Hierarchical Model Based LAN Architecture & VSAT-based WAN for a National Telemedicine Network in a Developing Country: Case of Ethiopia

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ABSTRACT

Due to difficult terrain and limited transportation infrastructures, developing countries continue to suffer from the absence of extended and adequate medical and healthcare services. This inadequacy in basic health services is often accompanied by very low patient-doctor ratios. It has been suggested that telemedicine offers a basis for a cost-effective health-care system in geographical remote areas in such developing countries minimizing the disparity between rural and urban areas. It now seems, despite a slow start, that this awareness has slowly gained traction in many developing countries among both governmental and private health professionals and policy makers. We argue, however, that there is a gap between current telemedicine efforts in developing countries and the actual existing connectivity infrastructure resulting in faulty, inefficient and expensive designs. The particular case of Ethiopia, one such developing country where telemedicine continues to carry significant promises, is investigated and reported here. In this paper, we proposes 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. The proposal includes a web based telemedicine system, which provides basic services for medical tele-consultation. The system can be used by healthcare providers to store and retrieve patient information, write referrals and give feedback to referrals by using a relational database for data management and a web based Graphical User Interface (GUI) specifically designed for telemedicine. We also provide a prototype network architecture that allows the integration of new hospitals and clinics into the network with VSAT and terrestrial LAN. The architecture also supports the provision of Internet Protocol (IP) interface that enables seamless integration of a trans-national telemedicine component for the physicians and other health care professionals currently practicing anywhere in the world.

Keywords: *telemedicine network, VSAT, network design, network architecture, ICT.*

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1. INTRODUCTION

In general, people tend to seek access to proper healthcare, which meets their needs at affordable costs. Healthcare has to be available when they need it to their proximity. Physical separation between the seekers of healthcare services and healthcare facilities must not pose any limitation to the efficient healthcare delivery to remote areas. In this regard, Information and Communications Technology (ICT) has been demonstrated to offer a competitive choice for access to healthcare service to the expectation of people, when there is limited access [1]. In this regard, telemedicine has entered an implementation stage in recent years with the continued maturity of technologies such as Integrated Services Digital Network (ISDN) and Asynchronous Transfer Mode (ATM) networks [1]. Both the healthcare providers and patient can now benefit from these networks. In the case of Ethiopia, which is perhaps a good example of a developing country with significant challenges in meeting basic healthcare services, such technology are emerging. We argue that the development of telemedicine has to follow the same track.

IT-based horizontal and vertical communication between the healthcare facilities following the organizational structure of the healthcare system is essential. It facilitates efficient information exchange and hence helps delivering healthcare to underserved rural areas. Such communication is possible by implementing a nationwide telemedicine network, based on affordable telecommunications infrastructure. The network should connect all regional clinics to urban area hospitals. The benefits of such network are:

1. Establishing a reliable horizontal and vertical communication between the healthcare facilities driving a quality and an improved healthcare delivery to all citizens.
2. Achieving e-health commitment and bring healthcare closer to underserved and un-served rural areas.
3. Strengthening collaboration efforts among hospitals and facilitating information exchange and experience sharing among medical professionals practicing in remotely located clinics.
4. Minimizing long distance travels of rural people to urban areas or to the capital city seeking proper medical care during trauma.
5. 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 technologies such as Internet access and digital telephone networks, the communication infrastructure is not well developed in many rural areas. 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 with urban areas and further to the world.

The core technical contributions of our study includes a Web-interface for a hierarchical model based LAN architecture that enables design of the inter-network devices 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.

The rest of this paper is organized as follows. Section 2 presents the requirements for telemedicine network design. Section 3, presents the proposed LAN/WAN design followed by Section 4 which presents the telemedicine WAN design. Section 5 discusses the existing BMN (Broadband Multimedia Network) and VSAT infrastructure whereas Section 6 deals with the prototype implementation of the proposed national telemedicine network. Finally, Section 7 presents the conclusions and future work.

2. TELEMEDICINE NETWORK DESIGN CONSIDERATIONS

2.1. Background

Telemedicine refers to the delivery of healthcare and sharing of medical knowledge over a distance using telecommunication and information technology. It allows sharing and exchanging healthcare and medical data between physicians and patients or healthcare personnel regardless of physical distance or geographical terrain. It also facilitates communication among physicians and academic or research institutions. Since there is lack of communication infrastructure in developing countries, medical and clinical information exchange can be facilitated through telemedicine network. In developed nations, remote locations that may not be accessed due to harsh weather conditions such as parts of North America and Scandinavian countries that are heavily affected by snow can benefit from telemedicine services [2]. Telemedicine allows health professionals around the world to establish faster communication and exchange information with clients and regional authorities regardless of geographical locations. Telemedicine may allow rural dwellers to get healthcare delivery similar to the urban

counter parts. A mobile telemedicine system provides a platform for data acquisition, transmission and delivery to healthcare providers through 2G/3G-based wireless networks [3]. Recognizing these benefits, the International Telecommunications Union (ITU) has set a global agenda to promote telemedicine applications in developing countries. Ethiopia, as one of the beneficiaries of such network, has initiated some ICT projects such SchoolNet, WoredaNet and BMN to enable fully-fledged connectivity to make better use of the ICT in the health and education sectors.

2.2. Objectives

The main objectives of this study are to design a suitable communication infrastructure for national telemedicine in the country. The specific objectives are:

1. Design Local Area Network (LAN) architecture for local telemedicine network. Communications can be established using wireless cellular or ordinary fixed telephone lines.
2. Design Wide Area Network (WAN) architecture for national telemedicine network. This allows communication among local and national physicians, healthcare workers and clients covering urban and rural communities.
3. Design a suitable back-end (database) and front-end (user interface) applications and provide a prototype implementation of the proposed architecture.

2.3. Design Goal

The overall goal of the nation wide telemedicine network design is to provide affordable and low cost system that facilitates communication between physicians and healthcare professionals across the country. 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.

2.3.1. Expandability

Expandability is a concern in the telemedicine network design for the following reasons: First, 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. Second, 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. Third, the network should also support advanced applications, which require real time connectivity such as video conferencing in the future.

2.3.2. 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 [4]. 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 [5, 6].

2.3.3. 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 healthcare to rural areas. However, network connectivity among the healthcare 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.

2.4. 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 urban area referral hospitals, 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 various reasons. Among them are instantaneous access to patient information, access to medical information, and access to the Internet. 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 and next 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* located in the capital Addis Ababa as a model. 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. The decision to make the selection between the various LAN technologies was done based 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.

3.1.1. Expected application to run on the network and their traffic patterns.

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.

3.1.2. Physical locations of the offices and users to be connected in campus.

The sample hospital (*Tikur Anbassa Specialized Hospital*) is composed of 5 buildings (Block A-E). The blocks are not physically separated. Thought we could not get the exact figure, the five buildings are built on 8,000 to 10,000 Square meters area. The main offices and departments in the hospital are located in either of the blocks. However most of these offices are in either of the first two stories of the block they belong. 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.

3.1.3. The rate of network growth.

The rate of the hospital LAN growth depends on the level of computerization in the hospital. Currently in the hospital, there is a LAN that connects few offices and a computer room. The network uses star topology, using a centrally located hub and Unshielded Twisted Pair (UTP) cables forming a peer-to-pear LAN. The purpose of this LAN was to enable offices share printer and students get access research documentations. In this design it is anticipated that as the web based 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.

3.1.4. The abundance of the network technology in the market.

To make use of the abundance network technology in the market in Ethiopia, we gathered data from Network technology vendors and organizations that implement computer networks in the capital city Addis Ababa. Ethernet technology is common in organizations that implement computer networks, such as Addis Ababa University (AAU Net). AAU Net is a network backed by triangular shape fiber optic cable connecting the three main campuses. The topology is extended star topology that extends fiber optic cables for vertical cabling (backbone cabling) between buildings that belong to faculties and departments. These backbone cabling provides interconnection between wiring closets and Point of Present (POPs). The zones that fall within area of department were served by internetworking devices such as hubs and UTP cables.

It was also identified that, since such networks dominate the small number of networks existed in the capital Addis Ababa, network technology devices and support can be found from limited number of vendors.

3.1.5. Simplicity of installation and maintenance.

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 [5]. The model required the following three layers

3.1.5.1. Layer One (Core 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 will be connected to switches in this layer shielded by a firewall.

3.1.5.2. The second layer(Distribution 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 one 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.

3.1.5.3. The third layer (Access 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 shows the hospital LAN design.

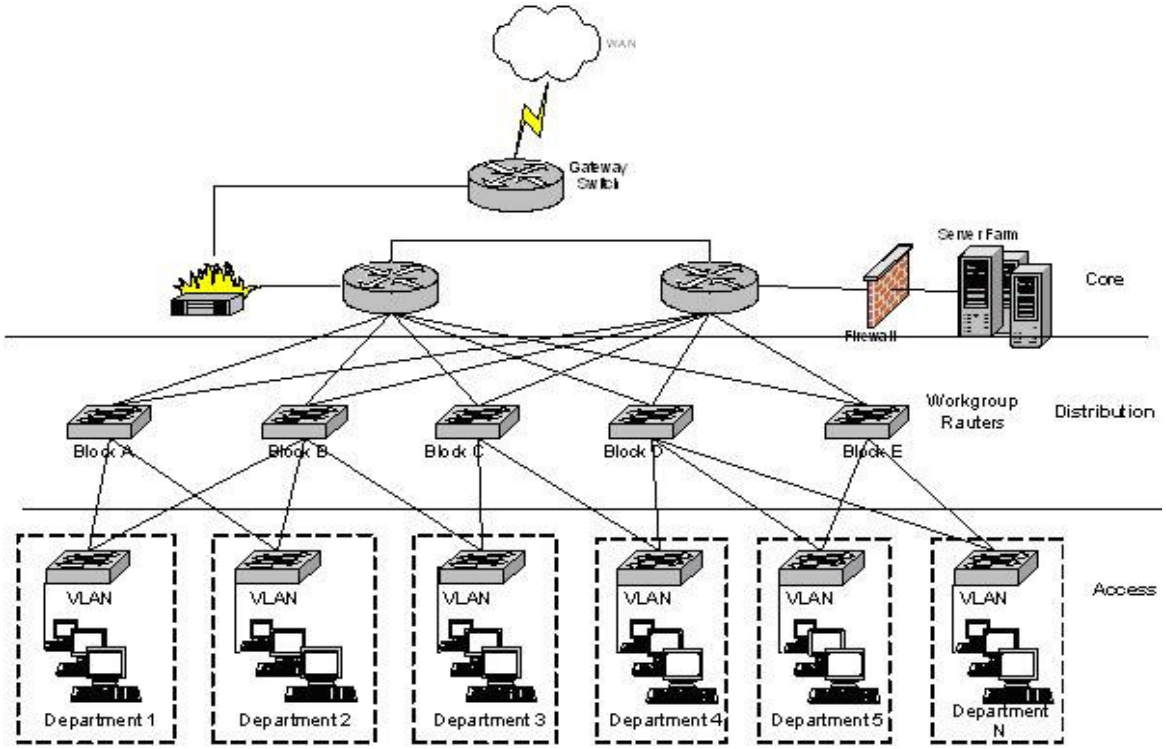

Figure 1: Hospital level LAN

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 [7] among which we have selected the WAN infrastructure that is suitable for the nationwide telemedicine network. The following services are considered in this design.

- Internet Services: provides basic internet services over dial-up or Leased Lines.
- Digital Data Network (DDN): provides dedicated Internet, ISDN and frame relay services.
- SchoolNet VSAT network: covers secondary schools and institutes of higher learning.
- WoredaNet VSAT network: covers districts (Woreda) administrations.
- Broadband Multimedia Network: Provides high speed optical communications to major cities.

4.1. Summary of ICT Selection

To pick one of the infrastructures for telemedicine the parameters considered are the geographical coverage, bandwidth, mode of communication, rental cost of WAN connection and capacity to add more LANs. Table 1 provides a summary of existing ICT infrastructure.

	Internet	DDN	SchoolNet	WoredaNet	BMN
Coverage	Telephone coverage areas only	The capital and regional Urban areas only	About 500 schools covered. There are Woredas 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	0.11 birr/min dialup 1000 birr/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

Table 1: Summarized comparison of existing ICT infrastructure

4.2. Recommendation

Based on the comparison we have made 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, when the coverage is good the capacity is limited. BMN will be best for 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 networks and terrestrial Broadband Multimedia Network. VSAT based connectivity is believed to be cost effective and in case of WoredaNet and SchoolNet it goes down to the public even in the rural areas. In addition to its coverage in the rural areas it also covers urban areas providing modern but economical connectivity to hospitals. For even better state-of-the art applications such as video conferencing, 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. Figure 2 shows our proposed telemedicine network.

This WAN connectivity required 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 3.

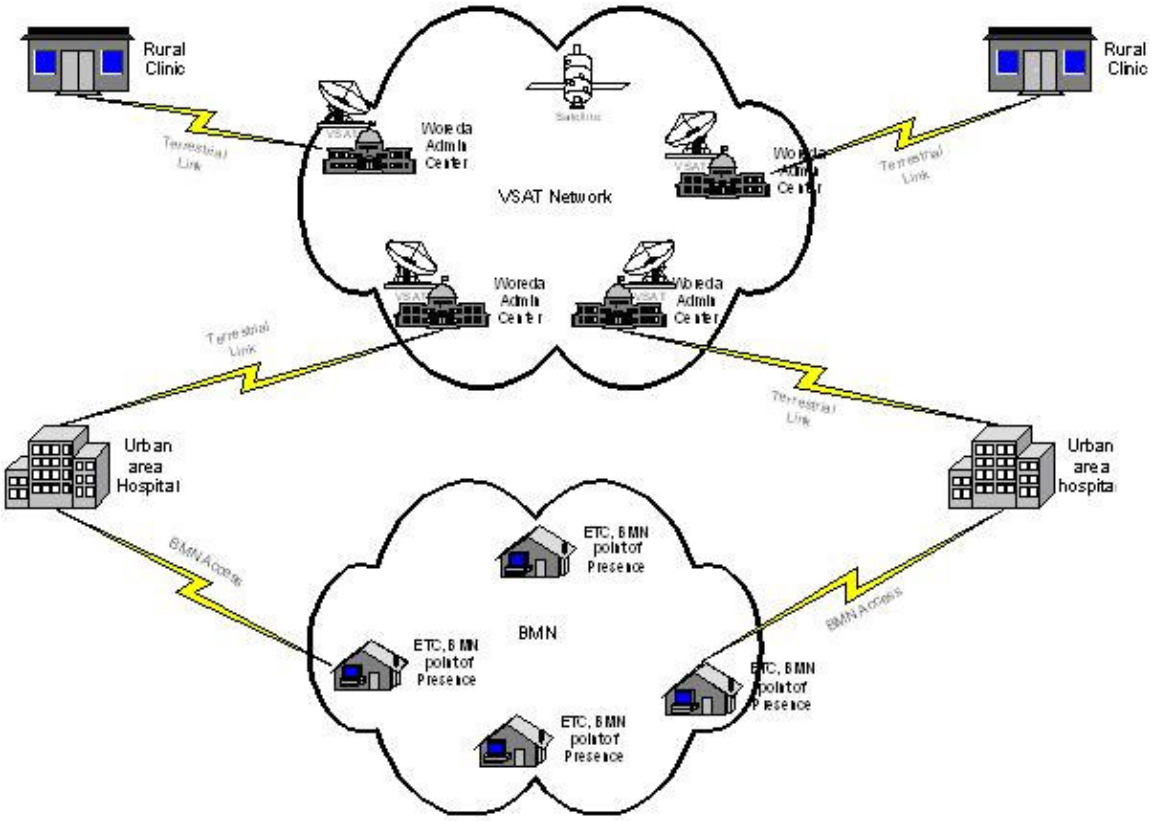

Figure 2: Logical WAN design based on BMN and VSAT networks alternative one

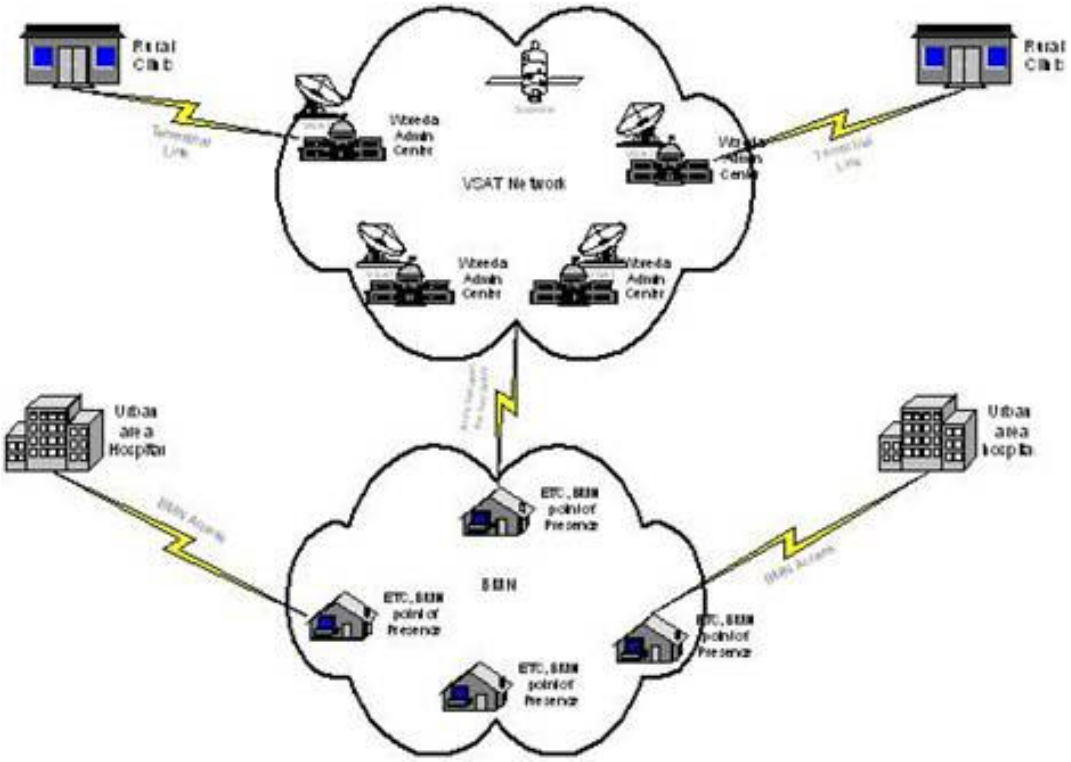

Figure 3: Logical WAN design based on BMN and VSAT networks alternative two

5. CURRENT INITIATIVES AT THE ETC

The recent development in the Ethiopian Telecommunication Corporation (ETC), in providing multimedia network infrastructure shows that the VSAT based networks (SchoolNet and WoredaNet) are integrated with the

Broadband Multimedia Network (BMN) [15]. This implies that, these VSAT based networks can also be used as a point of access to the BMN.

ETC has planned an e-Health setting that tries to cover rural areas, schools, clinics, hospitals, prisons, and nursing homes/ assisted living, with the following requirements, as part of ETC's Vision and Mission of broadband initiatives for socio-economic development in Ethiopia.

1. High quality patient data, video and images to be exchanged between different medical institutions
2. ICT (Infrastructure) to connect geographically dispersed institutions, nation wide or world wide
3. The infrastructure should support data, video and voice/audio (multimedia) services
4. Quality, secured and fast delivery of medical information
5. High speed (BW) connectivity or Broadband Infrastructure required

The challenges are covering multiple locations, using multiple access technologies, delivering multiple services and addressing multiple user markets.

5.1. Current BMN Development

ETC have already completed building the Core Terrestrial Broadband Infrastructure, which is capable of providing data, video, and voice services with 24 Point of Presences – covering business sites (urban areas). It supports Multiple Broadband Access via: ADSL, FWA, WIFI, and Fiber networks.

5.2. Current VSAT Development

A Broadband VSAT Network platform is currently in place in Ethiopia, which supports integrated services such as video, data /Internet, and voice on a single infrastructure. It has country wide coverage (450+ schools and 550+ woredas) as part of SchoolNet and WoredaNet deployments. It is integrated with the core multimedia network, also serving as broadband access means. Figure 4 shows the two recent developments.

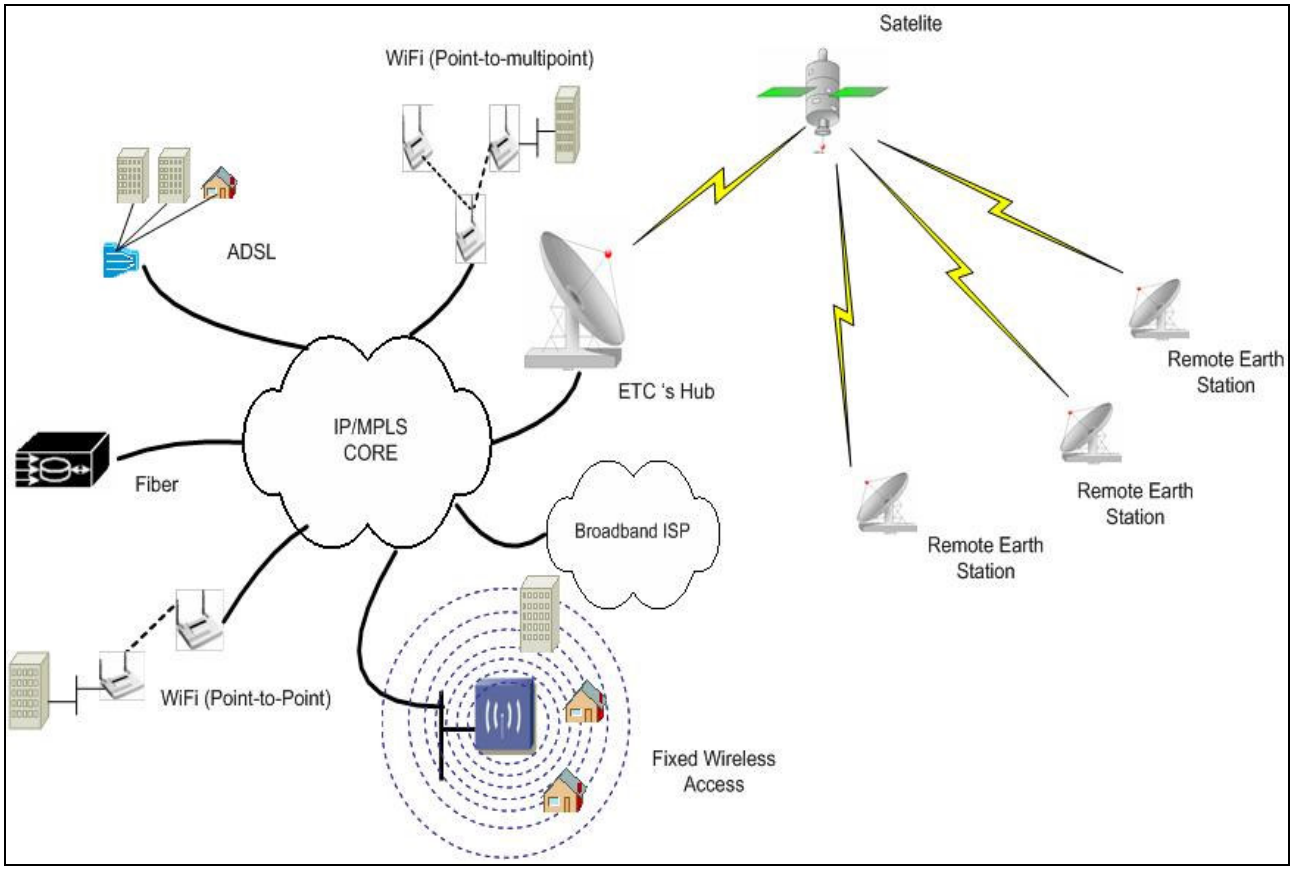

Figure 4: ETC's Broadband Integrated Infrastructure for e-Health Applications

We believe that, the new development in WAN infrastructure supports our proposed, second alternative Telemedicine WAN architecture shown above in Figure 3.

6. 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:

6.1. 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 [10]. 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 relational database to store user and patient information. Unlike e-mails, this approach allows us to insure structured information exchange between the communicating healthcare providers.

6.2. Major Features of BTS

Basically BTS is a database driven website. The main functions are to:

1. 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.
2. Provide patient management services where healthcare providers can register patients, search patients and view patient information on a traditional patient card like interface, when necessary.
3. 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.
4. 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.
5. 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.

6.3. 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 [8]. The user interface and text of web pages are implemented by the Java Server Pages (JSP) [10, 11]. 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 [11]. 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 [11].

The database we have used is the open source MySql to back up our database driven application. MySql works on many different operating system platforms and is known for its speed of data retrieval [12]. 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 [13]. Figure 5 shows the BTS system architecture.

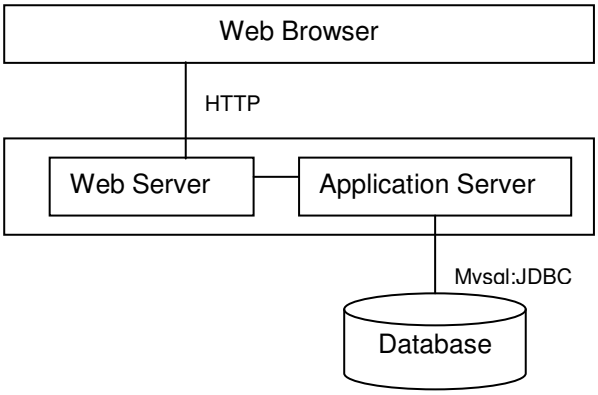

Figure 5: Architecture of BTS

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.

6.4. Database Design Issues

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 [14]. Our database is expected to maintain and manipulate basic entities such as Users, Patients, and Medical Records.

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, Hematology, 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.

To minimize connectivity cost and increase performance, a distributed database is suggested. Horizontal partitioning that splits tables along rows, based on the location of patient and healthcare facility is an ideal choice in the telemedicine application that tries to create nationwide connectivity. In the applications that run over the network to use the database transparent data access schemes must be defined.

6.5. BTS Interfaces

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. The administrator's main page is used for managing users. It allows registering new user, searching existing user by various attributes. The physician's main page allows opening Patient Manager Page and contains list of referrals forwarded the department where the physician is working. The Lab technicians' main page is used to mange the laboratory requests to the department she/he is working. 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.

7. CONCLUSIONS AND FUTURE WORK

In this paper, we proposed a hierarchical model based LAN architecture and VSAT-based WAN for telemedicine network for a developing country. The paper addresses the challenges of healthcare services and explores how to exploit telemedicine technologies to provide basic healthcare to remote areas. We have identified the network requirements and challenges, and then designed a telemedicine network architecture that can be implemented over the existing/emerging ICT infrastructure. We have also developed a web based prototype of Basic Telemedicine Service (BTS) to integrate with the network design. The system can be used to facilitate both intra- and inter hospital communication for information exchange. The proposed solution can improve quality of healthcare services while protecting the privacy, confidentiality and integrity of sensitive patient information.

As future work in the area of telemedicine, we recommend the following issues: First, we will design a system that supports real time tele-consultations via video and audio conferencing to support doctor-to-patient communication, facilitate remote training for healthcare professionals. Second, we will design a distributed database, where all the hospitals should keep their own databases, which can be treated as one database. The definition of standards is essential to facilitate information exchange among private and government hospitals as well as overseas. Third, the integration of expert systems such as case based system where doctors can query the database to get experience from previously stored similar cases should also be considered. Such a system shall help future physicians working anywhere in the country to learn from the specialists success and/or failure, when they come across difficult patient cases. Fourth, systems that support physician to remotely monitor the patients over heterogeneous networks including handheld devices in 2G/3G mobile networks are beneficial to user in developing countries. We intend to design an architecture that supports heterogeneous networking environment for use under different bandwidth requirements. To overcome bandwidth limitations, mechanisms such as data compression and congestion control methods will be employed.

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