Design of Architecture for a Terrestrial LAN & VSAT-based National Telemedicine Network in Ethiopia

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Abstract

For a developing country such as Ethiopia with a difficult mountainous terrain and limited transportation infrastructure coupled with one of the lowest patient-doctor ratios anywhere in the world (almost 30,000 to 1), telemedicine offers a cost-effective health-care system. This awareness is slowly gaining traction in the country with a pilot program entering a trial and implementation stage. Looking forward, however, we argue that telemedicine should play a more prominent role in the national health-care plan mainly due to its cost-effectiveness and the availability of a substantial number of Ethiopian physicians living abroad - in some accounts more Ethiopian physicians live outside Ethiopia than inside - whose expertise can be tapped.

Further, we propose a comprehensive design of network architecture for a nation-wide telemedicine network that connects all regional hospitals and health centers with the urban public and government hospitals. Specifically, we propose a high level telemedicine network architecture, which can be implemented over the existing/emerging ICT infrastructure in Ethiopia. The network connects all regional clinics with public/government urban hospitals for the purpose of data transmission in the form of text and images, as well as instantaneous access to patient information. We also propose a web based telemedicine system, which provides basic services for medical tele-consultation. The system can be used by health care providers to store and retrieve patient information, to write referrals and give feedback to referrals, by using a web based Graphical User Interface (GUI) specifically designed for Telemedicine.

The core technical contributions of our study include a Web-interface for a hierarchical model based LAN architecture that enables design of the inter-network devises in layers and a WAN architecture – both fine-tuned for the conditions in Ethiopia. The hierarchical model adopted for the LAN is a preferred model due to its ease of expandability and improved fault isolation characteristics. The WAN design considers the currently existing VSAT-based WAN infrastructure in the country, namely the WoredaNet and SchoolNet.

The study also demonstrates a prototype network architecture that provides ability for the growing number of private hospitals to be able to join the network. VSAT and terrestrial LAN will form the backbone of the network architecture. This will enable the provision of Internet Protocol interface that will feature a seamless integration of a trans-national telemedicine component for Ethiopian physicians and other health professionals currently practicing outside Ethiopia.

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1. Introduction

People want to get access to proper health care, which meets their needs at affordable costs. Health care has to be available when they need it to their proximity. Physical separation between the people and health care facilities must not pose any limitation to the efficient health care delivery to remote areas. Information Technology (IT) is a best choice to offering access to health care service to the expectation of people, when there is limited access to health care. In this regard, Telemedicine has developed during recent years with the development of technologies such as Integrated Services Digital Network (ISDN) and Asynchronous Transfer Mode (ATM) networks [1]. Both the health care providers and patient can benefit from those networks. In Ethiopia, such a technology is emerging. The development of telemedicine has to follow the same truck.

IT based horizontal and vertical communication between the health care facilities following the organizational structure of the health system is essential. It facilitates efficient information exchange and hence helps delivering health care to underserved rural areas. Such communication is possible by implementing a nation wide Telemedicine network, based on affordable telecommunications infrastructure. The network should connect all regional clinics to urban area hospitals in the country for the purpose of:

- Establishing a reliable horizontal and vertical communication between the health care facilities driving a quality and an improved health care delivery to all citizens.
- Achieving e-health commitment and bring health care closer to underserved and un-served rural areas.
- Strengthening collaboration efforts among hospitals and facilitating information exchange and experience sharing among medical professionals practicing in remotely located clinics.
- Minimizing long distance travels of rural people to urban areas or to the capital city seeking proper medical care during trauma.
- Providing medical information to the medical practitioners, which will help them to keep themselves up to date with the current technology.

Even if urban areas are relatively better equipped with adequate ICT technology such as Internet access and digital telephone networks, the communication infrastructure is not as developed in many other rural regions. These regions have to be equipped with an access to urban areas. In this regard the newly emerging state owned, low cost VSAT networks such as SchoolNet and WoredaNet provide the rural areas with suitable means of communication to urban areas and further to the world.

2. Telemedicine Network Design Considerations

2.1. Design Goal

The overall goal of the nation wide telemedicine network design is to provide a system which meets the needs as outlined in the previous paragraphs. The system implements connectivity among rural clinics and urban area hospitals to be used mainly for tele-consultation, and maintaining patient information.

As the main design goals, the network should be cost effective, expandable, secure which provides state-of-the-art ICT access scheme to rural area clinics. Existing ICT infrastructure will be given priority to minimize cost of implementing the network. In this design the following specific design goals were given priority.

2.1.1. Expandability

Expandable system is one in which additional inputs and outputs (such as the number of incoming data, the number of simultaneous users served, the number of clinics to get connected, etc) can be added without a major reworking of the network design. So the design should consider the

network's ability to continue to function well as it is changed in size or volume to meet new traffic or application requirements [2]. In this regard expandability is a concern in the telemedicine network design for the following reasons:

- The number of hospitals built in the county is few in number. However there are more clinics being added to the health system of the country every year.
- There is also a chance to incorporate private hospitals in the nation wide telemedicine network as necessary, which will ultimately increases the number of sites to be connected in the future.
- The area of telemedicine applications will not be limited to some specific diseases, but will be expected to increase in type and number in the future.
- The network should also support advanced applications, which require real time connectivity such as video conferencing in the future.

2.1.2. Security

During consultation or patient referral, most of the data exchanged over the network is sensitive patient information. Confidentiality of patient information must always be respected. For a secure communication, protocols such as Secure Socket Layer (SSL) could be used. SSL permits users to conduct secure communication over web-based applications. This provides the ability to safely exchange patient information across the network [17].

When doctors exchange patient information, they should adhere to medical protocol that defines the rules to be followed during this process. In addition to these the network and involved servers should be protected by firewall against external invader. Firewalls could be software or hardware for the sole purpose of keeping digital pests such as viruses, worms, and hackers out of the network [3, 4].

2.1.3. Cost

Implementing a nation wide telemedicine network may seem to be more expensive than building clinics or equipping existing regional clinics with medical personnel and medical instruments. A cost benefit analysis, comparing various approaches has to be done, to come up with a lower cost solution to the problem of delivering proper health care to rural areas. However, network connectivity among the health care facilities, both in the urban and rural areas over an existing ICT infrastructure is considered as a cost-effective solution.

Considering the installation cost, our design will consider an already existing WAN, provided by the Ethiopia Telecommunication Corporation. Set-up costs depend on the type of WAN to be used in the telemedicine network design. But cost is taken as one of the selection criteria to choose from the existing/emerging ICT infrastructures in the country.

2.2. Design Requirements

Most of the inter-hospital communications used to be by telephone and hand delivered referral messages in this country. During referrals patients have to travel to one of the referral hospitals urban areas, carrying the referral messages written by referring physician. Clinics located in the telephone coverage areas communicate using telephone to exchange information about availability of specialist or bed in another hospital. However, the communication needs of hospitals are beyond what have been practiced so far.

Geographically dispersed clinics need telecommunication technology for the following purposes:

2.2.1. Data Transmission

The data is in the form of both text and image about patients that need to be exchanged between clinics during remote consultations. Textual data may contain referral messages and feedback, clinical notes of patients etc. Medical image files such as x-rays and dermatology pictures acquired by digital cameras have to be accessed for remotely diagnosing a patient.

2.2.2. Instantaneous access to patient information

When consulting a general practitioner, specialists need to get access to patient information instantaneously. This requires a system, which maintains patient information in a standardized format and be accessible through a secure communication means by authorized users.

2.2.3. Access to Medical Information

Doctors need to get access to medical information databases to get informed on the current medical practices. This helps them to stay up to date with the new development in the field and get experience from similar cases when they come across difficult patient case.

2.2.4. Access to the Internet

In the Internet doctors need to visit web sites related to the medical field. Medical expert systems and Medical databases are some examples among the sources of information in the Internet. They can also use e-mail to communicate among themselves and benefit from sharing experience of senior specialists.

These and other communication needs of healthcare providers also require the development of telemedicine application software backed by electronic patient record systems. Design of such communication networks will also require the understanding of organizational structure of the clinics involved in the network. Since the government/public clinics are owned and organized under their respective regions, the WAN design should follow the organizational structure of the administrative regions in the country.

3. Proposed LAN / WAN Design

A detailed study about the inclusion of various clinics, their locations relative to the nearest access point to existing ICT infrastructure, traffic load and its characteristics, security, LAN/WAN protocol, topology and bandwidth requirements and utilization, allocation of bandwidth etc, have to be considered while trying to design telemedicine network. In addition to these, issues of communicating patient information electronically may raise question of medical ethics, and a need for developing medical protocol to be used in the day-to-day activity using telemedicine network.

In this section the proposed LAN and WAN for the nationwide telemedicine network are described. The necessary internetworking devices to be used will be presented in logical diagrams. The decision to make which specific internetworking device is yet to be identified. We will start with hospital LAN design.

3.1. Hospital LAN Design

To design the LAN for each hospital, we will consider the central site, Tikur Anbassa Specialized Hospital as a sample. The hospital is organized in to 16 departments. Each department will have units as necessary. For instance, the Internal Medicine department has units such as Renal Unit, Cardiology Unit, Neurology Unit, etc. The physicians in these departments/units need to communicate whenever a patient visits more than one of the units. The proposed LAN will follow the hierarchical structure of the hospital.

A variety of LAN technology can be employed. The decision to make the selection between the technologies depends on:

- Expected application to run on the network and their traffic patterns.
- Physical locations of the offices and users to be connected in campus.
- The rate of network growth.
- The abundance of the network technology in the market.
- Simplicity of installation and maintenance.

Currently we expect a web-based telemedicine application to run on the network. The application will use a central database server where all the user and patient information will be stored. The type of data to be transmitted on the network shall be in the text and image formats. Since all

communication shall be through the server, the traffic pattern around the center is expected to be heavy. Higher speed devices will be used at the center of the LAN where there will be servers.

The sample hospital (Tikur Anbassa) is composed of 5 buildings (Block A-E). The blocks are not physically separated. They are built on a number Square meters area. All the departments and offices are located in either of the blocks. Having routers switches in each of the departments is ideal to design a high speed and expandable LAN, but makes it expensive. A cost effective choice is to put switches per building and then have the departments be connected and form groups by using Virtual LAN technology.

The rate of the hospital LAN growth depends on the level of computerization in the hospital. In this design it is anticipated that as the application is used and becomes familiar, there is a chance to add more applications and connect more computers and offices to the LAN. The switches/routers selected in this design should have many free ports to help cascade the growing number of connections in the future.

To design the LAN architecture we have selected the hierarchical model. It enables us to design and arrange the inter-network devise in layers. It is a model preferred by most of network design experts for its ease of understanding, expandability and improved fault isolation characteristics [3]. The model required the following three layers

At the first layer – Core layer high performance switches that are capable of switching packets as fast as possible should be deployed. This layer connects the LAN backbone media. It also connects to the outside world to WAN via a firewall.

In this design the devices in the core layer will be placed at a central location in the hospital. The devices in this layer will be connected with high-speed cables such as fiber optics, or fast Ethernet cables. The servers necessary for the applications will be connected to switches in this layer shielded by a firewall.

The second layer – Distribution layer will contain switches and routers capable of VLAN switching and allow defining departmental workgroups and multicast domains. The devices should also support connectivity of different LAN technologies since they also serve as the demarcation point between the backbone connections in the core layer and the access layer.

In this hospital LAN design the distribution layer represents switches/routers at each building connected to the core layer on the on end and to the access layer on the other end. Use of redundant links will be used for maximum availability. The departments could be grouped forming their own Virtual LAN.

The third layer – Access Layer is where the end users are allowed in to the network. This layer contains switches/hubs from which PCs in each department get access to the Hospital LAN. Each department will have at least one switch/hub, which in turn will have redundant links to more than two of the switches in the distribution layer.

Figure 1 represents the hospital LAN design.

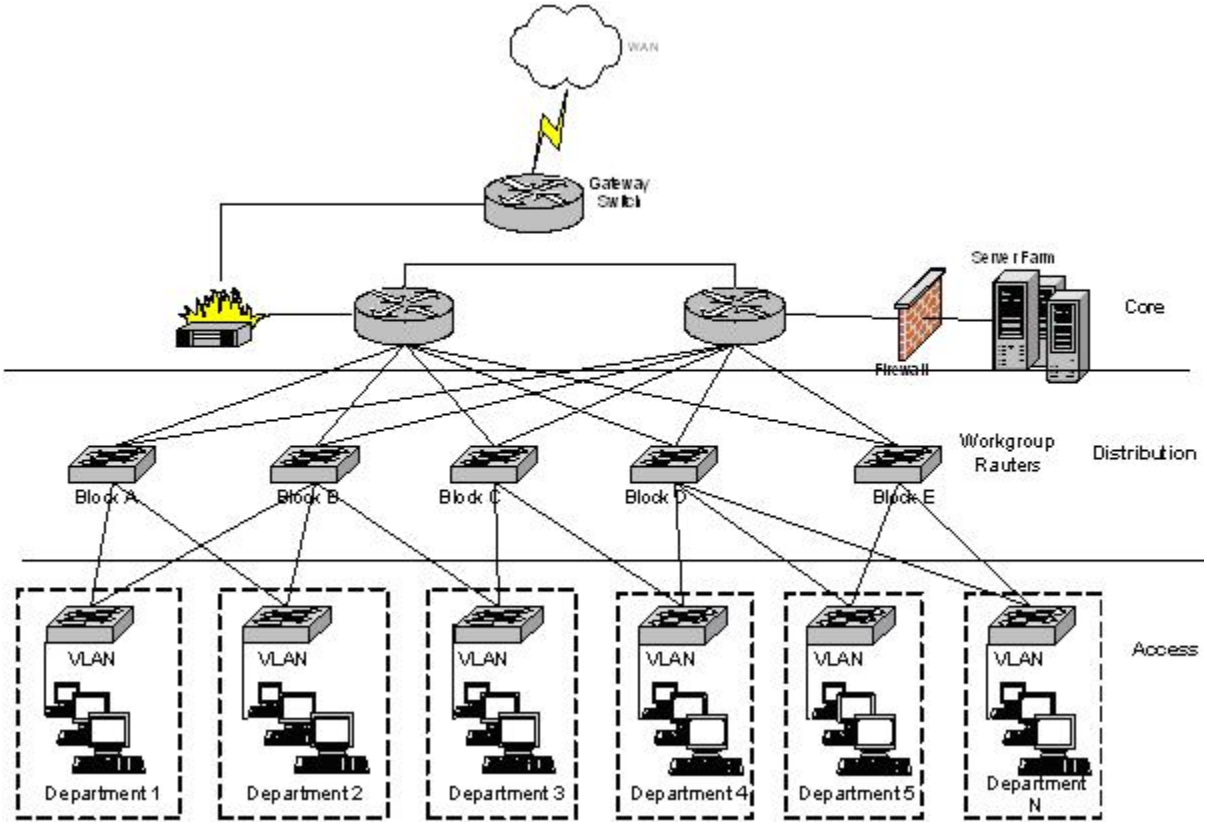

Figure 1: Hospital level LAN for Tikur Anbessa hospital.

4. Telemedicine WAN Design

The design of the WAN for the nation wide telemedicine network raises the issue of WAN service provider. Unlike LAN, WAN connectivity depends on the availability of WAN infrastructure in the country. The sole WAN service provider is the Ethiopian Telecommunications Corporation (ETC). ETC provides a number of services [5] among which we have to select the WAN infrastructure that is suitable for the nationwide telemedicine network. The following services are considered in this design.

- Internet Services
- Digital Data Network
- SchoolNet VSAT network
- WoredaNet VSAT network
- Broadband Multimedia Network

4.1. Internet

ETC started providing Internet Services in 1997 using one gateway in Addis Ababa. Currently the server capacity is 10Mbps uplink and 4Mbps downlink [5]. The Internet service is provided to the customer in either by dialup or leased line connectivity.

4.1.1. DialUp

This connectivity is the cheapest Internet connectivity provided by ETC. It uses the exiting telephone line, which was originally setup for voice transmission. A maximum of 56Kbps bandwidth is provided to the dialup subscribers, but usually on can get 28 – 33Kbps in the daytime and 35 – 45Kbps during the night-time.

This service covers the telephone coverage areas in the country. The telephone network is concentrated in the urban areas in Ethiopia, with 505 exchanges, out of which only 159 are automatic digital exchanges. 58.6% of the exchanges serving the capital city Addis Ababa [3].

4.1.2. Leased Line

Unlike the dialup Internet connectivity, leased line subscribers can get access to the Internet on the 7 day 24 hour (7/24) basis, dedicated, fixed bandwidth connectivity [5]. Bandwidth can go up to 1Mbps [6]. The infrastructure used for leased line connectivity is a data network.

Currently there are very limited subscribers to the leased line Internet. As we have learned from engineers in ETC, the reason for this few number of customers is lack of awareness and high connectivity costs.

4.2. Digital Data Network

In 2001 ETC established a digital data network, which is capable of providing dedicated (leased line) Internet, ISDN and Frame Relay services. As it was announced by ETC, DDN supports digital lease at multiples of 64Kbps, to be used by a variety of applications [5, 7].

But still the DDN covers the urban areas where there are other means of WAN services such as dialup Internet service. The ISDN service is not matured and has not been affordable. DDN is known to have a number of limitations as the provider itself specified them [6].

- It can only give up to a maximum speed of 1Mbps.
- It cannot provide bundle (voice, data, and video) services
- It does not support multicasting, etc

4.3. VSAT Networks

Very Small Aperture Terminals have been used by ETC as a means of transmission link to reach remote areas. So far 292 VSAT terminal stations have been operational and are being used by the telephone network [5].

In addition to these, there is a plan to install VSAT terminals in every secondary schools and higher learning institutions to form a broadcasting VSAT network called SchoolNet [19]. There is also another VSAT network to connect about 600 Woreda administration centers forming a government network called WoredaNet. Since our focus in this design is to have low cost but wide coverage connectivity among the regional clinics and urban hospitals across the country, these VSAT networks were considered as candidates of our WAN infrastructure selection.

4.3.1. SchoolNet

SchoolNet is a VSAT network, which is designed for broadcasting multimedia data to all secondary schools and higher learning institutions in Ethiopia. The network is owned by ETC. Though the network currently supports only one-way traffic, it can be upgraded to have up to 384kbps upstream, to support two way interactivity.

4.3.2. WoredaNet

WoredaNet is also a VSAT based network, which is designed for integrated services of voice, data and image. Currently the WoredaNet covers 571 Woreda administration centers.

The network supports two way interactivity of 45Mbps down to all the Woreda administration centers and 256kbps upstream from each Woreda. The network is expected to scale up and include many government offices in each Woreda. The switches installed in each Woreda consist of more than 10 free ports to support more connections cascading out of the network point of presence.

4.4. Broadband Multimedia Network

A new Broadband Multimedia Network (BMN), which has been fully operational by the end of June 2004, is announced by ETC. The network interconnects the capital city with high speed Optical metropolitan Network and 13 other provisional towns using radio digital systems [5,6].

As the name indicates, BMN is a high bit rate network, which supports voice as well as full motion video, on the same network infrastructure, with better quality and availability as well as relatively low price to customers [5, 6].

4.5. Summary of ICT Selection

To pick one of the infrastructures for telemedicine the following factors were considered:

- The geographical coverage
- The bandwidth
- Two way interactivity
- Rental cost of WAN connection
- The capacity to add more LANs

Table 1 summarizes the process of WAN infrastructure selection.

4.6. Recommendation

Based on the comparison we have made, we submit that WoredaNet will be best suited to the national telemedicine network, as long as the existing infrastructures are concerned. But as can be observed in the table, whereas the coverage is good, the capacity is limited. BMN will be the ideal choice because it represents state-of-the art service and higher bandwidth. However, it is centered in the urban areas only. It is also under development and we have considered it as a potential to be used integrated with the VSAT based networks to enhance nationwide telemedicine network. The SchoolNet needs to be upgraded to support two way interactivity.

The solution we propose is that of a nationwide telemedicine network that uses the combination of VSAT network that is cost effective and which goes down to the public even in the rural areas and urban area terrestrial network that provides modern but economical connectivity to hospitals. In this regard, we propose connectivity via the emerging BMN to connect urban area hospitals in the capital city and in the regions where the network can easily be accessible. The WoredaNet VSAT network is proposed to be used to connect rural area clinics to the telemedicine network. **Figure 3** represents our proposed telemedicine network.

This WAN connectivity requires that urban hospitals have two WAN connections. Getting more than one WAN connection may be more expensive. If the two WAN infrastructures could be integrated, an alternative WAN design will require only one WAN connection to the urban hospitals through which the hospitals will be connected to BMN and the rural are clinics to the WoredaNet. The second alternative of the WAN design is shown in **Figure 4**.

A typical simple scenario where the network is used for telemedicine consultation between a practitioner in the rural area clinic and a specialist in the urban hospital can be viewed in **Figure 5**. The practitioner inputs patient data and referral messages using the graphical user interface provided by a telemedicine application. On the other end, a specialist reads the referral massage, displays the patient information, after which the specialist can input the referral feedback to advice the practitioner.

Table 1: Summarized comparison of existing ICT infrastructure

	Internet	DD N	SchoolNet	WoredaNet	B M N
Coverage based on the network's ability to go down to Woreda	Telephone coverage areas only	The capital and regional Urban areas only	About 500 schools covered. There are wordas that do not have schools	571 Woredas out of 594 are covered	The Capital city and 13 regional towns.
Bandwidth	Maximum of 56k dialup and 1Mbps in Leased line	Maximum of 1Mbps	Can be upgraded to 384k upstream	Downstream/ upstream 45Mbps/ 256k downlink	ADSL Services: Variable bandwidth Downstream/upstream: 512k/128k and 1024k/256k
Interactivity	Two way	Two way	One way broadcasting	Two way	Two way
Cost	0.11birr/min dialup 1000birr/month leased line		Free for schools	Free For Woredas	Not yet determined, under development
Capacity to scale	Not scalable	Not scalable enough		Will have more than 10 ports free at each Woreda	Can be expanded

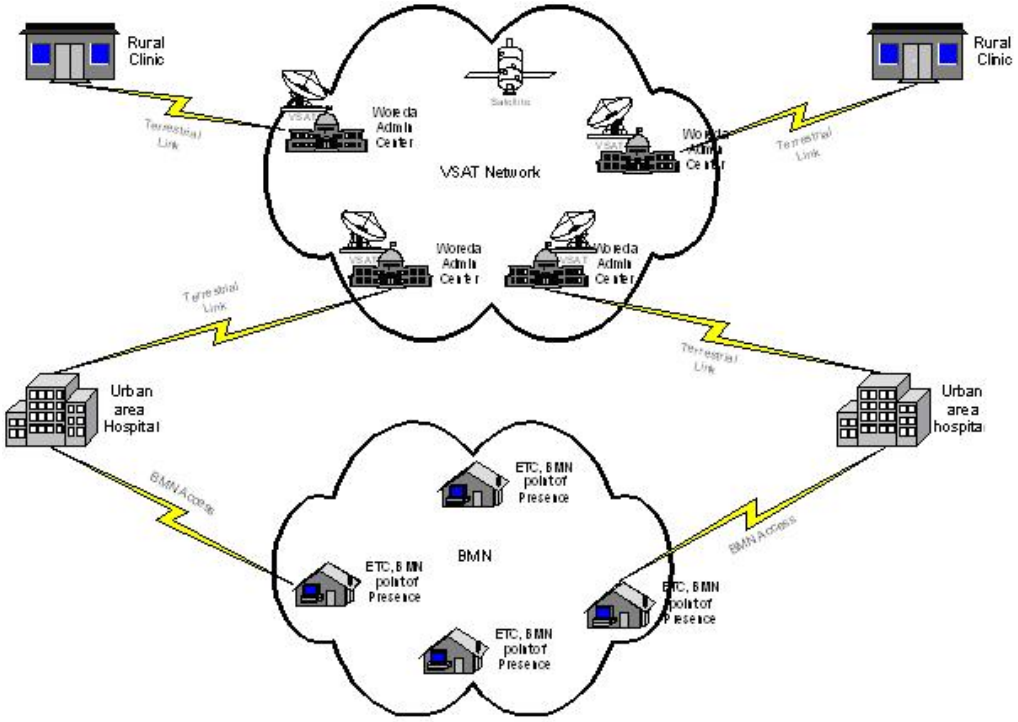

Figure 2: Logical WAN design based on BMN and VSAT networks alternative one.

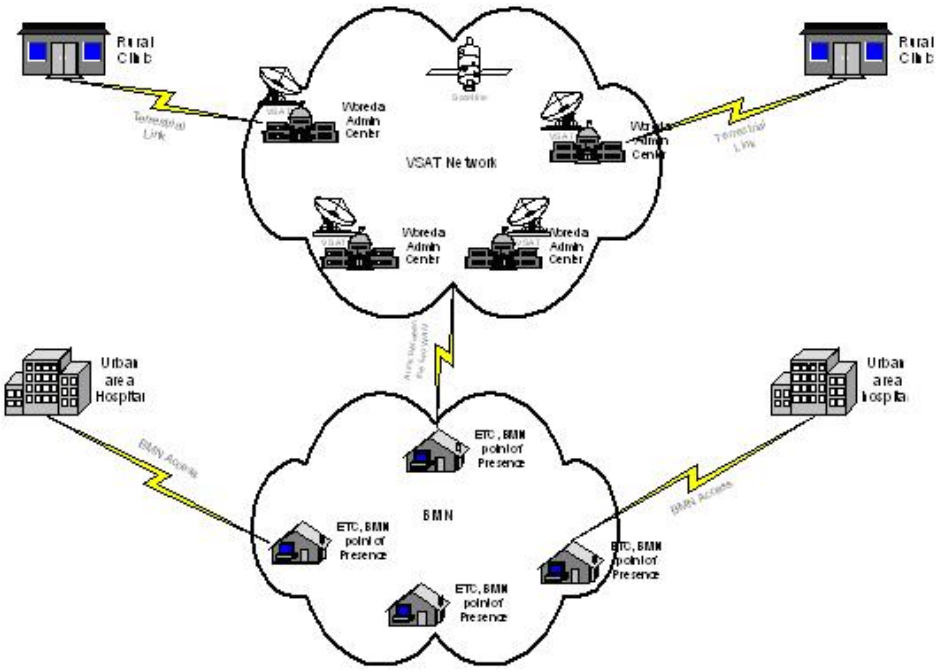

Figure 3: Logical WAN design based on BMN and VSAT networks alternative two.

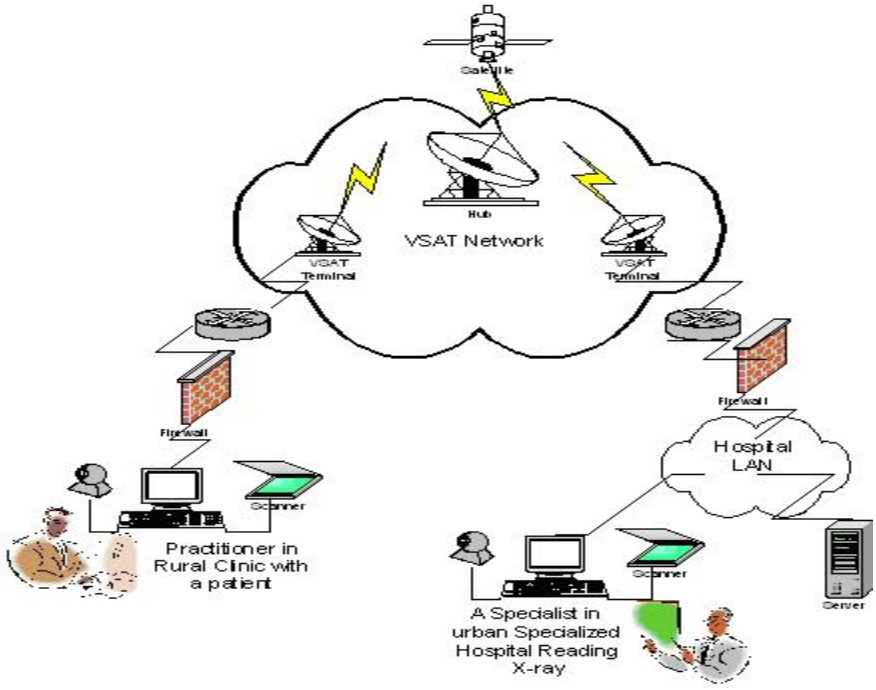

Figure 4: Scenario of the telemedicine network.

5. The Prototype

With the specified network requirements and architecture design, we have developed a working prototype for a national telemedicine network. The operations of the prototype telemedicine network are summarized below:

5.1. Overview

The prototype is a Basic Telemedicine Service (BTS), which provides a web based Graphical User Interface (GUI) for healthcare providers. BTS facilitates the information exchange between remotely located healthcare providers for the purpose of medical consultation, as well as for maintaining patient information. We have tried to reproduce electronically, the traditional paper based forms and patient cards used in the hospitals.

We have selected the web-based technology for its universality. Using web-based technology constitutes not only a network that can be used universally but also system independent platforms providing access to many different computer systems at client site [8]. The only requirement in the client site is web browser software installed and network connectivity.

To secure the system, we have used password protected system where the users have to login to get access to the functionalities provided by the system. In addition to that, user types are defined so that there will be a role based access to database and system functions in BTS. We have used a centralized database to store user and patient information. Unlike e-mails, this approach allows us to insure structured information exchange between the communicating healthcare providers.

5.2. Major Features of BTS

Basically BTS is a database driven web site, the major features of which can be described as follows:

- Provide user management services where administrator can register users, assign username and password, and define user type, as well as search and edit user information.
- Provide patient management services where health care providers can register patients, search patients and view patient information on a traditional patient card like interface, when necessary.

- Provide referral systems where physicians can write referral messages to a particular department and hospital, and on the other hand provides a system by which a physician can see the list of referrals forwarded to the department she/he is working and allow the physician to write feedback after examining the referral message and patient information instantaneously.
- Provides a system by which physicians can request lab test to any hospital laboratories so that patients can get tested in the clinic/hospital they are being treated.
- Provides list of lab test requests to laboratory technicians and allow them to input lab test results.

In the prototype we have tried to implement the above list of functionalities.

5.3. BTS System Architecture

The architecture of BTS is a three-tiered Client Server architecture. It is a web-based application, which will have a web server to provide all the interfaces of the system and database server to contain all information required in the system.

The prototype is constructed with a combination of open source products and freely available software components. The web server we have used is the Apache Jakarta's Tomcat web server [9]. The functionalities as well as the business rules necessary are programmed in Java [10]. The user interface and text of web pages are implemented by the Java Server Pages (JSP) [11,12]. Some scripting is included on the web pages in JavaScript. JSP has a capability to import java classes and run them from the web pages when the pages are downloaded to client machine [12]. Unlike other server side languages such as Active Server Pages (ASP), JSP makes the system platform independent. JSP also allows us to use the full power of java programming language which other scripting languages such as PHP lacks [12].

The database we have used is the open source MySql to back up our database driven application. MySql works on may different operating system platforms and is known for its speed of data retrieval [13]. It provides Application Program Interfaces (API) for many programming languages including Java. Passwords are secure because all password traffic is encrypted when connecting to the MySql server. For database connectivity we have used mm.mysql driver, which is a Java Database Connectivity (JDBC) driver, from MySQL AB, implemented in 100% native Java. [14]. **Figure 6** shows the BTS system architecture.

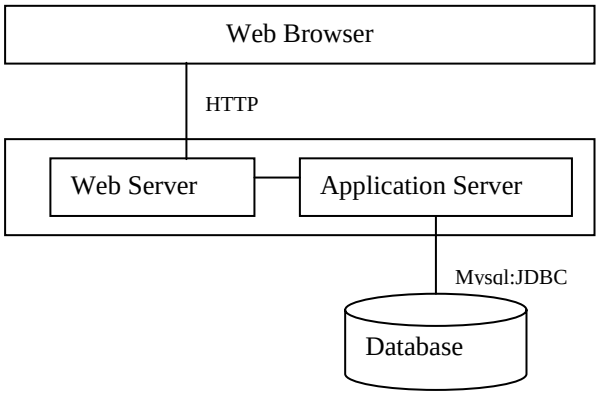

Figure 5: Architecture of BTS

The first layer is where the client machines run web-browser software. This layer is used to display the user interface (web-pages) of the system and send secure HTTP request to the web server in the second layer. Along with the web-server, application server resides in the second layer. This application server manages the clinical business logic. The bottom layer contains the persistent data of the system. All the data of patient's information, doctors and messages will be stored and maintained in this third layer. This layer runs the database management system software.

5.4. Database Design

Basic Telemedicine Service needs to keep track of information about patient and related medical records, user's information, and messages for both medical referral requests and feedbacks. A well-designed minimal database should be employed to manage this information. A relational database model is selected to store the persistent data of the system, as it could be easier to manage, and provides better management for complex query of such data [15]. Our database contains the following basic entities:

Person: The generic information of each person: user, patient or relatives are stored in the person entity. The generic information includes:

- Personal bio data such as Name, data of birth, gender, etc
- Address data such as: region, town, Woreda, kebele, telephone etc
- Occupation data such as: hospital, department, job title, etc

Users: This entity will contain user's information. Keeping users' information is needed for authentication and authorization purpose. User's type and authentication information such as username and password are stored in User entity.

Patient: This entity will be used to maintain patient record. It will be used to identify the patient. The patient medical information and associated medical record should always be available during consultation. Each patient is represented by a medical record entity.

Medical Record: This entity represents the medical information associated with each patient. It will contain Lab results; medical images such as x-rays, clinical notes written by doctors, follow up information and medical certificates as sub entities.

Each component of the medical record of a patient is composed of different type of data which are to be stored in the database. In the traditional paper based system, medical record of a patient is identified by an Out Patient Card (OPCard) Number, which is usually called patent record number. OPCard is a four page hard paper card, which contains patient's generic information, such as name, sex, age, address on the first page and a table of two columns for date and clinical note to record chronological list of clinical notes. All other components such as Lab Test Results, x-ray reports, etc are stored inside the hard paper card referenced by the card number or name of the patient. The lab test results may contain zero or more test request forms along with the results for Urine, Parasitology, Blood Chemistry, Haematology, Serology, Bacteriology, Fine Needle Aspiration Cytology and Biopsy.

When a patient is admitted to the hospital, Admission and social data information is stored. The admission data includes identification information and name and address of next of kin, marriage and children information if any, occupational information etc. Then follow up data such as Vital Sign measurements, Fluid Balance information will be collected and recorded. Order sheet, which contains list of treatments to be ordered after admission is also part of inpatient medical record.

In addition to these, information about the hospitals, departments and laboratories are stored in respective entities. The entities and the relationship existing among them are presented in the following **Figure 7** below.

5.5. Graphical User Interface

BTS is accessed by opening the initial web page where user authentication is performed. The initial page contains a login screen to submit username and password of users. There is no need of menu or different buttons to be submitted based on the user types. Since the user types are defined in the database when the user registered, the page corresponding to the specific user type will be opened upon successful login. Currently Administrator, physician and lab technician user types are defined and all the user types will have their own main page as described in the following paragraphs. **Figure 8** shows the login screen.

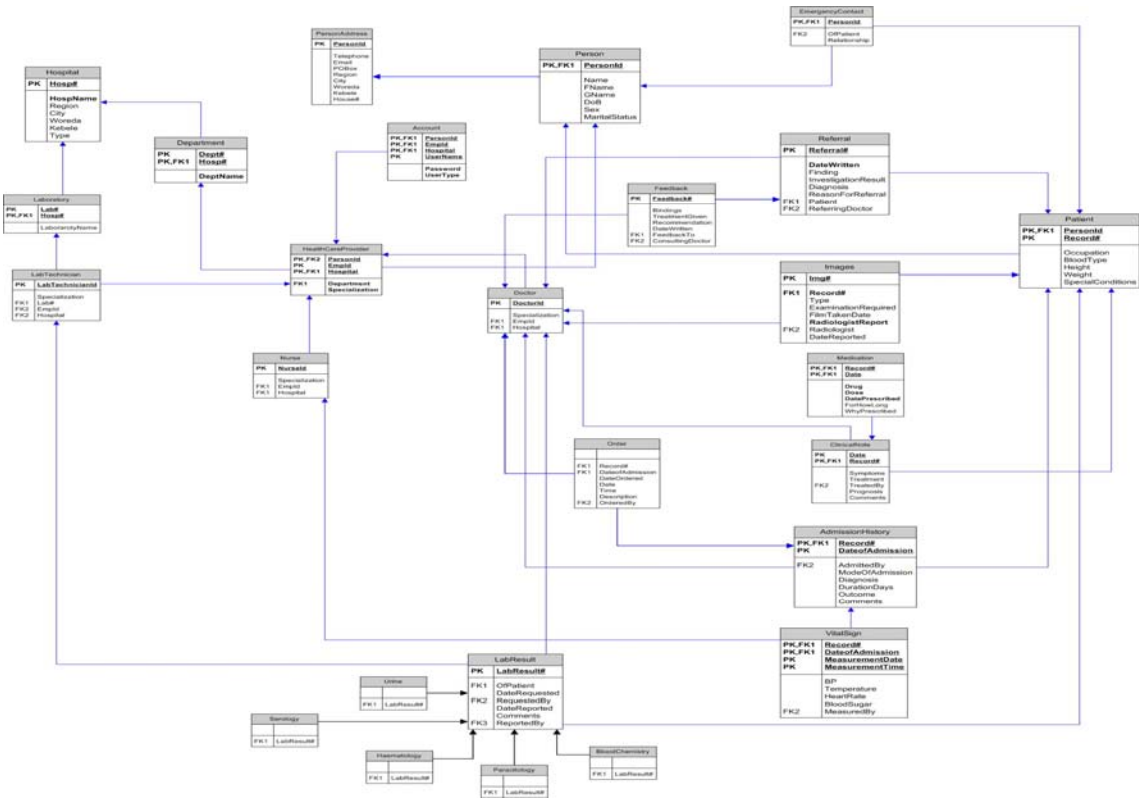

Figure 6: The database tables used in BTS.

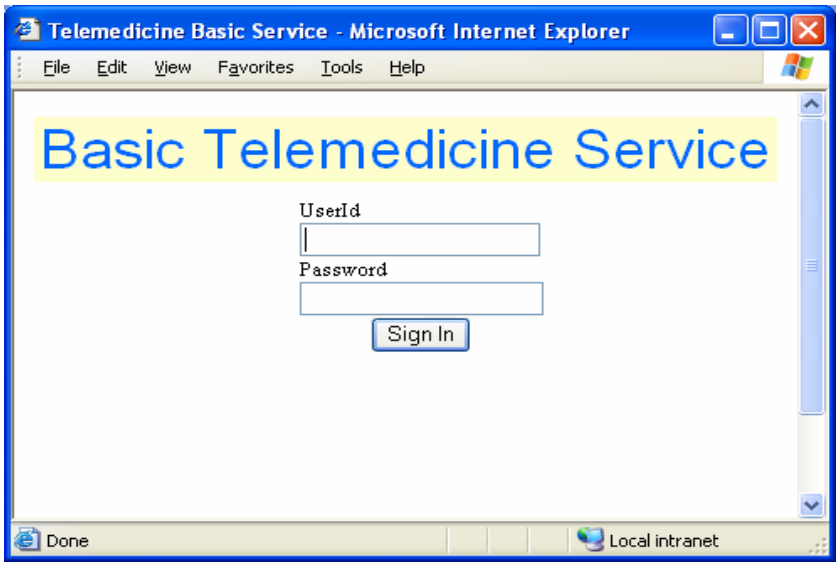

Figure 7: BTS login screen.

5.5.1. Administrator's Main page

The administrator's main page is used for managing users. The functionalities accessible from this page are: **Register New User** and **Search User** by either or a combination of Name, Father Name, and User Name. **Figure 9** shows the Administrator's main page.

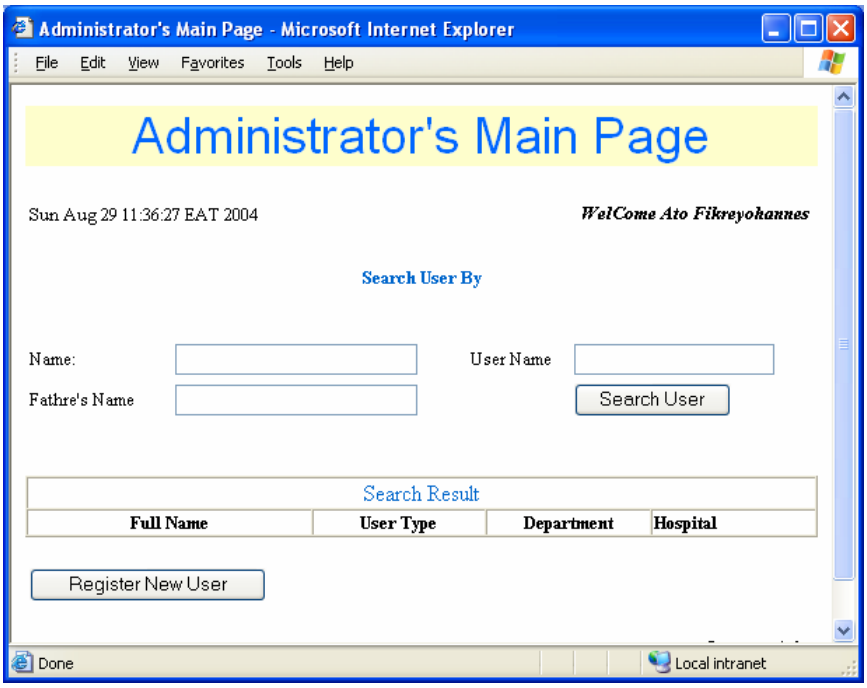

Figure 8: Administrator's main page of BTS

The registration function, invoked by clicking a button (Register New User), opens up a user registration form where the administrator can input all the information necessary about the user and define the user type. **Figure 10** shows the second half of the user registration page. The form is divided in to four parts where the admin can input the Generic user information, Address information, Profession information and Authentication information. One of the authentication information is the user type, where the admin can select from the list of user types.

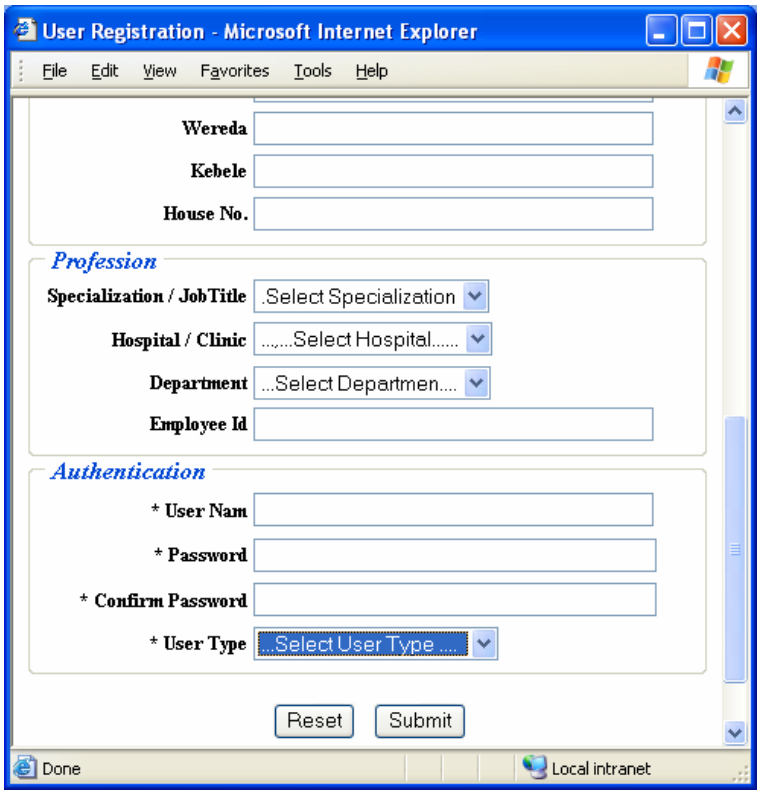

Figure 9: User registration page.

The other function provided to administrators is the Search User function. It is possible to search users using any combinations of Name, Father Name and User Name. If username is provided, there is no need to search for users by name and father name. This is because username is unique in the user table.

The search result is displayed in the table below the search criteria input boxes. **Figure 11** shows the admin page after including a search result.

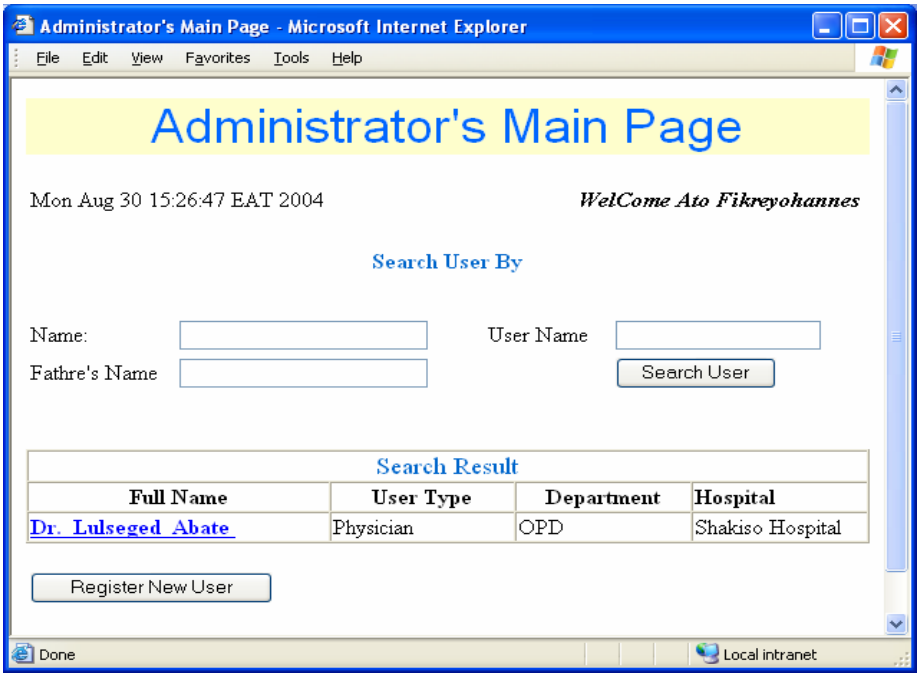

Figure 10: Administrator's main page showing search result.

As it can be seen in the search result, the full name of the search result is a link. The link leads to a page containing user information from which the admin can edit that particular user.

5.5.2. Physician's Main page

The physician's main page contains a button to open Patient Manager Page, and list of referrals forwarded the department where the physician is working. The physician could either click the Manage Patients button or a link to one of the referrals. In each case new pages will be opened. **Figure 12** shows the physician's main page showing one referral forwarded to the department where physician called Dr. Aman is working.

If the physician chooses to treat the patients in the hospital where she/he is working or if there is no referral forwarded to the department she/he is working, the physician can then open the patient manager page by clicking the 'Manage Patients' button.

The Patient Manager Page has two buttons namely, Register New Patient and Search Patient. The physician will have two options:

- To register a new patient.
- To search a previously registered patient or

Figure 12 shows the patient manager page.

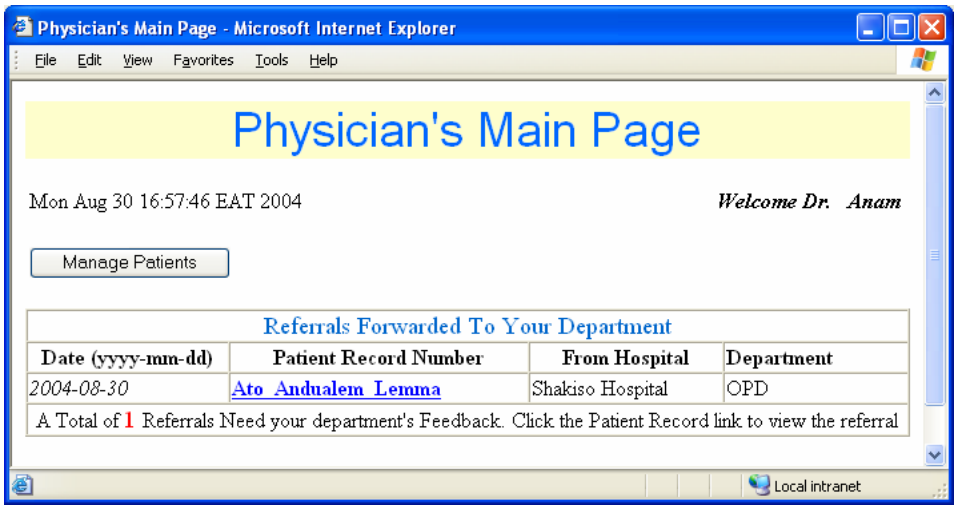

Figure 11: Physician's main page of BTS.

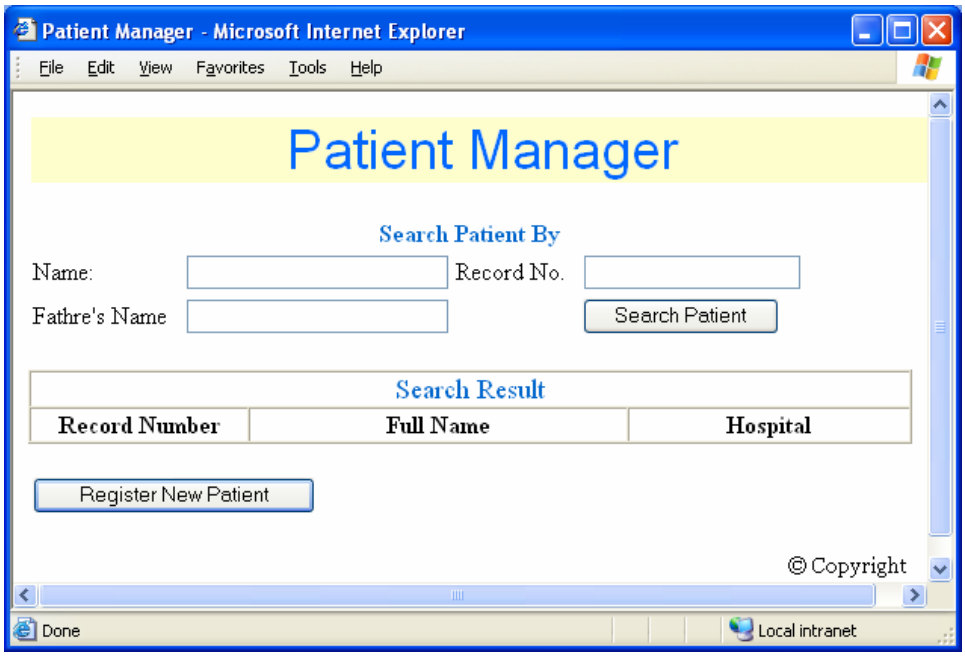

Figure 12: Patient manager page.

When 'register new patient' is selected, a patient register form, similar to the user registration page will be opened. The patient information is grouped in to three categories namely: General, Home Address and Occupation information. **Figure 14** shows the first half of the Patient registration page.

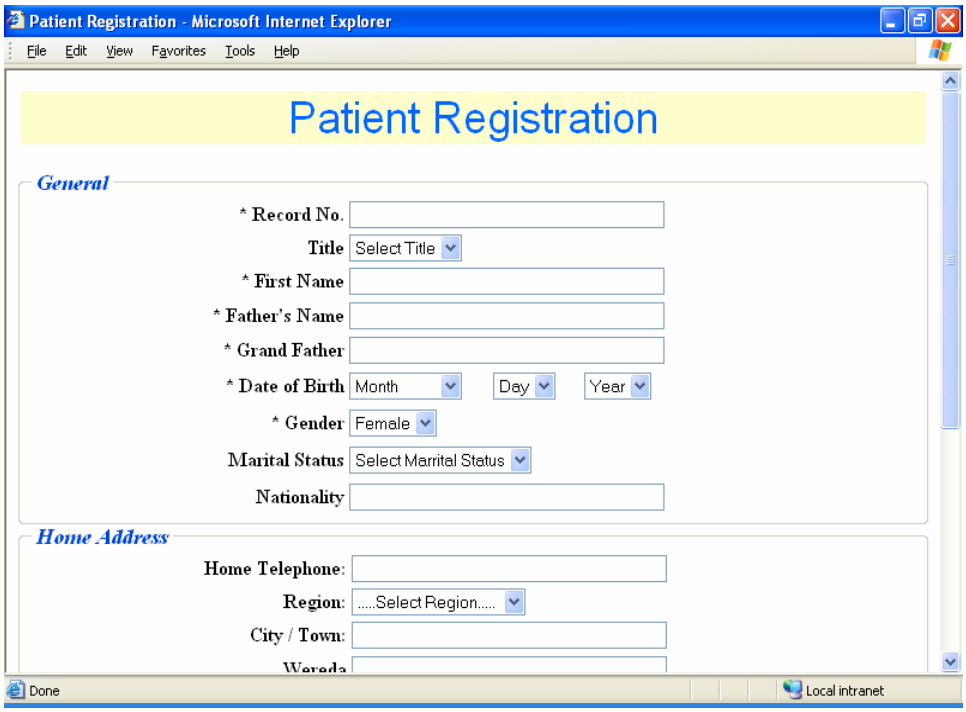

Figure 13: Patient registration page.

On the other hand if the physician wants to look for a patient, she/he can input one of the search criteria namely Name, Father Name or Record Number of the patient. After providing the search criteria, the physician clicks the search patient button to display the list of search result. The search result contains the record number, Full name and the hospital where the patient was first registered. **Figure 15** shows the Patient manager page including a search result.

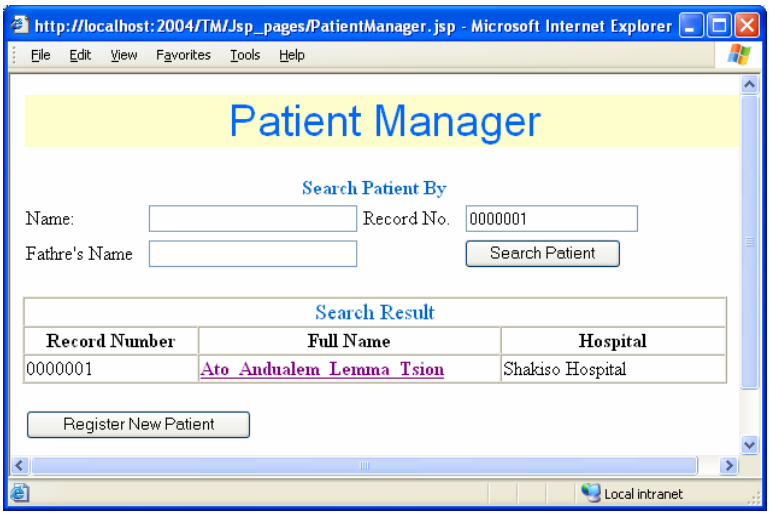

Figure 14: Patient manager page showing a search result.

The patient full name is a link that leads to patient information page similar to the traditional Patient Card used in the hospitals. An example of the patient card, which opens up when the full name link in the previous interface is selected, can be seen in **Figure 16** below. The patient card contains patient's general information, address information and clinical notes. The clinical notes ordered in descending order. In addition to the information displayed on the patient card, laboratory test results and medical images related to the patient are accessible by clicking corresponding buttons from the patient card interface.

The physician can add clinical notes or refer or admit the patient. All the functionalities are provided by buttons from the patient card. These buttons open the corresponding input pages.

From the physician's main page, the other option provided to the physician is to see referrals forwarded to her/his department. This is possible by clicking the link that opens a referral page corresponding to the patient. The patient referral page contains the referral messages and buttons that lead to patient information, as well as a button that lead to the feedback input page. **Figure 17** shows the patient referral information page.

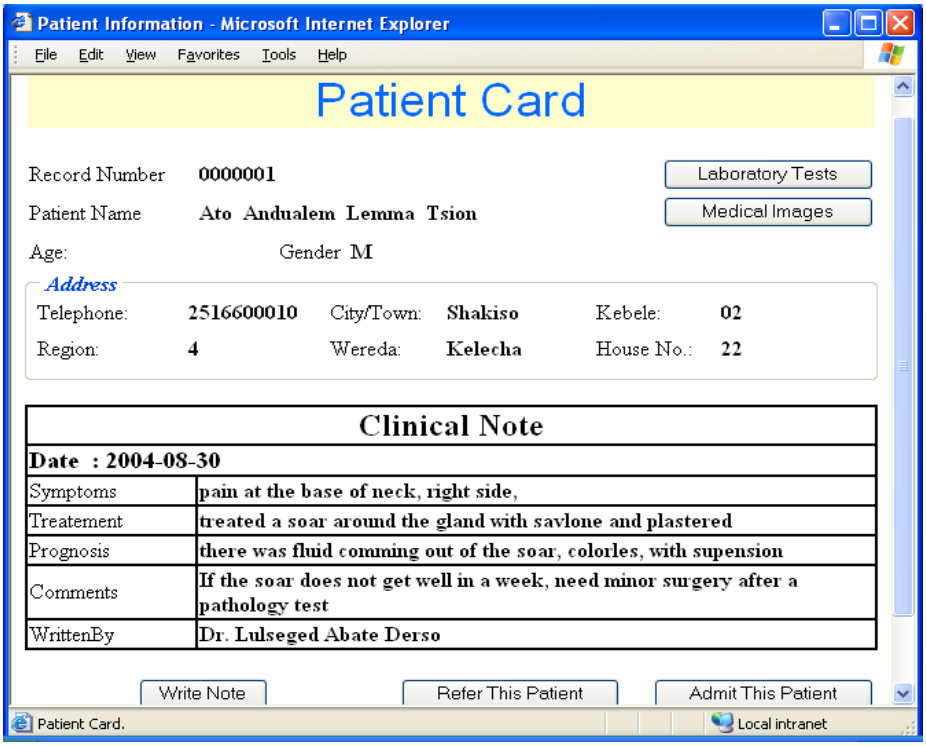

Figure 15: Patient card page of BTS.

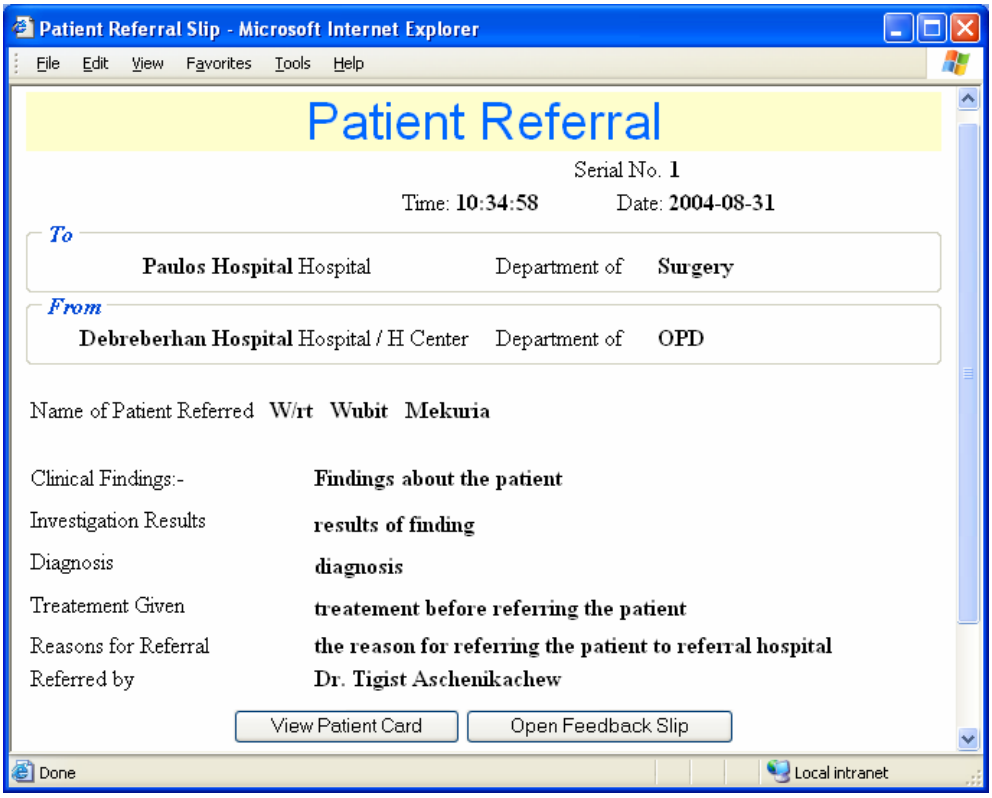

Figure 16: Patient referral information page.

If the physician wants to view the patient information, she/he will click the View Patient Card button to open the patient card shown above in **Figure 15**. On the other hand the physician can give feedback to the referral using the feedback slip, which will be opened by clicking the Open Feedback Slip button. The feedback slip is an input form where the physician can input feedback information related to the current referral.

The physician can also request laboratory test after viewing the patient laboratory information page, which is accessible from the patient card page by a button called Laboratory Tests. The Laboratory information page and a parasitological test request pages are shown in the **Figure 18**. When a physician wants to request lab test, she/he need to click the button corresponding to the type of test required from the Laboratory Information page. The specific lab test request page provides the physician with dropdown list from which the physician can select where the lab test should be performed. This was found to be important in order to forward the lab test request to the other user types called, the Lab technicians.

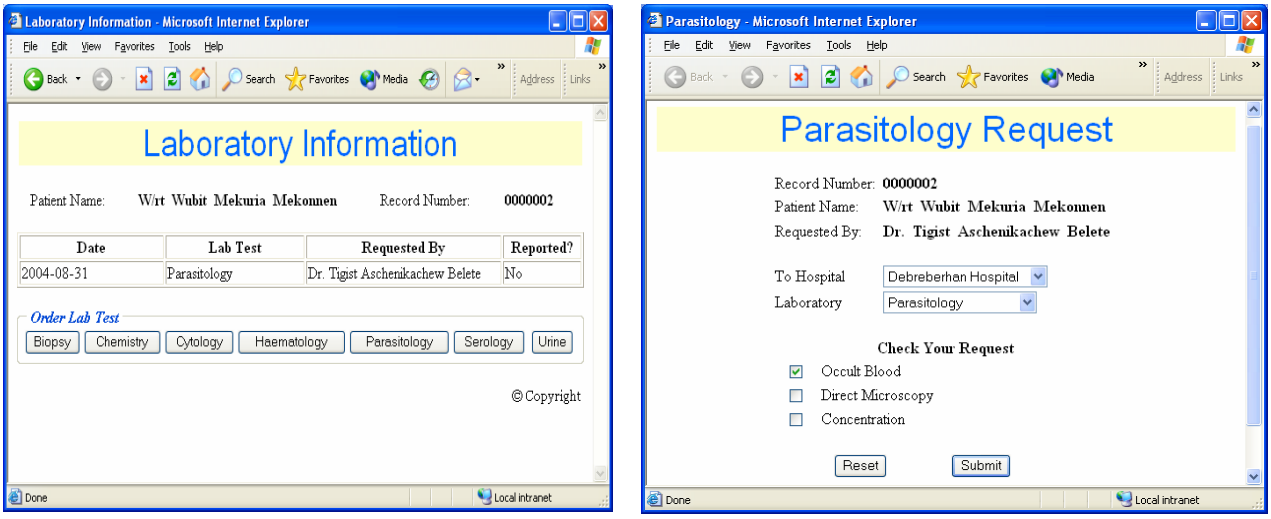

Figure 17: Laboratory information and parasitological test request page of BTS.

5.5.3. Lab Technician's Main Page

The third type of user, Laboratory Technician sees a list of laboratory requests to the department she/he is working, on the Lab Technician's main page. The list contains a link to open lab test result input form where the lab technician can enter her/his report. See **Figure 19**, for the Lab Technician's main page.

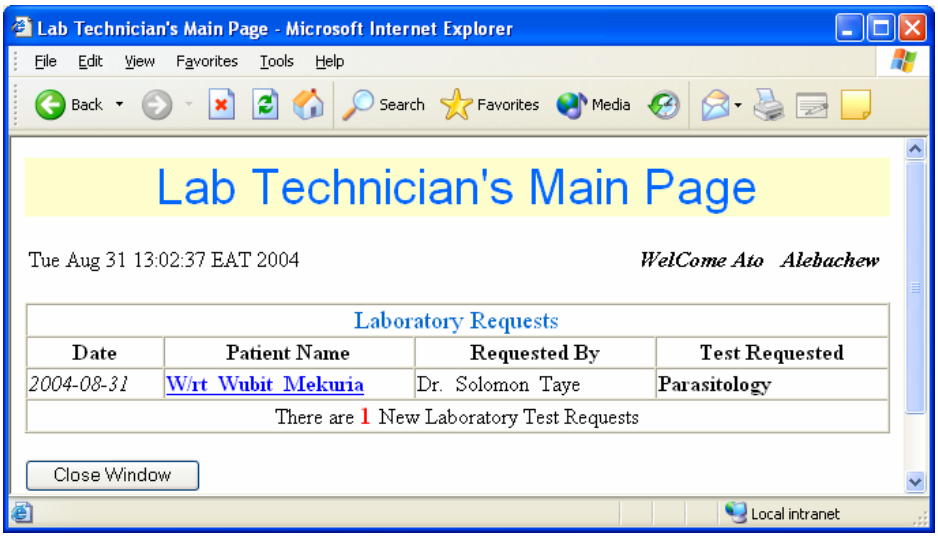

Figure 18: Lab technician's main page of BTS.

The lab technician can either click the on of the links to report the lab request or close the window, if there is no request forwarded to her/his department.

In addition to these interfaces, the application consists of many other pages containing forms similar to that of the paper forms used in the hospitals.

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