Figure 3.3 Use Case Diagram for User Management Component

3.3.3 Use Case Description

Description is required for each use case so that how it is accomplished, what is required to complete it is easily understood.

Name: Register Institution

Identifier: UC01

Description:

Create a new institution of the system. Usually this will be an institution which will add members later as a user of the system

Preconditions:

- Administrator is logged in
- Manually filled form submitted

Postconditions:

- Institution account is created

Basic Course of Action:

1. The use case begins when the administrator shows an intent of creating a user from a filled form
2. The administrator enter name, location and other profile data to the system
3. The system validates the data supplied (Alt Course A: *Invalid data supplied*)
4. The use case ends when it displays a successful creation of users

Alternate Course A: *Invalid data supplied*

A-3. The system determines the data is invalid

A-4. The use case resumes step 2 showing error message

Name: Remove Institution

Identifier: UC02

Description:

When institutions need to became inactive in the system, they and their members would be denied from participating in services of the system

Precondition:

- Administrator is logged in
- There exists an active user

Post condition:

- An institution is inactive

Basic course of action:

1. The administrator chose and click the Inactive button
2. She/he approves to remove the users (Alt Course A: *administrator cancels operation*)
3. Use case ends displaying updated list of institutions and showing a success message

Alternative course of action A: *Administrator cancels operation*

A-3. S/He wants to cancel the removal action

A-4. Use case ends by displaying list of users

Name: Login

Identifier: UC03

Description:

Allow registered users to log into the system so that s/he can use it

Precondition:

- Registered users must exist

Postcondition:

- Users logged into the system

Basic course of action:

1. User enter username and password to the system
2. System determines that the user is legitimate (Alt Course A: Invalid user name or password is entered)
3. System displays the message form and the use case ends

Alternative course of action A: Invalid user name or password is entered

A-2. The system determines the user is illegitimate

A-3. Use case displays error message and resumes at step 1

Name: Logout

Identifier: UC04

Description:

Lets users log out of the system

Precondition:

- A user is logged into the system

Postcondition:

- The user is logged out of the system

Basic course of action:

1. The use case begins when user indicates s/he wants to log out
2. The system closes user sessions
3. The use case ends by displaying login page

Name: Add Members

Identifier: UC05

Description:

Add member users of the system. This is completed by institutions, which are in turn created by administrators. These members are clinicians and specialists of health institutions.

Precondition:

- Institution is logged into the system

Postcondition:

- New member is added under an institution

Basic course of action:

1. The use case begins when the institution indicates s/he wants to add member
2. Institution enters name, profession and related profiles to the system
3. The system validates the entered value is correct (Alt Course A: *Invalid form date entered*)
4. The use case ends after displaying message about successful addition of members

Alternate course of action A: Invalid form data entered

A-3. The system determines the entered value is invalid

A-4. The use case ends after displaying error message

Name: Delete Members

Identifier: UC06

Description:

Removes an existing member

Precondition:

- Institution is logged in to the system
- A registered member exists in the system

Postconditon:

- A member is deleted

Basic course of action:

1. The use case begins when the institution indicates to delete a member
2. The system displays list of members
3. The user selects member to delete
4. The system confirms this action (Alt Course A: *Institution cancels removing user*)
5. Use case ends displaying a message

Alternate course of action A: *Institution cancels removing user*

A-4. The institution reject the action

A-5. The use case ends by canceling the action

Name: View News

Identifier: UC07

Description:

Online health related news from different sources, accessed via feeds will be displayed

Precondition

- User has logged in

Postcondition:

- News are listed

Basic course of action:

1. Use case begins by listing news titles along with their link
2. User indicates to view news
3. Use case ends displaying the news following a link

Name: Remove Articles

Identifier: UC08

Description:

Removes a submitted article when it is no more wanted to be available

Precondition:

- Administrator is logged in
- Article is uploaded
- List of articles is displayed

Postcondition:

- An article is removed

Basic course of action:

1. Use case begins when administrator select an article to delete
2. Administrator indicate to remove the article
3. System confirms the removal action
4. Use case ends removing the selected article and display the list

Name: Download Articles

Identifier: UC09

Description:

Displayed list of articles are possible to be downloaded for utilization.

Precondition:

- Articles are uploaded
- User is logged in

Postcondition:

- An article is downloaded

Basic course of action:

1. User indicate to download an article from the list of articles
2. Use case ends downloading the selected article

Name: Upload Articles

Identifier: UC10

Description:

Users can upload articles, which will be available for others after they are approved by administrator

Precondition:

- User is logged into the system

Postcondition:

- An article document is submitted to administrator

Basic course of action:

1. User indicates to upload an article
2. User choose the article document
3. The system validates the chosen article
4. Use case ends displaying acknowledgment message when article document is uploaded

Name: Display Message List

Identifier: UC11

Description:

Before working on messages, they need to be listed down. It lists messages sent to a user. These messages are messages sent to a user and stored in the inbox

Precondition:

- The user is logged in

Post Condition:

- System displays list of messages

Basic Course of Action:

1. The user indicates to view list of messages
2. The system displays list of messages
3. The use case ends

Name: Display Sent Items

Identifier: UC12

Description:

Allow users to display and view list of sent messages

Precondition:

- The user is logged in

Post Condition:

- System displays list of previously sent messages

Basic Course of Action:

1. The user indicates to view list of sent items
2. The system displays list of sent messages
3. The use case ends

Name: Read Message

Identifier: UC13

Description:

Allows the user to read messages sent to him/her.

Precondition:

- The user is logged in
- System displays the inbox page

Post Condition:

- The user reads incoming messages sent to him/her

Basic Course of Action:

1. The user indicates to read a message
2. The user selects the mail to read
3. The system displays the message to the user
4. The use case ends

Name: Forward Message

Identifier: UC14

Description:

Allows the user to forward messages to different contacts

Precondition:

- The user logged in to the system

Post Condition:

- The user forwards a message

Basic Course of Action:

1. The user indicates to forward a message
2. The user completes and submits the receiver's address (Alternative Course A: *Blank field or Incorrect Information)*
3. The system forwards the message to the receiver (Alternative Course B: *Receiver's address not found*)
4. The system displays confirmation message
5. The use case ends

Alternate Course A: *Blank field or Incorrect Information*

A.2 The system displays error message

A.3 The use case resumes at step 2

Alternate Course B: *Receiver's address not found*

B.3 The system displays error message

B.4 The use case resumes at step 2

Name: Reply Message

Identifier: UC15

Description:

Allows the user to reply to messages sent to him/her

Precondition:

- User is logged into the system

Post Condition:

- The user sends a reply to a message

Basic Course of Action:

1. The user indicates to reply to a message
2. The user completes and submits the message to be sent (Alt Course A: *Blank Subject line*)
3. The system sends the message to the receiver
4. The system displays confirmation message
5. The use case ends

Alternative Course A: *Blank Subject line*

A-2. The system displays error message

A-3. Use case resumes at step 2

Name: Compose Message

Identifier: UC16

Description:

Allow users to compose a message so that they can send it to a recipient

Precondition:

- The user is logged in

Post Condition:

- New message is composed (prepared)

Basic Course of Action:

1. The user indicates to compose new message
2. The system displays the compose form
3. User fills the appropriate fields – to, subject, cc, and the actual message body
4. The use case ends

Name: Send Message

Identifier: UC17

Description:

Sends the message to the destined recipient. It also send the message as an email using the user's email address

Precondition:

- The user is logged in
- There is a composed message

Post Condition:

- The message is sent to another user

Basic Course of Action:

1. The user has a composed message and indicates to send it
2. The system validates various fields of the message (Alt Course A: blank recipient address and/or blank subject line)
3. User checks the availability of the recipient (Alt Course B: invalid recipient addresses)
4. The system sends the message to the given recipient and send copies to the accompanying cc values
5. The system sends the message to the email of the recipient user
6. The use case ends

Alt Course A: *Blank Recipient and/or blank subject line*

A-2. System displays error message to correct the illegal values

A-3. Use case resumes at step 2

Alt Course B: *Invalid Recipient addresses*

B-3. System displays error message showing the unavailability of the addresses

B-4. Use case resumes at step 3

Name: Delete Message

Identifier: UC18

Description:

Deletes a message from the list if it is not needed anymore

Precondition:

- The user is logged in
- List of messages is displayed

Post Condition:

- A message is deleted

Basic Course of Action:

1. The user indicates to delete a message
2. The system confirms this operation, since it is undoable (Alt Course A: *User cancels the operation)*
3. The system deletes the message and display the message list
4. The use case ends

Alt Course A: *User cancels the delete operation*

A-2. The use case ends with out deleting a message

Name: Search Messages

Identifier: UC19

Description:

Search messages using a given criteria and display the list of messages satisfying the criteria

Precondition:

- The user is logged in
- List of messages is displayed

Post Condition:

- Messages satisfying a criteria are displayed

Basic Course of Action:

1. User indicates to search messages
2. The system displays the search form
3. User fills the appropriate criteria fields – subject, and date or date range
4. System gets list of messages satisfying the required criteria
5. The use case ends displaying the search result

Name: Attach File

Identifier: UC20

Description:

Attaches a file to a message so that it could be possible to send it along with the message. From different file types, image files are strong candidates, since they can be x-ray images or other medical images. Due to performance and compatibility reasons only limited image types are allowed.

Precondition:

- The user is logged in
- User is currently composing a message

Post Condition:

- A File is attached to a message

Basic Course of Action:

1. User indicates to attach a file
2. User select the file to attach
3. User submits the selected file to be attached (Alt Course A: *Invalid File Type Selected*)
4. Use case shows success of the attachment and ends

Alt Course A: *Invalid File Type Selected*

A-3. System shows error message

A-4. Use case resumes at step 2

Name: Save Draft Message

Identifier: UC21

Description:

Messages can be saved to be sent later. These draft messages do not contain attachment, though. But whether attachment is present stored as a yes/no value.

Precondition:

- Member user is logged in
- Compose message is completed

Postcondition:

- Draft message is saved

Basic course of action:

1. Member shows to save message
2. System checks form entries
3. System save draft message and open the inbox page

Name: Display Draft Message

Identifier: UC22

Description:

This use case lists message saved as draft by member users

Precondition:

- Member user is logged in

Postcondition:

- List of draft messages is displayed

Basic course of action:

1. Member click the draft link
2. System gets list of draft messages
3. The draft page is displayed showing list of draft messages

Name: Search Articles

Identifier: UC23

Description:

Articles are documents contributed by users to share with others. After their approval by administrators, it could be possible to access them via the list of articles or searching. Articles can be search by title, authors and/or publication date.

Precondition:

- User is logged in

Postcondition:

- Article Search result is displayed

Basic course of action:

1. User click on Search link
2. System display the search form user fill the form and submit
3. System search articles based on the given search criteria
4. Use case ends displaying search result

Name: Approve Articles

Identifier: UC24

Description:

To access an uploaded article, it must be approved by administrators

Precondition:

- Administrator is logged in
- Uploaded articles is available

Postcondition:

- An article is approved

Basic course of action:

1. Administrator seeks to edit approval of an article
2. System sets the approval flag of the article
3. Use case ends displaying updated list of articles

Name: Delete Institution

Identifier: UC25

Description:

Deletes an already registered institution. When an institution is deleted, members of that institution will automatically be deleted.

Precondition:

- Administrator is logged in
- A registered institution exists

Postcondition:

- An institution is deleted

Basic course of action:

1. Administrator shows to delete an institution
2. After confirming, the system deletes the institution
3. Use case ends displaying updated list of institutions

Name: Search Users

Identifier: UC26

Description:

Searches member users registered in the system

Precondition:

- User is logged in

Postcondition:

- List of users found displayed

Basic course of action:

1. User click the Search button
2. System displays the search form
3. User enter search criteria and submit
4. System search users
5. Use case ends displaying the search results page

Name: Modify Member

Identifier: UC27

Description:

Enable institutions to modify member profiles

Precondition:

- Institution is logged in

Postcondition:

- A member profile is modified

Basic course of action:

1. After selecting a member from a list, institution click the edit button
2. System displays the edit member form
3. Institution enter new member data and submit
4. System validate the newly entered data and update it

5. Use case ends displaying list of members with the new data

3.3.4 UML Class Diagram

UML class diagram is a mechanism of depicting the different class and their activities together with the relationship that exist among the classes. A class diagram shows the declarative model components such as classes, types, and so on with their contents and relationships. They contain behavioral elements, but their dynamics are shown using other diagrams. The class diagram for Wonfel is shown in figure 3.4. In the diagram the while the Institution class represents the institutions, the Clinician and Specialist classes are used to define the members created by institutions. Messages transmitted between users are defined via the Inbox, Draft, and Sent classes. The Article class is used to define articles to be shared among users of the system.

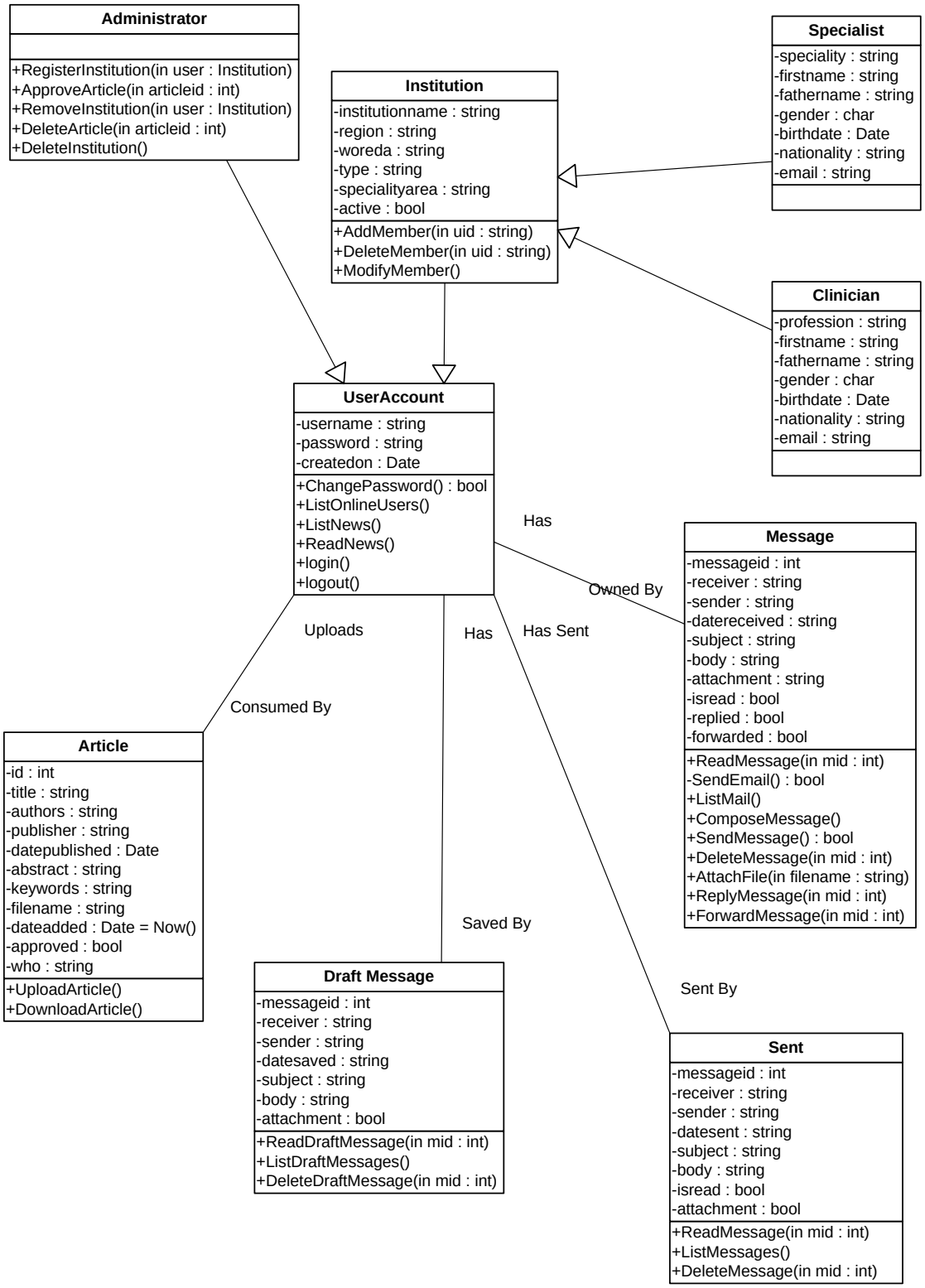

Figure 3.4 Wonfel Class Diagram

3.3.5 UML Activity Diagram

UML Activity diagram is a technique that shows the workflow using stepwise activities and actions which has beginning and ending events. Activity diagrams show the interaction among business processes. Activity diagrams convey what is happening inside a use case or inside a class through activity description. These are used to model the flow of the system.

Wonfel basically provide a messaging service along with a way to share articles and other documents. Wonfel has gone through different activities to make articles available. Figure 3.5 shows the activities carried out in uploading as well as viewing and downloading articles. In the diagram, although, administrators are only privileged to approve and delete articles, registered users with different role can perform other actions.

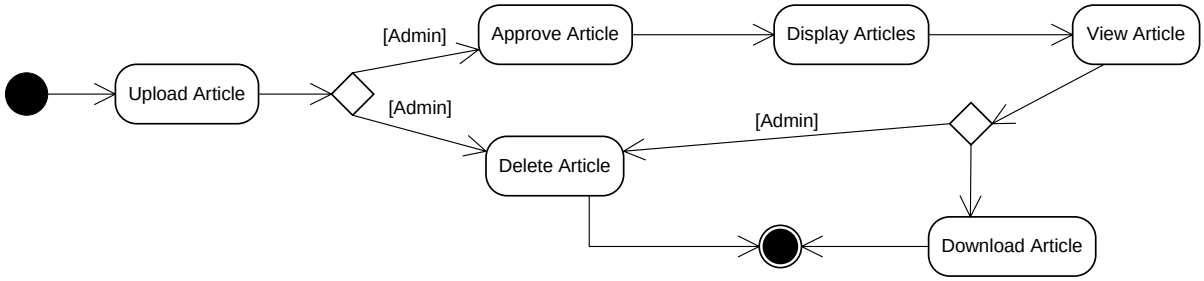

Figure 3.5 Activity Diagram of Sharing Articles

The system provides a messaging environment whereby users communicate via text messaging. The flow of activities that occurred in messaging is shown in figure 3.6. In the diagram to use the messaging functionality, users must login and these users must have either clinician or specialist role. Other roles such as administrator and institution are not liable to send and/or receive messages.

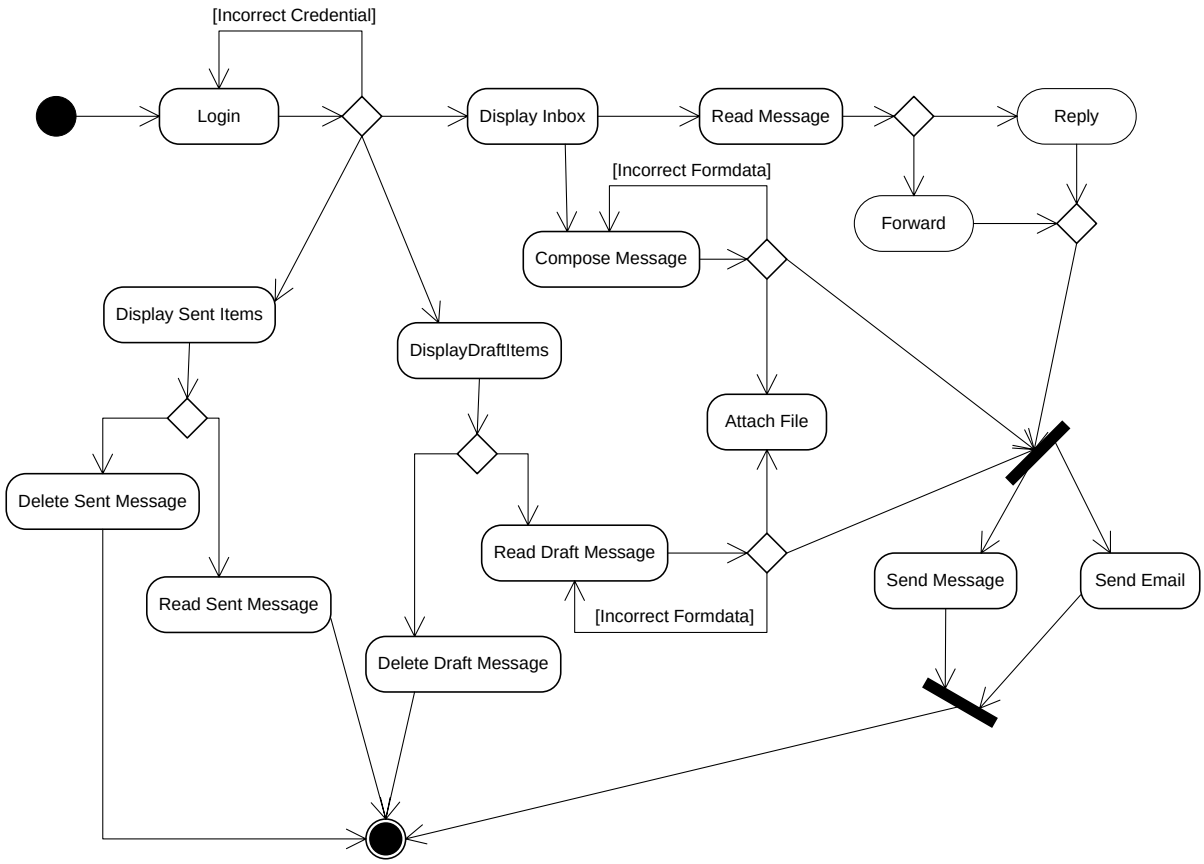

Figure 3.6 Activity Diagram of Messaging

3.3.6 UML Sequence Diagram

Sequence diagram is a diagram that shows object interactions arranged in time sequence. In particular, it shows the objects participating in an interaction and the sequence of messages exchanged[20]. Following is a set of sequence diagrams from Wonfel. In these sequence diagrams while the actor User refers to any type of Wonfel user, members are those created by institutions. Institution refers to a user of role institution.

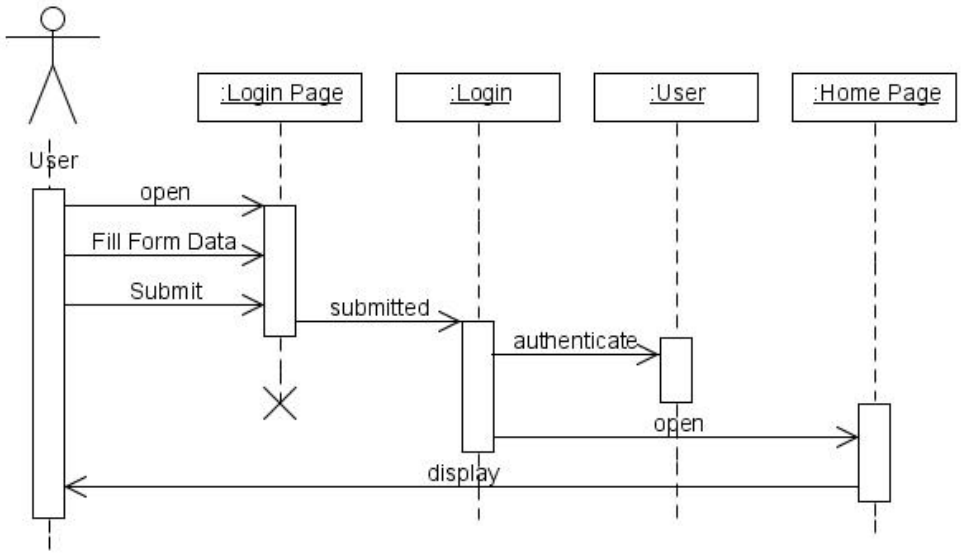

Figure 3.7 Login Sequence Diagram

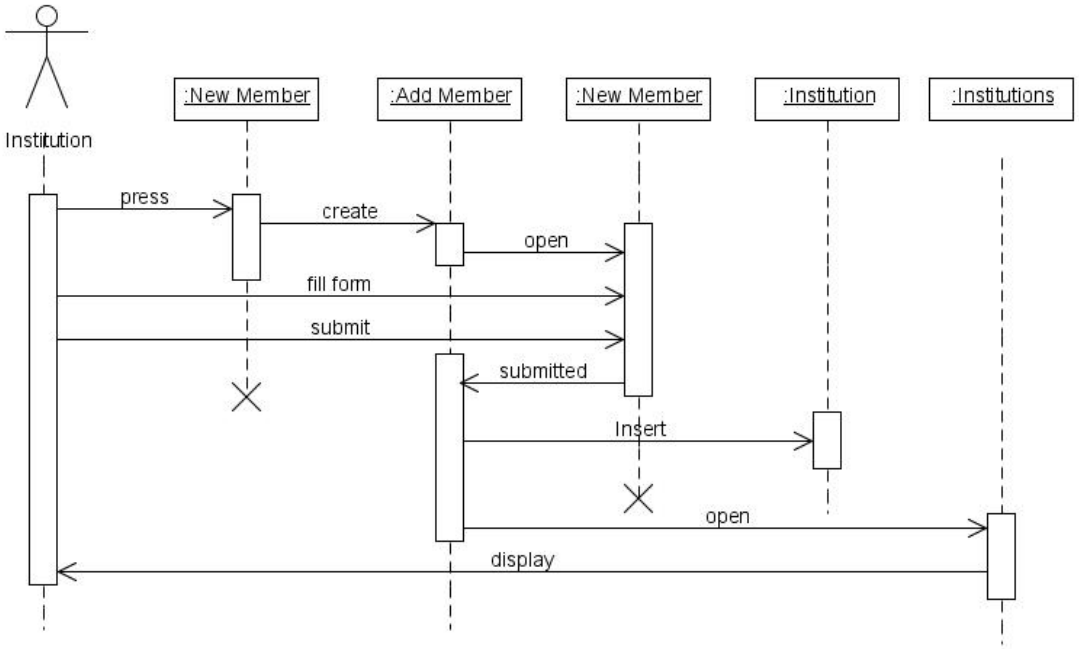

Figure 3.8 Add Member Sequence Diagram

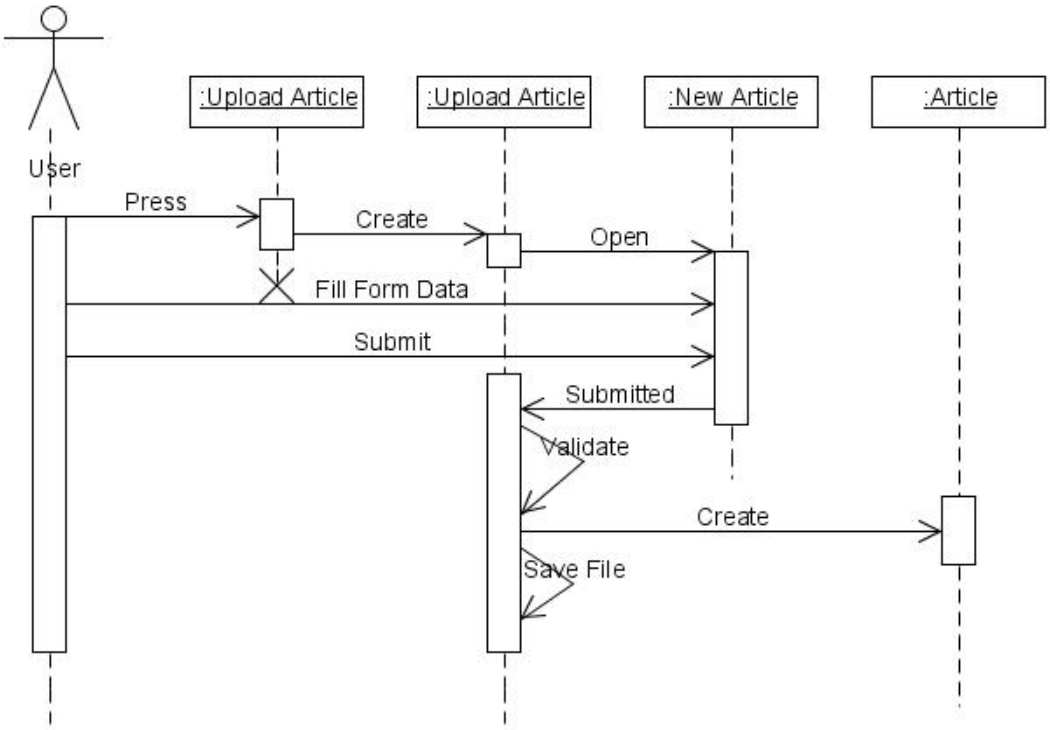

Figure 3.9 Upload Articles Sequence Diagram

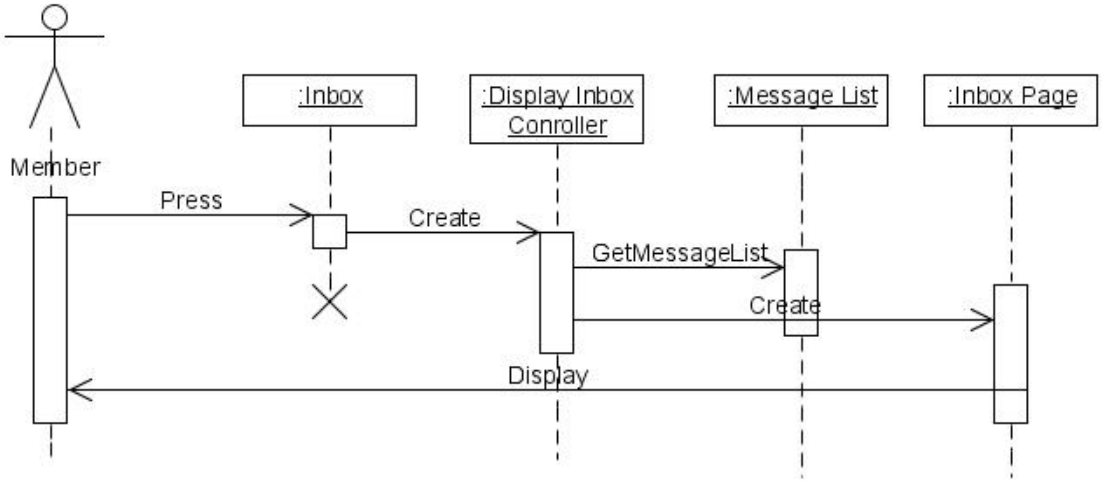

Figure 3.10 Display Inbox Page

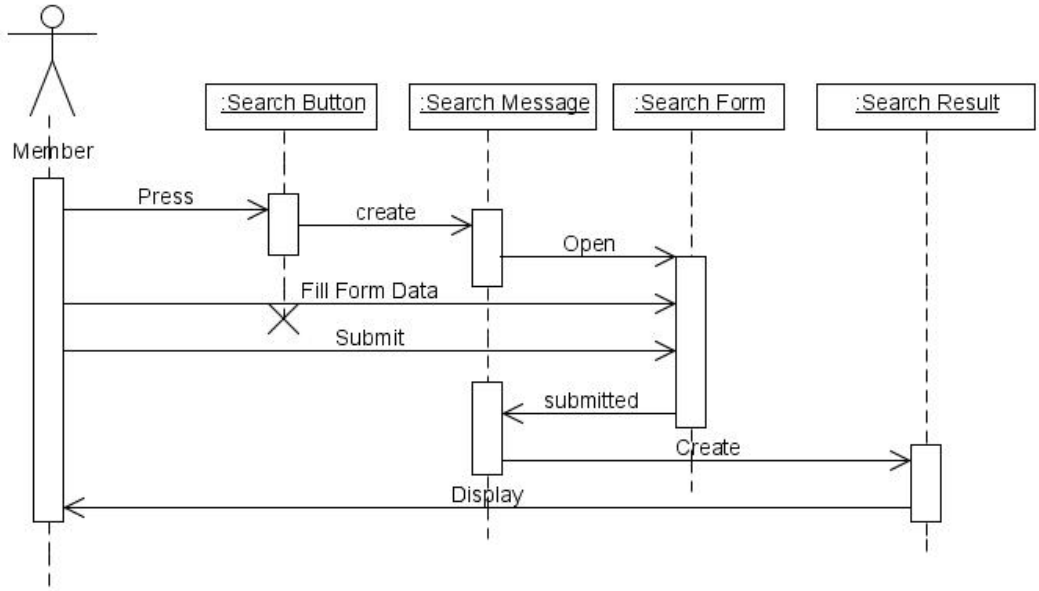

Figure 3.11 Search Message Sequence Diagram

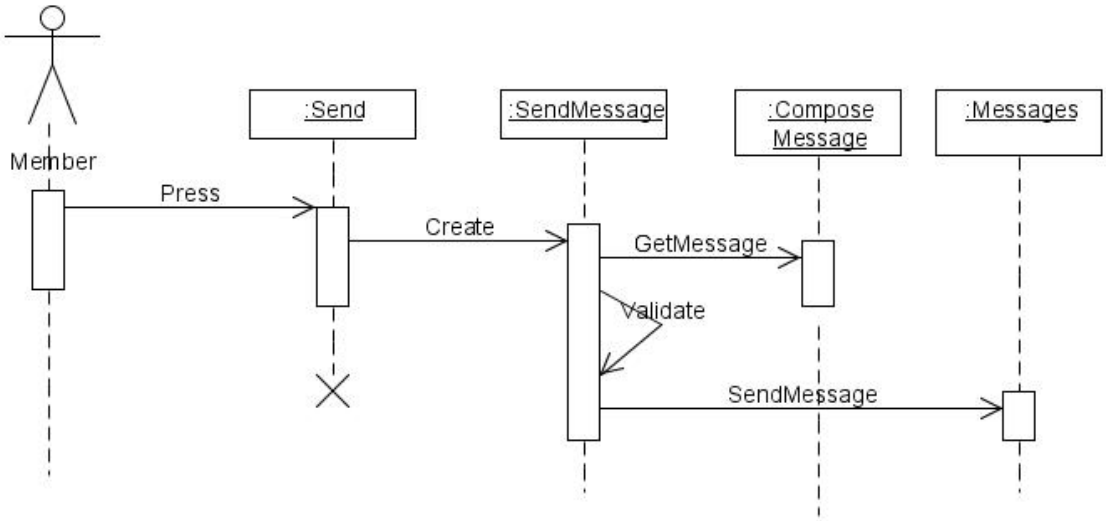

Figure 3.12 Send Message Sequence Diagram

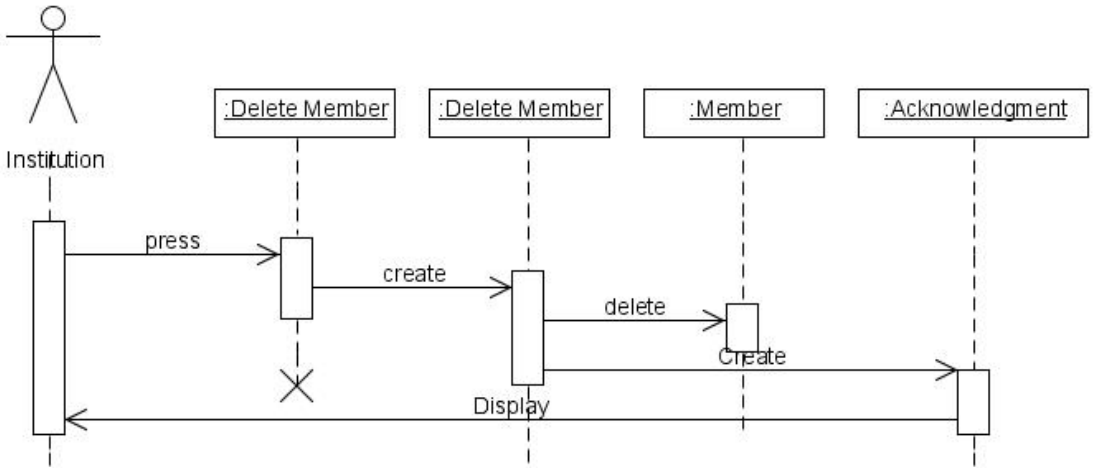

Figure 3.13 Delete Member Sequence Diagram

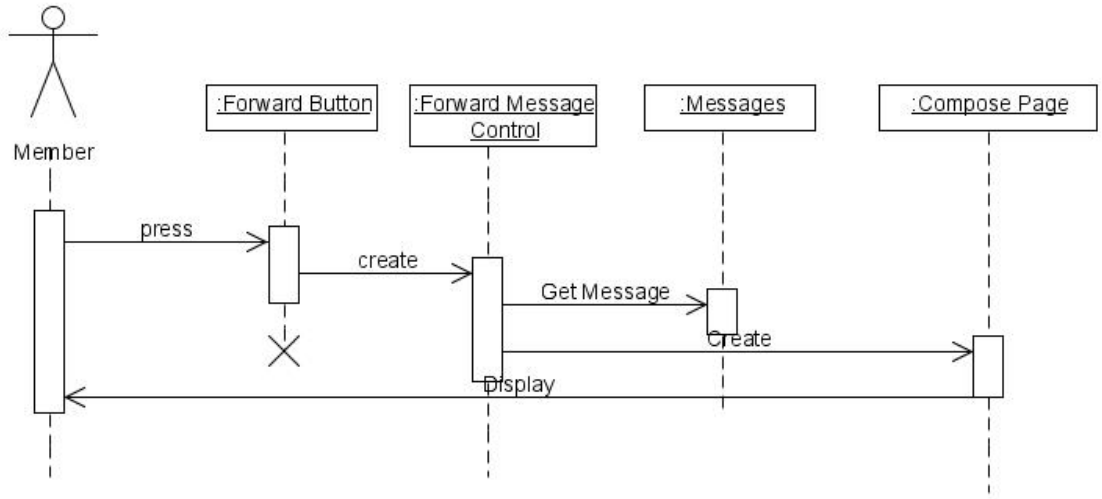

Figure 3.14 Forward Message Sequence Diagram

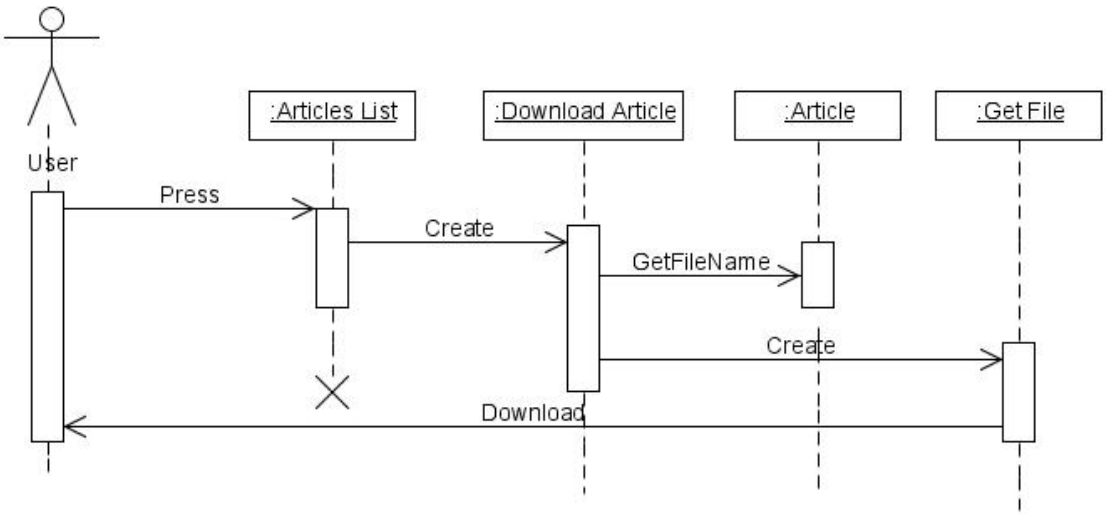

Figure 3.15 Download Articles Sequence Diagram

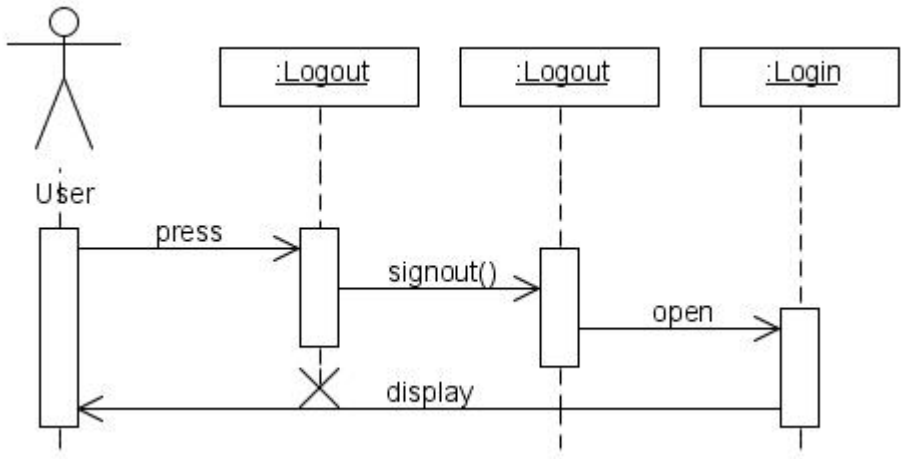

Figure 3.16 Logout Sequence Diagram

Chapter 4 System Design

4.1 Design Goals

Design goals refer to what is expected when the system under consideration become fully functional. When Wonfel is designed it is destined to have a set of desirable characteristics. Among list of goals it should achieve, the following were considered.

4.1.1 Maintenance Issues

Any system should consider what to do during a need for maintenance. It may be required to add services, serve more users, etc. Hence, Wonfel should allow seamless expansion and possess painless scalability capability. Using the layered architecture, one module can be modified without affecting the other as long as the interface is not affected. Moreover, the services can be used to add users by simply accessing those services outside the system.

4.1.2 User Interface

The system should possess a very simple user interface that let users feel easy when using it. Since it is web based the interface elements involved are thought to be very familiar to anyone having prior experience. The interfaces comprise of buttons and links which are very simple to use and make users feel comfortable in using.

4.1.3 Cost

The major challenge for telemedicine systems is bearing cost. In different stages, costs are incurred; however, it should not outweigh the benefit it brings. Therefore, any cost sustained for the system should be preserved to the possible minimal level. For users what is required is just a single general purpose computer to access the remote using the existing network.

4.1.4 Availability

Wonfel should be available whenever it is needed. Users must get the appropriate resource to send a message whenever they want to. In doing so, the system can run on the internetwork or intranetwork over the woredanet or other available networks in the nation. Since there is no external module or component involved, Wonfel can be deployed on any capable computer. When the load of the system increases, it might

hamper its performance. However the system should be able to use its utmost performance to handle greater throughput and ensure availability.

4.1.5 Security

Privacy of users, let alone in telemedicine, in any other area is very sensitive issue. Users sending their credentials to a remote site should have a certain level of guarantee. Data should be stored and/or transferred in a secured manner. Each service is available to authenticated users and the password is stored after it is hashed.

4.2 Architecture

Wonfel as a web based telemedicine system involves set of components and technologies. As the architecture is shown in figure 4.1, it involves communication of disparate computers from one site to the other over a network.

4.2.1 Network Architecture

Wonfel is a web based system, thus, it should use network infrastructure. The system is designed and developed considering the existing network infrastructure in the country. The two remotely located sites use the central server to communicate. The server is used to store text messages with images and articles.

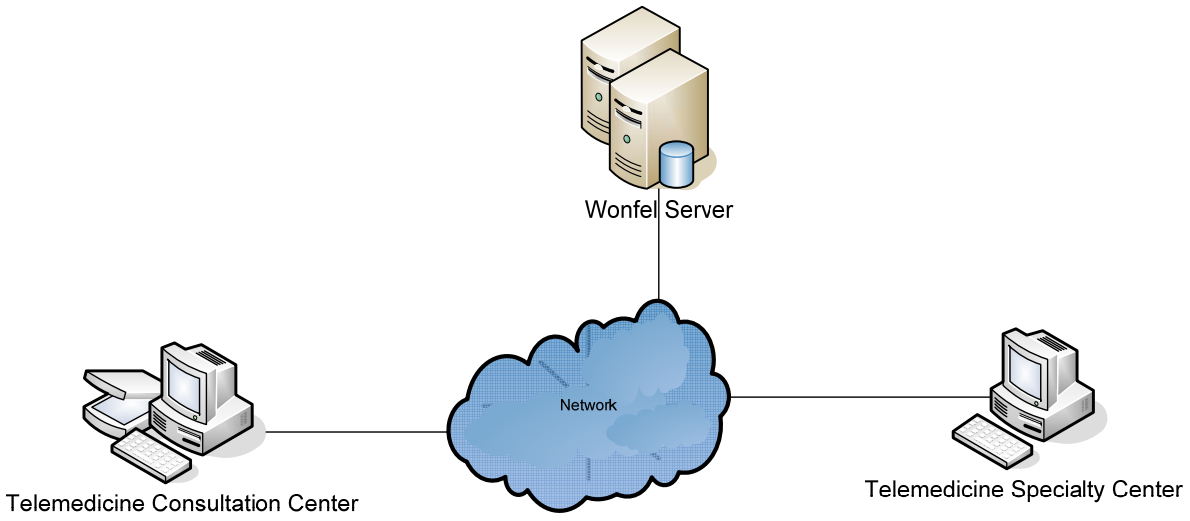

Figure 4.1 General Network Architecture of Wonfel

The Telemedicine Consultation Center (TCC), where the patient is present, initiates the communication by sending the patient symptom to the Telemedicine Specialty Center (TSC) via the centralized Wonfel Server.

4.2.2 System Architecture

Wonfel provide a messaging environment whereby users could communicate each other using the network. To promote the benefits of modular programming, Wonfel is designed using layered architecture. The layered architecture is shown in figure 4.2. The Interface Layer represents the web browser which is used to access the presentation layer. The presentation layer is created using ASP.NET web forms. The business Logic Layer is defines business rules using code behind files of web forms. The Service layer realizes services that are designed as web services so as to maintain interoperability, and extensibility. Users accessing Wonfel using web browsers use the business logic layer to work on different functionalities. The Data Access layer is used to access data from the database using different database operations via the ADO.NET API. Other layers access data through this layer.

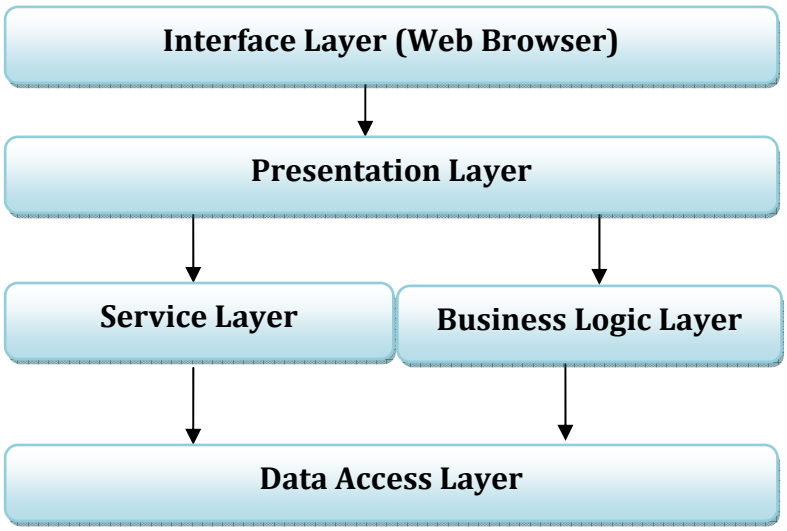

Figure 4.2 Wonfel System Architecture

The Service Layer is used to provide interfaces for functionalities exposed as web services. This layer is used by different systems and applications accessing web services. These Web services in turn serve data using the data access layer.

4.3 Services Design

In order to empower Wonfel so that extending the services and making interoperable is quite straight forward, it is designed using SOA. Some of the functionalities of the system are exposed as services. These services are realized using web services. The

service layer from the system architecture represents these services. In Wonfel there are about three messaging services made available to external systems and applications.

The exposed services are designed and implemented as a single module. In the module, the services are provided as simple method calls. But to complete the call authentication header must be added to the SOAP request. The services available are:

1. GetMessages: This service is designed to deliver list of messages for a specific user. The messages sent to the user are returned.
2. GetArticles: The list of articles is returned using this service. All these articles are approved to be shared. But this simply gives list of them with no option to download the actual article file.
3. SendMessage: This service is used to send a message between users. The sender and receiver along with the message to be sent should be provided as arguments.
4. ReadMessage: Since messages in Wonfel are stored as text messages, it is possible to read them on any platform. This service is used to access the actual message to be read.

This web service module is enabled for Microsoft WSE (Web Service Enhancements) to empower the services in terms of security. The username token is added to the soap header. This will then be checked during service operation to ensure authenticated users are accessing this service.

4.4 Hardware and Software Mapping

The hardware and software mapping is modeled using deployment diagrams and depicts a static view of the run-time configuration of processing nodes and the components that run on those nodes. In other words, deployment diagrams show the hardware for a system, the software installed on that hardware, and the middleware used to connect the disparate machines to one another[18]. This section of the project shows the set of hardware and software components in Wonfel.

In Wonfel, web browsers request a Wonfel server and the server depending on the request the server returns the appropriate page using Hyper Text Transfer Protocol (HTTP). Apart from such communication, services can be requested via their service interface by other systems. External Systems send SOAP requests to access services

from the server. Data from the database is accessed using ADO.NET and served via appropriate data access layer interfaces. Figure 4.3 shows the deployment diagram of Wonfel.

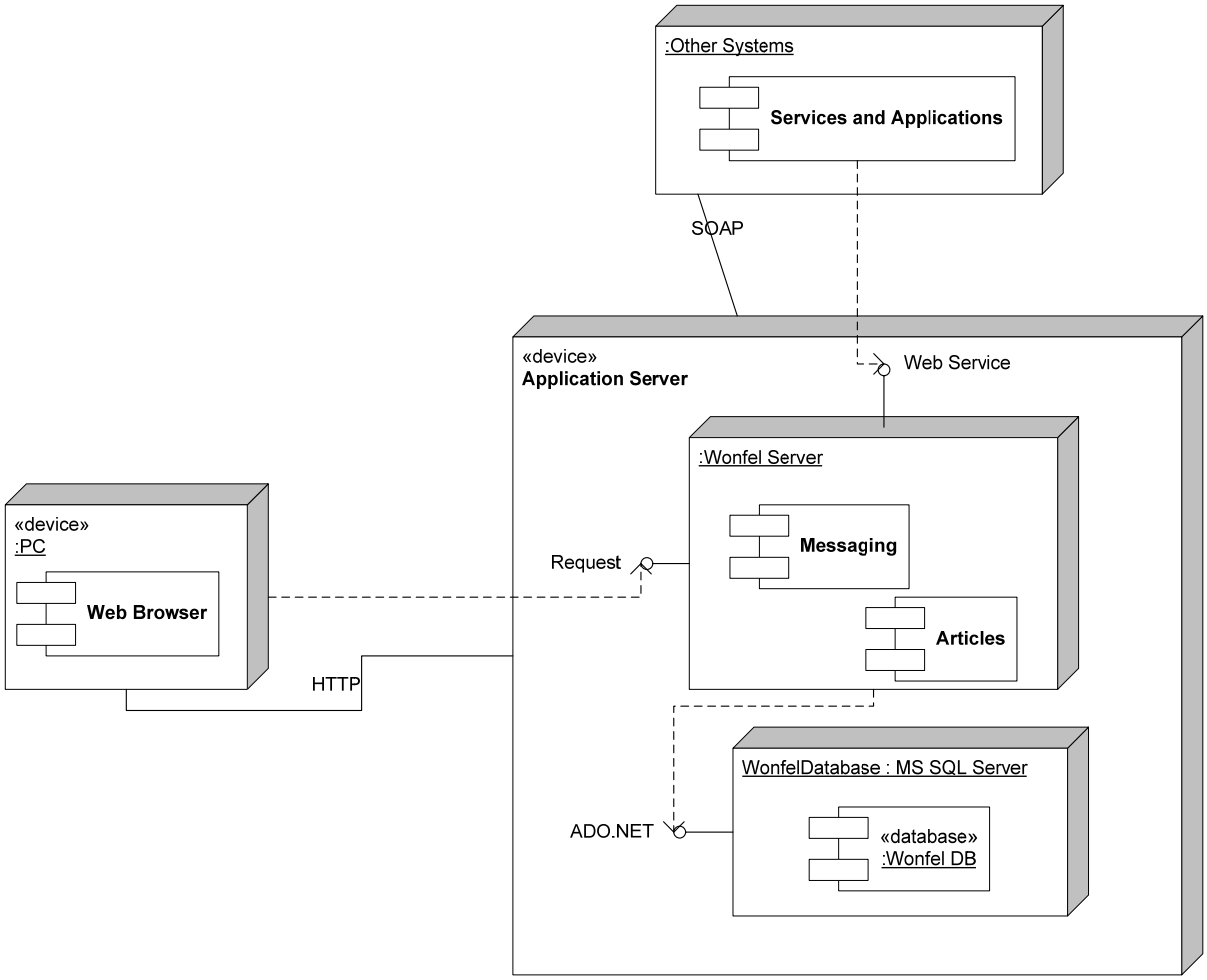

Figure 4.3 Wonfel Deployment Diagram

4.5 Persistent Data Management

Most functionality in Wonfel deals with data. Hence this section discusses the data that is stored persistently. Database system is designed to store data about the messages transmitted between users. Persistent data about users themselves required to be stored so that they can be authenticated and let them communicate each other. Moreover data about articles to be shared are stored in the database as well. Figure 4.4 shows the tables designed in the database and their relationships. Apart from the appropriate field values, files such as articles or attachments are store in the file system while their filename is stored in the database.

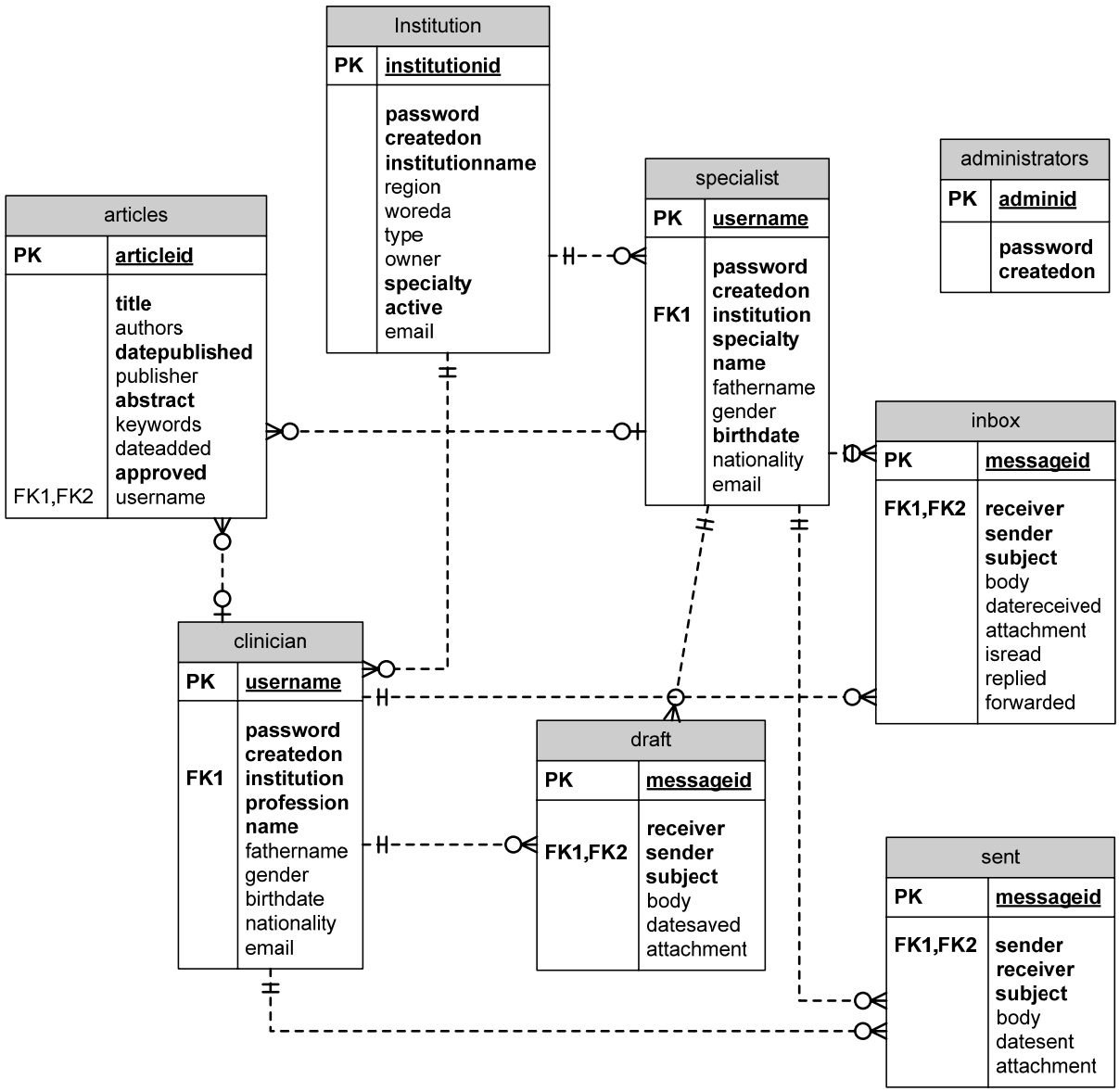

Figure 4.4 Identified Tables and their Relationships

Chapter 5 Implementation

5.1 Tools

The system is designed using various tools that are used to accomplish a different task and define a certain components of the system. Since it is web based, it is developed as ASP.NET web forms using .NET Framework 2.0.

The user interface is designed using Macromedia Dreamweaver 8, along with Visual Studio 2005 to generate automatic interface elements. But the business logic is defined using C# programming language in the Visual Studio 2005 environment. The services are realized using ASP.NET web services via C#.

The system uses database to store messages as well as user profiles and shared documents. This database is developed using Microsoft SQL Server 2005. Finally, as a web based system developed via ASP.NET, it runs under Microsoft Internet Information Server (IIS).

Hence, the system requirements of a computer to run Wonfel include the following:

- ➔ Microsoft SQL Server 2005 – to manage the database
- ➔ .NET Framework 2.0 – to run the application logic
- ➔ Microsoft IIS 6.0 – to run the web application
- ➔ Microsoft WSE 3.0 – to secure the services

5.2 Prototype

When the system is started, it displays the login form so that users should authenticate. Unless users are authenticated they cannot use the system. The login form, which is shown in figure 5.1, requests users to enter their username and password.

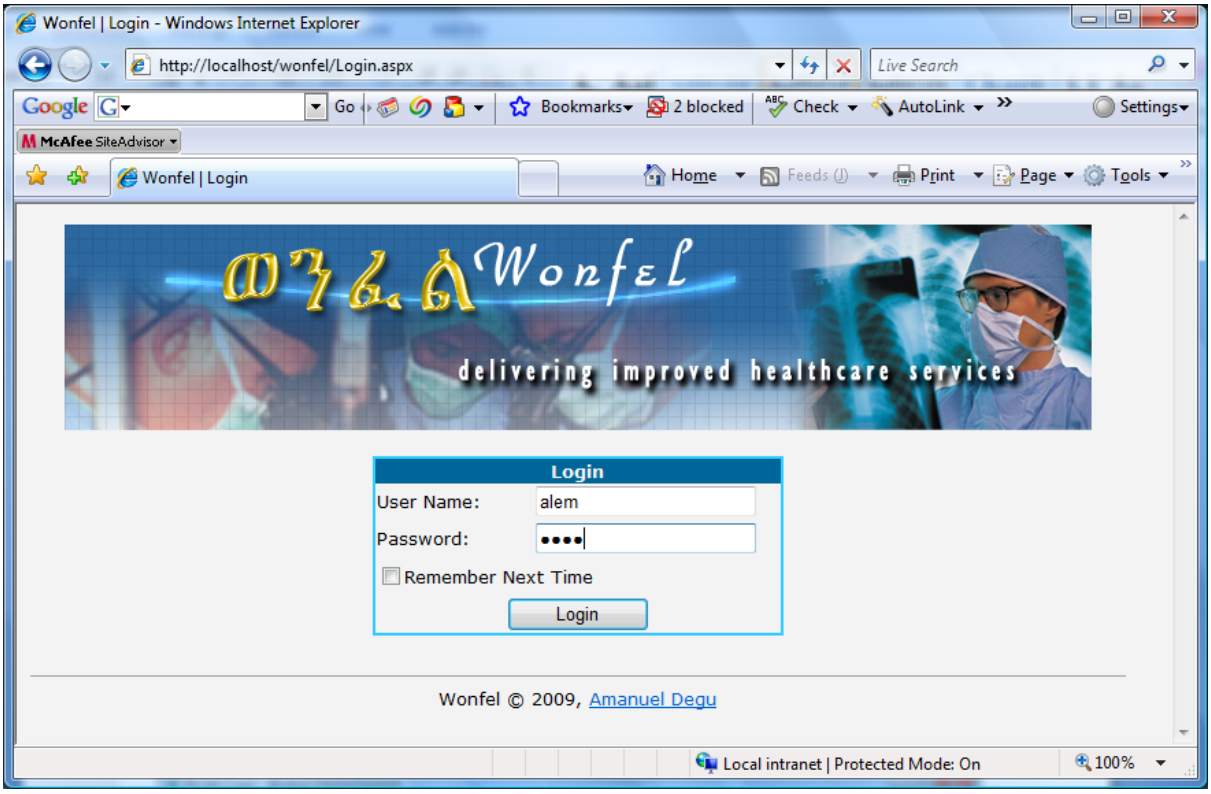

Figure 5.1 Login form window

After users are authenticated, depending on their roles the home page id displayed with varying links. Member users (clinicians and specialist) can participate in messaging; hence, messaging links would be shown. However articles are available for all system users. As the home page shows in figure 5.2 health related news are fetched from three different feeds and displayed along with links and appropriate short descriptions. When news are displaying it might took moments depending on the internet connection speed.

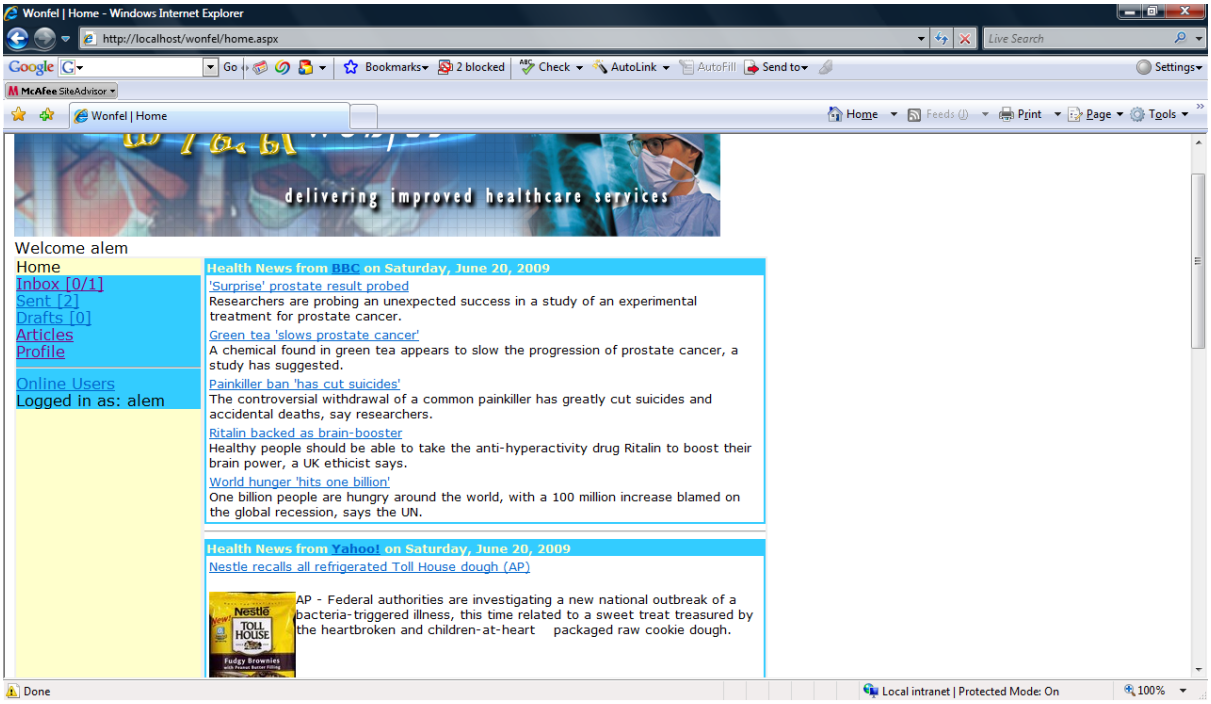

Figure 5.2 Home Page Window

Once the home page is displayed, it becomes apparent to use the system via the links given on the left side of the window. It is easy to access available articles through the articles link and message related functionality is available through the Sent, Inbox and Draft links. All links won't be available to all users, because of the role users have in the system. This is possible by setting the role of the currently logged in user. Institutions cannot access messaging functionality, for example.

Articles and other documents are shared through the articles page. The articles page as shown in figure 5.3 lists approved articles. Users can download these articles after viewing the article's detail information via the title's link.

Figure 5.3 Wonfel Articles Page

Articles are contributed by users of the system. However, articles need to be approved by administrators so that users can share it. The administrator's article page allows approving or disapproving an article.

Apart from sharing articles, the main functionality of Wonfel is messaging. The messaging tasks can be reached via the appropriate links and buttons. But these user interface elements are only accessible to member users. The inbox link display the inbox page as depicted in figure 5.4 and that lists messages sent to a user. From this list messages can be read by just clicking on their subject text. Messages can also be replied, forwarded or even deleted using appropriate buttons. From the list, while only one message can be replied or forwarded, multiple messages can be deleted.

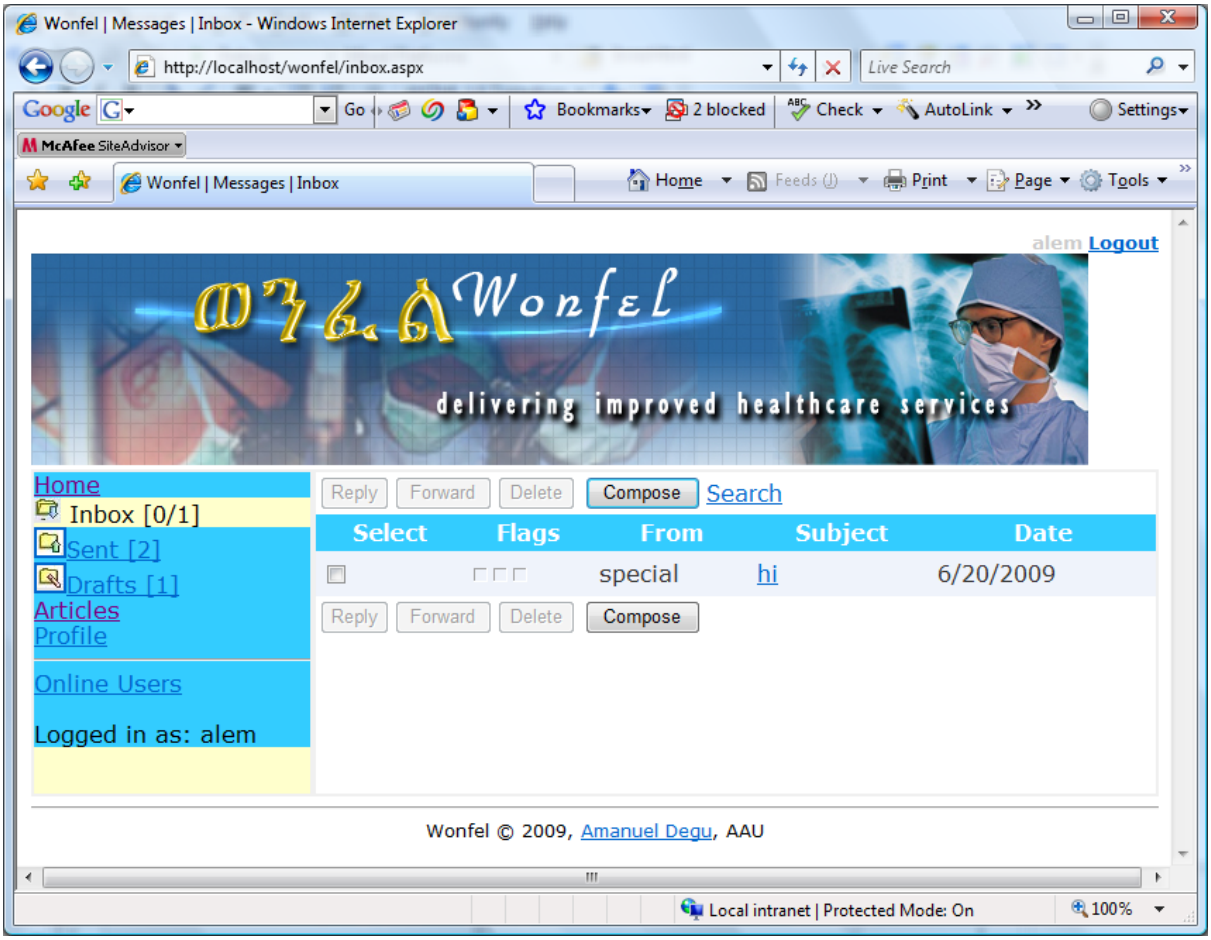

Figure 5.4 Wonfel Inbox Page

Messaging functionality starts with displaying inbox where list of messages sent to a user is displayed. Attachments are also possible for messages, and the filename of an attachment is displayed when the message is read. Then it is possible to open the attachment image by clicking on the filename. The draft messages and sent messages are stored for later reference, though without attachment files, if any. The draft and sent pages display list of respective messages as shown in figure 5.5 displaying list of draft messages.

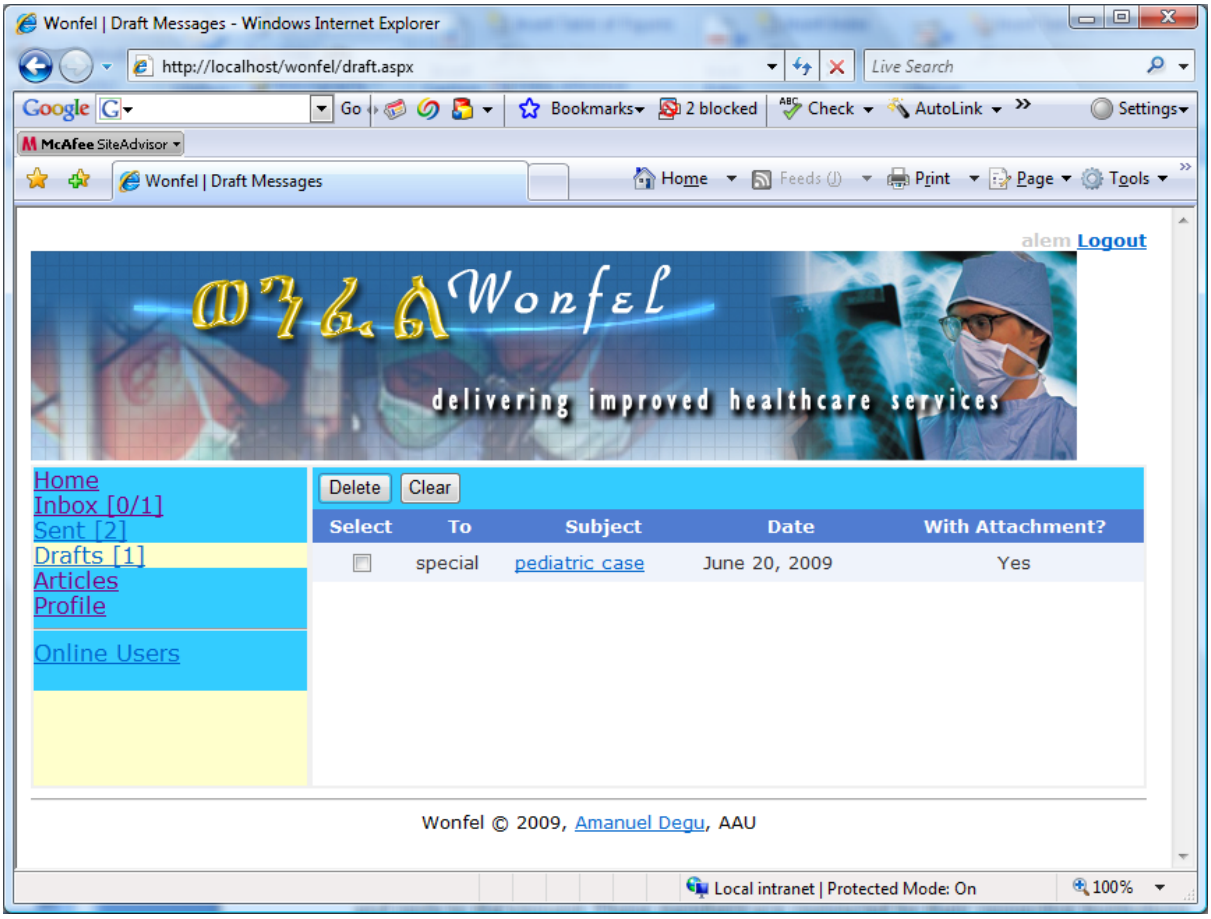

Figure 5.5 Wonfel Drafts Page

Member users can use the messages to communicate about a clinical case. Request for consultation is initiated by the consultation center where as the specialty center read and reply to the request. These members are registered by their respective institutions. Institutions can manage their members, deleting, adding and modifying member users is done using the members page.

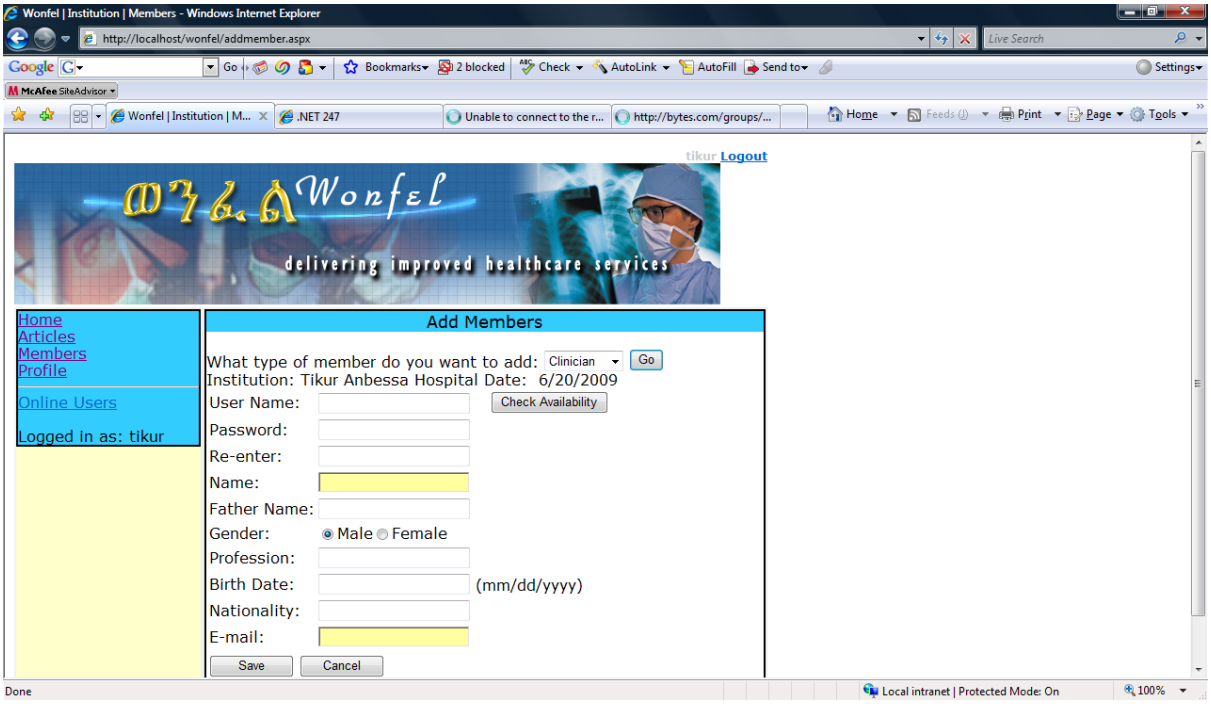

Figure 5.6 Add Members Page

When institutions add members using the page shown in Figure 5.6 duplicate usernames are avoided by checking before setting a given name. The current username is checked for its existence via the Check Availability button. Then after the member is registered s/he can communicate with others from remote site.

Institutions are registered by administrators after a form filled by institutions is submitted. But these institutions should be active to participate actively in order to login and create members. When institutions became inactive after a while, they couldn't login to the Wonfel. Members of inactive institutions are also unable to login and access Wonfel's functionalities. The administrator's institutions page as shown in figure 5.7 is used to manage registered institutions.

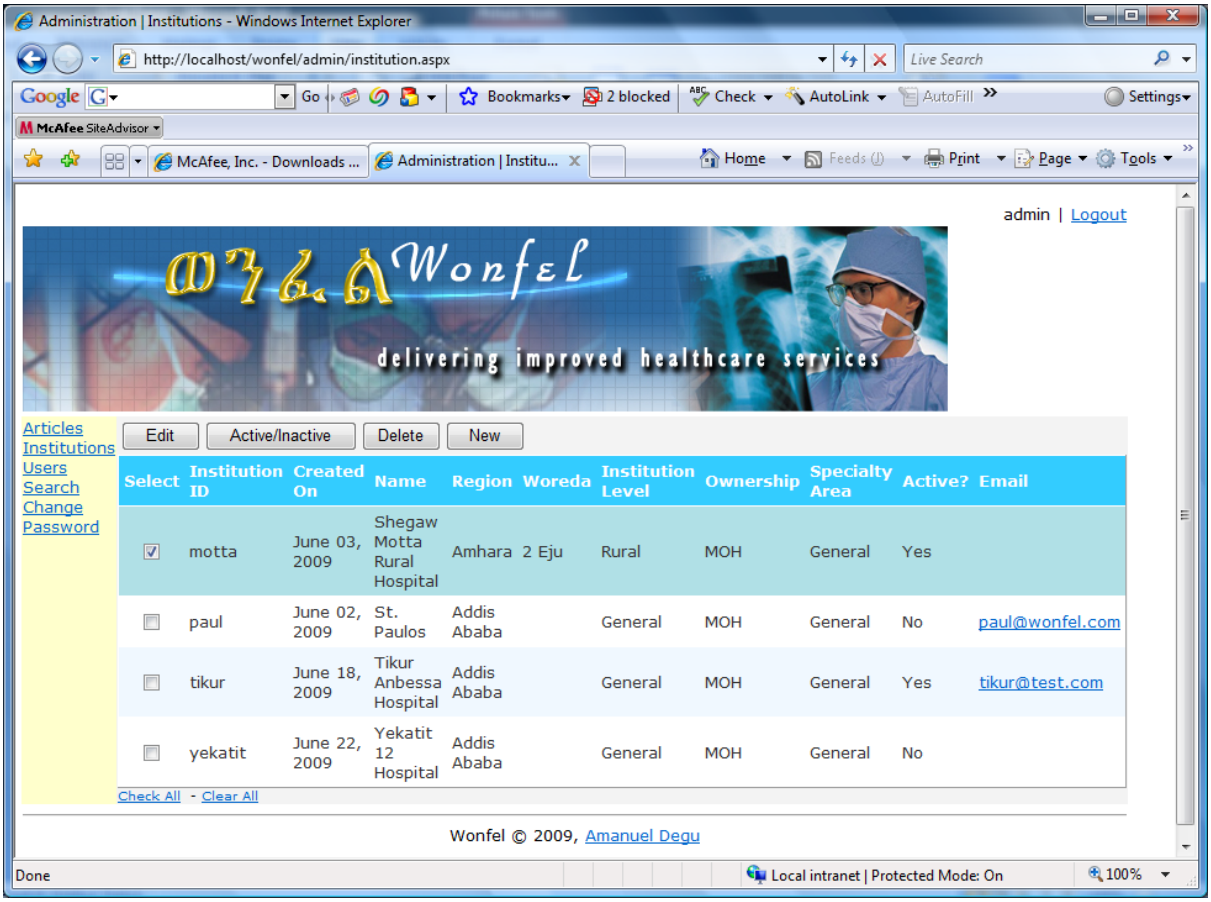

Figure 5.7 Institutions Page is used to manage existing institutions

In addition to institutions, administrators manage articles. They could approve, delete or edit articles uploaded by users. Articles are administered using the articles page. The articles page as shown in figure 5.8 is used to edit, toggle approval state and/or delete an article.

Figure 5.8 Articles Page

After the articles are uploaded by users and approved by the administrator, they could be downloaded by users. To download an article, users need to use the article page which lists only approved articles whereby the article's title is linked to the page to enable download. When the title is clicked, it will start the download process by prompting to either open or save using the Download window as it is shown in figure 5.9.

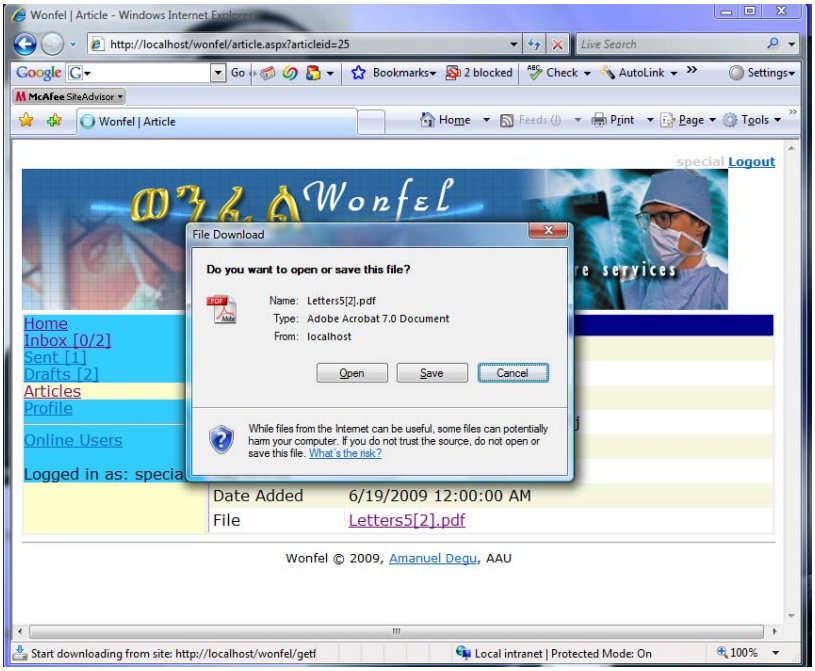

Figure 5.9 The file download window to download an article

5.3 Testing

Systems are methodical and systematic approach to the elements of software development: requirements analysis, modeling, design and architecture. To what extent of curiosity is the entire process carried out, some mistakes in the process of development are unavoidable. Hence, systems are subject to tests before implementation in order to:

- ➔ Leave no error
- ➔ To unearth potential problems
- ➔ To ensure the right software product is delivered
- ➔ To achieve user satisfaction and customer acceptance

In order to deliver Wonfel without compromising its functional requirements, testing is performed. Tests on Wonfel are carried out to ensure the functionalities of the system. Functional testing is carried out to confirm that the system meets functional requirements identified in requirements analysis.

For the seamless integration of components, integration testing is carried out. This test ensures the various components are working together. Although the functionality is tested individually, integration testing assures the perfect integration of components.

Although, professionals informally respond that they are using general purpose email services, it may not be appropriate to decide the usability of the system. From the interview it is learnt that health professionals are participating in the telemedicine system established in Jimma. Hence, it would be correct to deduce that Wonfel can be usable.

Chapter 6 Conclusion and Future Works

The level of healthcare service provision in the country is low. The number of professionals and health infrastructure is not enough to serve the current population level. The government is striving and vowing to fulfill the millennium development goals in providing basic healthcare service. However, still communicable diseases remain to be threats of Ethiopians.

Nowadays, it is not uncommon to see the involvement of ICT in various instances to facilitate different developments of human society. Though, there had been minimal involvement of ICT in healthcare, it is now playing a pivotal role in improving provision of healthcare services.

The use of ICT in medical care is termed as either telehealth or telemedicine depending on the coverage and application. Advanced ICT equipments and technologies are used in enabling communication as well as accessing and accurately measuring data. If the communication between parties in healthcare is followed by clinical diagnosis, it is most often called telemedicine.

Telemedicine is the use of medical information exchanged from one site to another over network. Telemedicine is conducted based on two technological concepts: store-and-forward and real-time. The first is to send a message that is to be accessed sooner or later. The reply is considered as a consultation of the previous message. The later telemedicine type involves advanced electronic equipments to interactively let the two sides communicate.

Based on the interest of system owners, telemedicine systems could be tailored to a specialty area or serve for any clinical discipline. Different applications of telemedicine are referred with terms starting with ‘tele’ as in teleconsultation, teleradiology, telecardiology, etc.

In this sense, Wonfel is designed as a store-and-forward teleconsultation system. It allows users communicate each other via text messages with a possibility of attaching an image. The system doesn’t focus on a specialty field; rather, any case can be consulted.

Using the system, health professionals in rural areas can reach specialists residing in cities. This enable to lift the level of healthcare delivered to patients. Specialists could also reach wider patients.

For example, a nurse in a rural health center might get confused on the symptoms and test results of a case. S/he could send the symptoms and test results to a specialist in a city. The specialist reads the message and reply to the message giving the appropriate interpretation.

Health professionals need to update their medical knowledge so that they can handle clinical cases. Additionally, new epidemic in different parts of the world is communicated through the Internet. Currently Wonfel fetched news from three different sites to display and let users browse it using the link on those sites. At the moment these news are accessed from BBC, Yahoo, and AllNews sites.

Although, the current news from these sites is one good thing, it is definitely not a comprehensive source. There should be a mechanism to access reference materials. Wonfel enable sharing documents that are written and/or contributed by pro users. These articles should of a certain formats so that their accessibility is not thwarted.

Apart from its design to consider the current network infrastructure, the major characteristics of Wonfel lie in the support for SOA. Some functionalities of Wonfel are exposed as services realized through web services. These services can be accessed by other systems and be integrated into these systems.

6.1 Future Works

Wonfel is a telemedicine application enabling users communicate via text messages in a store-and-forward concept. The following features are deemed to be future points of interest on Wonfel.

- ➔ Allowing multiple attachments on a single message
- ➔ Extend the services exposed to the public
- ➔ Sending alert message to specialist's mobile phone as SMS
- ➔ Enable interactive communication – in line with the network capacity
- ➔ Maintaining its simplicity, improving the user interface

References

[1] *Health and Health Related Indicators*, FDRE Ministry of Health, January 2008.

[2] *Telemedicine Defined-American Telemedicine Association*, http://www.americantelemed.org/i4a/pages/index.cfm?pageid=3333 accessed on March 1, 2009.

[3] *Telehealth and Telemedicine*, http://www.telecare.org.uk/information/42290/46200/telehealth_and_telemedicine/ accessed on March 1, 2009.

[4] *Privacy, Security, and Confidentiality in Telemedicine, Telemedicine Report to Congress*, January 31, 1997.

[5] Liqiong Deng, Marshal Scott Poole, *Learning Through Telemedicine Networks*, Proceedings of the 36th Hawaii International Conference on System Sciences, 2003.

[6] Asadullah Shaikh, Muhammad Misbahuddin, *A System Design for a Telemedicine Health Care System*, Master Thesis in Software Engineering and Management, Department of Applied Information Technology, IT University of Goteborg, Goteborg, Sweden, 2007.

[7] S. Sridhar and S. Kanakaraj, *Telemedicine Systems*, Raja Rajeswri Engineering College, Adayalapattu, Chennai, India.

[8] Firat Kart, Gengxin Miao, L. E. Moser, P. M. Melliar-Smith, *A Distributed e-Healthcare System Based on the Service Oriented Architecture*, IEEE International Conference on Services Computing, 2007.

[9] Wail M. Omar and A. Taleb Bendiab, *Service Oriented Architecture for E-Health Support Services Based on Grid Computing Overlay*, IEEE Internatioal Conference on Services Computing, 2006.

[10] Fasil Terefe, AAU Computer Science, MSc Thesis, *A national telemedicine system with multi-criteria doctor's unit selection model for developing countries: the case of Ethiopia*, 2008.

[11] *Survey of Current Efforts and Potentials in Application of Telemedicine in Ethiopia,* Fikreyohannes Lemma, Solomon Atnafu, Samuel Kinde Kassegne, http://www.digitaladdis.com/sk/TeleMedicine_Ethiopia_Paper1.pdf, accessed on April 21, 2009.

[12] *What is Telemedicine and Telehealth*, http://www.americantelemed.org/files/public/abouttelemedicine/What_Is_Telemedicine.pdf, accessed on April 20, 2009.

[13] Tayab D Memon, B. S Chowdhry, Mohammad S Memon, *The Potential of Telemedicine System: An Approach Towards a Mobile Doctor*, National conference on Emerging Technologies, 2004.

[14] *The Potential Uses of ICTs*, http://cbdd.wsu.edu/kewlcontent/cdoutput/TR501/page10.htm accessed on May 1, 2009.

[15] *Recommended Guidelines & Standards for Practice of Telemedicine in India*, B S Bedi, Department of IT, http://www.solutionexchange-un.net.in/health/cr/res30090501.pdf, accessed on April 20, 2009.

[16] Fikreyohannes Lemma, Samuel Kinde, Solomon Atnafu, *Design of Architecture and Implementation Issues for a Terrestrial and VSAT based National Telemedicine Network in Ethiopia,* MSc. Thesis, Department of Computer Science, AAU, 2004.

[17] *Telemedicine Pilot Project in Ethiopia*, National Telemedicine Coordinating Committee, http://www.itu.int/ITU-D/fg7/case_library/case_study_2/Africa/Ethiopia.pdf, accessed on May 20, 2009.

[18] Scott W. Ambler, *The Object Primer*, Third Edition, Cambridge University Press, 2004.

[19] Waman S Jawadekar, *Software Engineering: Principles and Practice*, Tata McGraw-Hill, New Delhi, 2004.

[20] James Rumbaugh, Ivar Jacobson, Grady Booch, *The Unified Modeling Language Reference Manual*, Addison Wesley, 1999.

[21] *Ethiopian Telecommunications Corporation Web Site*, http://www.ethionet.et accessed on April 2009

[22] Latha Srinivasan and Jem Treadwell, *An Overview of SOA, Web Services, and Grid Computing*, http://h71028.www7.hp.com/erc/downloads/soa-grid-hp-whitepaper.pdf

Annex

A. Ministry of Health Indicator Report

Table 2 Summary of Health and health indicators, FMOH, 2000 E.C.

Indicators	1996	1997	1998	1999	2000
Total population	69,127,021	73,043,510	75,067,000	77,127,000	79,221,000
PHS coverage (%)	64.0	72.1	76.9	86.7	89.6
EPI Coverage (%)*	60.8	70.1	75.6	72.6	81.0
Health service utilization	0.36	0.3	0.33	0.32	0.24
Contraceptive acceptance rate	23.0	25.2	35.8	33.6	50.9
Antenatal coverage	44	46	50.4	52.1	59.4
No of Facilities					
Hospitals	126	131	138	143	149
Health centers	519	600	635	690	732
Health stations +NHC	1,797	1,662	1,206	1,376	1,517
Private clinics not for profit	359	379	480	397	271
Private clinics for profit	1,299	1,578	1,784	1,756	1,788
Health posts	2,899	4,211	6,191	8,528	11,446
Pharmacies	275	276	246	320	NA
Drug shops	375	381	476	577	NA
Rural drug vendors	1,783	1,787	1,754	2,121	NA
Human Resource in Service					
Physicians	1,996	2,453	2,115	1,806	2,085
Health officers	683	776	715	1151	1,242
Nurses	15,544	18,809	17,845	18,146	16,765
Health assistants	6,628	6,363	4,800	3184	2,140
Para medicals	5,215	6,259	5,431	3,863	7,731
Health extension workers		2,737	9,900	17,653	24,571
Human Resource Graduated					
Specialists	96	183	57	207	168
General Practitioners	193	309	188	161	162
Health officers	249	333	247	789	2,289
Nurses	2,384	4,536	1,618	1,846	2,010
Para medicals	9,99	803	791	789	1,103
Health extension workers	2,737	7,090	7,136	8,560	6,918

Declaration

I, the undersigned, declare that this project is my original work and has not been presented for a degree in any other university, and that all source of materials used for the project have been duly acknowledged.

Declared by:

Name: Amanuel Degu

Signature: _____

Date: _____

Confirmed by Advisor:

Name: Ato Sebsibe H/mariam

Signature: _____

Date: _____