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Research Paper

An Interactive Telemedicine Environment to Improve Healthcare Access in Rural Areas of Developing Countries: A Case Study in Nigeria

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ABSTRACT
In many developing countries, such as Nigeria, many patients in remote rural areas require specific healthcare support services. They addressed this need and called for developing a robust system to transform and enhance healthcare delivery services. This research presents the design of an interactive-mode telemedicine environment to mitigate the unequal distribution of medical expertise and facilitate meaningful consultations between rural health workers and specialists in larger medical centres. The proposed system provides healthcare workers access to vital information for diagnosing patients' health states and developing appropriate treatment plans, ultimately improving healthcare services in rural and urban areas. In addition, the system recognises the importance of maintaining data confidentiality and security. To ensure this, communication networks are protected using the open-SSH library for data encryption. Role-based authentication is integrated into the system as a security measure for accessing information in the database. By implementing this interactive telemedicine environment, healthcare accessibility and quality can be significantly improved for patients in rural areas of developing countries like Nigeria, bridging the gap between available resources and the population's needs.
Keywords*: Telemedicine, Rural Healthcare, Medical Expertise Distribution, Data Confidentiality, Role-Based Authentication*

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I. INTRODUCTION

Several technologies have been developed globally to produce novel means of handling different health challenges (Ahmed et al., 2023). Electronic-related technologies, for instance, telemedicine, deployed interchangeably in telehealth and E-health, are pertinent innovations enabling the interaction between healthcare providers and recipients (Ahmed et al., 2023). Remote health services can be provided by call centres, cell phones, videoconferencing, and web-based platforms (Saigi-Rubio, 2022). Telemedicine is a cost-effective means of information recording, storing, and conveniently accessing a patient's electronic records to a healthcare provider (Saigi-Rubio *et al.*, 2022). Telecommunications have profited patient-related outcomes, enhanced health practitioners' performance, decreased health workers' assignments, and reduced the isolation of health care professionals in remote locations (Saigi-Rubio *et al.*, 2022). Multi-Agent Systems (MAS) are well-established modalities to model and solve real-world problems. The primary point of MAS is to produce communication and cooperation problems. This involves various telecommunication applications such as the Internet, robotics, and medicine. The current existence of telemedicine has a significant role in creating more efficient and patient-oriented care for chronic health challenges. This research proposes a system that provides opportunities for healthcare workers to gain access to vital information that can aid in diagnosing a patient's health state or developing suitable treatment plans and for the patients to fully enjoy an enhanced healthcare service in rural areas and urban cities. In recognition of the confidentiality of data in the system, communication networks are protected with open-(ssh) library for data encryption and role-based authentication is built into the system as a security pass mark for accessing information in the database.

II. METHODOLOGY

2.1 IMPLEMENTED SYSTEM DESCRIPTION

The system consists of four major modules. These are the Administrative, Consultations, Referral and Training modules. The entry point to some of the above modules requires that the user is authenticated. Since users access these modules remotely, a built-in security system forces users first to log in. There are several alternatives to user authentication. These alternatives include HTTP basic authentication and PHP session schemes. In implementing HTTP basic authentication, one must either properly configure it through the web server, such as using the .htaccess file on an Apache server or duplicate the functionality using the PHP Header function. Although the HTTP mechanism is acceptable, even with a proper setup, HTTP authentication has many shortcomings, such as a lack of security features (inactivity timeout); and developer-friendly benefits (the ability to display secure/non-secure data quickly on the same page).

As a result of the mentioned shortcomings, the module uses a PHP session authentication to control access to most of the systems' sensitive areas while providing a more practical and clean implementation. Sessions are a mechanism that allows PHP to preserve the state between executions or will enable the system to store variables from one page and use them on another.

The primary mechanism of this session works as follows:- first, PHP generates a unique, thirty-two-character string to identify the session. It then simultaneously passes the value to the browser; it creates a file on the server and includes the session ID in the filename. There are two methods by which PHP can inform a browser of its session ID: by adding the id to the query string of all relative links on the page or by sending it as a cookie (a small piece of information that PHP script can store on a client-side machine). When the browser requests another page, it tells PHP which session it was assigned via a MySQL query string or by returning the cookies. PHP then looked up the file it created when the session started and had access to the data stored within it.

Once the session has been established, it will continue until it is destroyed explicitly by PHP in response to a clicking "Logout", for example, or the session has been inactive for longer than a given period (twenty-four minutes by default). At that point, it becomes flagged for garbaged collection and will be deleted by the following PHP checks outdated sessions.

The basic steps of user sessions are starting, registering session variables, using session variables, deregistering variables, and destroying the session.

Because we want to tie a user to a session, each user (technologist) is assigned a unique username and password, and these are stored in a MySQL database table. The user's username and password will then be authenticated against the entries stored in the database table. The user authentication module has four main elements: user registration, login and logout, changing passwords and resetting passwords. A valid technologist could perform each of these elements.

The Authentication page consists of a dedicated script trigger. It is handled using simple HTML, allowing system users to input their name and password on loading the home page. The use of personal identification numbers ensures the security process. Also, role-based authentication is employed to specify access rights to the entire system database information.

To register a user, the user supplies his identification number and the *preferred username*, *password* and *password confirmation* via an html form, and if the patron identification number is found in the table and both password and password confirmation are the same, it then registers the username and password in the user table otherwise it reports error messages. Registered users can now log in by supplying their username and password details into an HTML form and submitting it, the entries will be processed, and the user will be logged on if the authentication is successful. Users are also allowed to change their passwords, and the system also deals with the common situation in which a user has forgotten his password.

2.2 ADMINISTRATIVE MODULE

This module consists of four sub-modules, which allow nurses to add/update patient demographic data, admit/discharge management, admission of drugs/injection for the patient and adds payment made by the patients. Solely the physicians and the remote rural health workers handle the addition/update of the patient's multimedia information sub-module.

This module aims to improve healthcare practitioners' clinical and administrative workflow. In essence, this will support clinical and administrative services, investigation of requests, result retrieval, diagnosis, treatment, drug prescriptions, etc. All the functions of this module will contribute directly towards on-the-ground support of medical practitioners, thereby allowing more accurate and informed diagnosis, more effective treatment and enhanced level of healthcare. The need to transform patient data into an electronic format is driven by the necessity of obtaining a patient's medical history during contact with a medical professional. This process often consumes a substantial portion of the practitioner's time, especially during episodic encounters with patients possessing a potentially complex case history.

2.3 CONSULTATION MODULE

The module is divided into three sub- modules:- consultation/diagnosis, remote consultation and lab test submodule.

2.4 CONSULTATION/DIAGNOSIS

The consultation/Diagnosis module is to be used by the attending physician to create and store a daily transaction carried out for each visiting patient in the clinical table according to the clinical problem presented. The CT tuple (SNO, PIN, HSN, TEST, S, R, LT, ST, ID) describes the clinical table data set's basic structure, where SNO is the serial number. It increases in the order of step one for each patient record in the clinical table; PIN stands for a personal identification number, which has a unique attribute for all patients' input or data, HSN is a unique number of the clinical problem, and T is the patients' visit date, TEST is a field that indicates whether a patient is required to undergo a laboratory test, or still image test, or both for diagnosing their illness. This field could either be NULL (meaning no laboratory test or still images required), L (laboratory test required), SI (still images required) or B (both). To trace the progress of therapies, the clinical table uses the S property to describe the processing state and the R property as a reference link to the previous record in the clinical table.

Table 1: Clinical Table (CT) – Associated with two Patients

SNO	PIN	HSN	DATE	TEST	S	L	ST_ID
1	1	1	T1	NULL	B	NULL	1
2	1	3	T1	NULL	B	NULL	1
3	1	1	T2	NULL	C	1	1
4	1	2	T2	B	P	3	1
5	1	3	T2	NULL	C	2	3
6	1	2	T3	NULL	E	4	1
7	1	3	T3	NULL	C	5	1
8	1	3	T4	NULL	C	7	2
9	1	4	T4	B	P	8	1
10	1	5	T4	B	B	NULL	1
11	1	4	T5	NULL	C	9	5
12	1	4	T6	NULL	E	11	1
13	1	5	T6	L	C	10	1
14	1	6	T7	NULL	R	13	1
1	2	6	T2	NULL	B	NULL	3
2	2	6	T5	L	A	1	3
3	2	6	T9	NULL	E	2	5

III. REMOTE CONSULTATION

The internet-based telemedicine system can support many patients who need specific health support locally. This is achieved by sending SMS through the net, with a terminal setup in a patient's home and connected or on the Internet, or using instant chatting messages or sending Emails all through the net. The remote consultation module makes many people's healthcare routines available worldwide, and homebound patients communicate daily with specialists.

Bringing the benefits of the expertise of hospital-based specialists to the rural populace has been the goal of telemedicine systems. This system provides a store-and-forward approach mechanism via email to enable consultation between the remote health workers and the specialists on any particular patient's cases.

Most people are familiar with the term email in this day and age. Email is a computer-based method of sending messages from one computer user to another. These messages usually consist of individual pieces of text which one sends to another computer user even if the other user is not logged in, that is, using the computer when the message is sent. The message can then be read at a later time. This procedure is analogous to sending and receiving a letter. Initially, email messages were restricted to simple text, but now many systems can handle more complicated formats, such as graphics and word-processed documents. When mail is received on a computer system, it is usually stored in an electronic mailbox for the recipient to read later. Each user typically has a mailbox. Electronic mailboxes are usually files on a computer that can be accessed using various commands. Emailing between users of different computer systems connected to major networks is straightforward. Most major academic and research institutions and companies worldwide can now be reached by email. In addition, a growing number of individuals can be contacted this way.

One common misconception with email is that messages will always arrive immediately or at least very quickly, that is, within minutes. Whilst this is often the case, email relies on many computers and networks. Therefore emails are at risk of delays at any stage. However, sending messages within one system should be immediate.

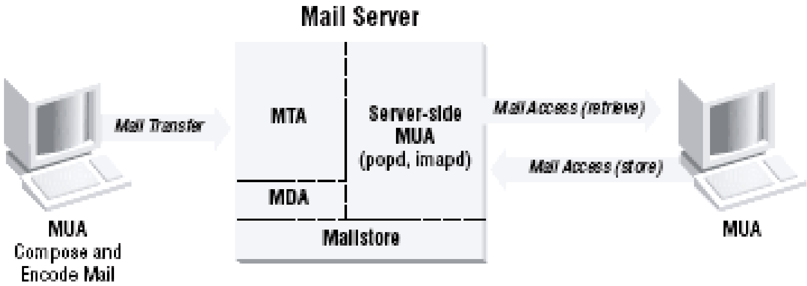

Figure 1: Email Framework

The telemedicine system uses a Postfix email server to receive email and deliver it to the user's inbox, but additional software is required to read them easily. There are two standards for the retrieval of email from a host. The first is called POP (Post Office Protocol). POP3 is the most commonly used. This is usually used to read an email from the server, store it in a client application, and remove the email from the server. ISPs often use this. The email is subsequently manipulated by the client application, for example, Outlook Express or Mozilla Thunderbird.

The second protocol is called IMAP (Internet Message Access Protocol). The IMAP system is usually used when the email is to stay on the server. IMAP allows users to create email folders and move or copy emails between the folders. The client application accesses the email on the server but does not have to store it on the client's machine. The email server must be able to keep all the emails for all its users, and the amount of data is expected to grow constantly as users rarely delete the email.

The main difference between these two is that POP is intended for, and is usually used by, people who connect to a network for a short time to download their mail from a server. IMAP is designed for online users to interact with mail permanently on the remote server.

IMAP is more frequently used in large organisations with centralised information technology facilities. Therefore, the Ask a Technologist email option is a web-based IMAP email client that would provide the system with more timely and cost-effective research quality information. This option would enable systems and technologists to communicate and connect to their IMAP email servers.

Certainly, this statement is true, but there's more to it than that. IMAP is a way of accessing email stored on a central server. More precisely, IMAP is a way to retrieve messages from one or more mailboxes on a central server without downloading a single message to a local hard disk. The messages remain on the server at all times.

By design, IMAP was intended to provide the same mailbox and message access and management functionality with a mailbox located on a local hard drive. Consequently, IMAP has server operations, such as the search for messages matching such and such criteria that are usually associated with mail clients.

The advantages of IMAP can be seen very clearly as it is possible to work from several computers, for instance, a home computer, office computer, and laptop. With the right IMAP client, you can do all of the following: learn when new messages arrive in any of your mailboxes; share your mailboxes with anyone or everyone; move messages from one mailbox to another; and mark messages with flags (such as *necessary*) that are preserved between IMAP sessions. Another distinguishing feature of IMAP is that not only is the inbox stored in a central location, but mail folders (mailboxes in IMAP parlance) are stored in a central location on the IMAP server. With the right IMAP client software, one can read his incoming email from anywhere on the net and access all the mail archived in his mailbox.

One feature that sets IMAP apart is that it supports not one but *three* interaction models. These interaction models include the online model, where email is never downloaded into the client host's hard disk but manipulated remotely by the mail client programs. The mail client maintains an open connection to the server for the duration of the session until the user decides to end the session. Next is the offline model, where email is downloaded from the client's hard disk and deleted from the server, that is, POP3- style and disconnected; model a situation where an email is kept synchronised on the server and client's host.

The Telemedicine email system first requires the patron to log in and then gives him options. He can set up a new mail account or select one of his existing accounts. He can also view his incoming mail, respond to, forward, or delete it, and send new mail. The email system also allows technologists to view detailed headers for a particular message. Viewing the complete titles can tell a lot about a message.

When a user starts using the web-based IMAP email client, he will need to set up some email account details before he can read his email. If he clicks the *Account Setup* button, Figure 2 is displayed to supply all the necessary information.

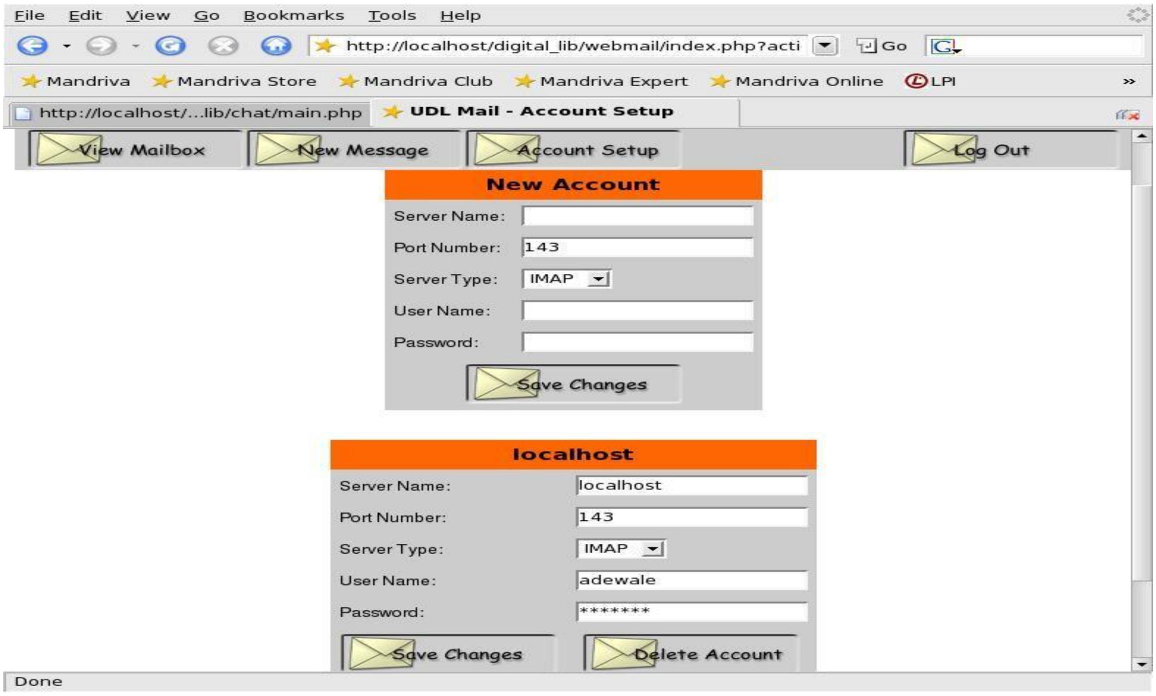

Figure 2: Account setup

When asking a system email option is clicked from the home page, the technologist's authentication will be performed. After a successful login, the user can begin using choices such as viewing mailbox contents, reading mail, viewing mail header, deleting mail and sending mail. After the technologist has set up some account details, he chooses which account to connect to so that he can read his e mails. The system also allows for modifying existing accounts, similar to setting up new accounts. A technologist can change his account details and click the save changes button. He connects the Delete Account button to delete a statement under his account listing.

There are a few ways to send mail. The technologist chooses this option by clicking the *New Message* button. He can send a new message, reply to, or forward mail Figure 3.

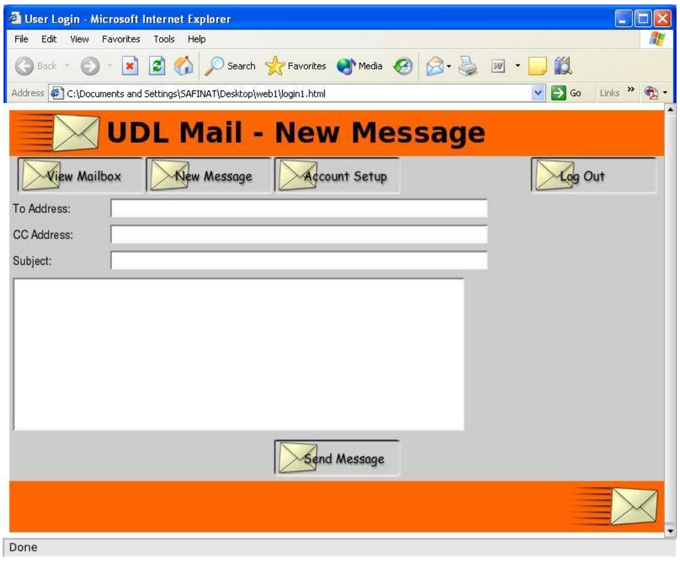

Figure 3: New message

The *Reply*, *Reply All*, and *Forward* functions send mail like New Message. The difference in how they work is that they fill in parts of the new message form before showing it to the technologist. The message Technologist wishes to forward has been indented with the > symbol, and the Subject line has been prefaced with *To*.

The Internet also enables a group of people to communicate in a meeting where the participants may be anywhere in the world. This group communication can be by text on the screen, voice, or video, and messages and responses can be exchanged "live," or they may be read and responded to later. These types of online communication are called *online chat* or *online conferencing*. In some kinds of chatting and conferencing, messages are sent immediately after they are complete, that is, as soon as enter key is pressed after typing a message. This type of communication is called *real-time communication*. The consultation/diagnosis module's *live chat* is real-time communication and works like instant messaging and could be used to ask librarian questions.

Chat systems come in various flavours, from text-only messaging systems to fully immersive 3D environments. By far, the most common form in recent times is instant messaging. The oldest form of authentic chat rooms is the text-based variety. The most popular of these kinds of the chat room is Internet Relay Chat (IRC). However, there are also talkers, bulletin board systems, and havens. Many of these kinds of chat rooms have waned over the years, but IRC's popularity remains strong.

At the next level are the 2D visual chat rooms. These are characterised by using a graphic representation of the user (avatar) that can be moved about a graphical background of the "room". Two examples of this chat room type are The Palace and, more recently, The Manor. These environments can incorporate elements such as games and educational material most often developed by individual site owners, who, in general, are more advanced users of the systems. Some visual chat rooms also incorporate audio and video communications so that users may see and hear each other. This is particularly popular with that keeping in touch with far-flung family members.

Finally, there are the 3D chat rooms. These are similar to the 2D variety except that they utilise 3D graphics. This allows a user a more realistic interaction with the environment. The most popular settings enable users to create or "build" their own spaces. However, some find these environments cumbersome and an impediment to chatting. Three examples of this chat type are There, Second Life, and Active Worlds.

Ask a Technologist live chat is a Multilanguage software support that allows real-time online conversation between multiple users and technologists. Using the full power of MySQL and DOM (Document Object Model), this live chat offers outstanding features and qualities. The live chat features include active links; user profiles with the actual name, location, email and the like; private messages in separate pop-up windows; save traffic (only new information will be transferred between client and server; guest login, registration and lost password features; multiple user levels with transparent rights system; advanced admin panel; and much more. Fig. 3.11 shows a sample of the live chat system. Currently, there is a browser flicker between message translations. This problem will be dealt with in the future.

Finally, ask a technologist phone option displays phone numbers of the library staff that users could use to talk to the team about their needs. In the future, *skype*, a free internet telephony software, may be incorporated to exchange calls between system and technologist staff.

Using videoconferencing techniques, obtaining a patient's medical history, diagnosing the patient, educating the patient, and making prescriptions are possible. The above scenarios mean that the patient does not have to travel to urban cities to see specialists and, in many cases, receive access to specialist care where none has been available previously. This also opens up new possibilities for continuing education for isolated or rural health professionals who cannot leave a rural practice to participate in professional meetings or educational opportunities.

Home healthcare is familiar to many people's healthcare routine worldwide, a situation whereby homebound patients can communicate daily with specialists. An internet-based telemedicine system in Nigeria can support many patients needing specific health support at home. This is achievable through an interactive two-way videoconferencing that runs over Internet protocol using videoconferencing and a TV for patient interaction. The videoconferencing terminal in a patient's home consists of the patient's existing TV set and remote control, an interface to the TV, which also houses conferencing application software and digital medical equipment. The multimedia data is transmitted to the telemedicine network through USB and RS323 ports. The video screens are patient-ready, easy to follow, and provide step-by-step instructions. Using this approach, it is possible to obtain a patient's medical history, examine the patient for primary healthcare, make remote measurements of vital signs, educate the patient and make some prescriptions if need be. The system requires the patient to have minimal competence to use the system and handle the medical equipment at his disposal.

Figure 4: Mobile phone devices used for remote measurement and signs detection

3.1 TEST MODULE

The test module allows the technicians to record the medical examination result and still images of any patient in the lab test table and the still image table in the database. The physician, after that, loads the result from the database and uses it to diagnose the patients in question.

3.2 REFERRAL MODULE

Referring a patient to another physician or hospital is one of the most common transactions in healthcare. When a patient is referred, a subset of his pertinent record to that referral is transmitted to the appropriate specialists or hospitals through the telemedicine network. This system provides a mechanism by which physicians can compose a package of referral queues. The process automatically processes the submission to select the appropriate specialists or hospitals for the patient's condition based on the available information.

The fundamental component of the Internet-based healthcare system's infrastructure is presented in Fig 3.2. This includes a user interface of access devices in remote rural areas and urban cities, a high-speed, highly reliable and scalable regional network and a content management gateway. This approach allows users to access the system through the Internet and a standard content management gateway. It takes service requests from the users (physicians and other health professionals) and passes them to the appropriate backend systems.

The standard content management gateway provides a single point entry to the system via the Internet. The action of the user invokes this. Once a user logs on, the browser presents the main module of the system to the user. Based on the user's selection and successful authentication, the browser presentation logic redirects the user to sub-modules or forms to perform the task the user selects. Furthermore, a procedure provides the presentation logic for processing the service request, for example, submitting a form to register a new patient or updating an existing patient's health history. It uses MySQL Transform's methods to convert the HTML form data into MySQL documents. This conversion provides for a structured data format that would be recognised by the backend systems in the hospitals.

After the data conversion, the application then invokes the database. The database provides a set of operations for the server and procedures for accessing the system. The application invokes, for example, the add/update method of the database to add/update patient data into the appropriate backend system. In case a patient is to be referred, a form where the physician will specify the referral information from the patient data and others are presented. After submitting the completed form, an application is invoked, converting the HTML form data into a MySQL document. This, in turn, invokes the Database referral methods to transmit and queue up the patient information into the appropriate queue server where the appropriate physician can access them. In both cases, it dynamically creates and returns to an HTML page with the results of the operation specified by the user to the browser.

3.3 TRAINING MODULE

Some digital medical material on the system for medical practitioner majors for remote rural health workers is available.

Through Nigerian Telemedicine System, academic professionals from major Nigerian Medical Academic Institutions will extend their educational capabilities to healthcare professionals throughout the rural communities of Nigeria without having to provide facilities and teachers in every rural location. The academic institutions will electronically provide practical clinical training to young doctors and help them obtain advanced medical professional credits. A National Clinical Grand Rounds will be conducted regularly to share information and decision-making regarding diagnosing and managing specific complex Nigerian clinical cases. By attracting primary healthcare providers to rural areas of the country, the telemedicine system will reinforce the policy of promoting immediate healthcare delivery to underserved Nigerian communities.

One of Nigeria's healthcare challenges is the drain of medical doctors from the less developed rural communities to the more developed urban areas. It is challenging to attract and retain doctors in rural communities because of professional isolation from their peers, lack of continued medical opportunities, low patient volume and loss of continuity when patients are referred to hospitals in larger urban centres. The recruitment and retention of rural medical doctors will be one of the main deliverables of the Nigeria Telemedicine System. Through telemedicine technology, medical doctors in underdeveloped communities will find their practice less isolating. The system will facilitate frequent contact with distant colleagues in more developed centres who share their interests. Such interaction will simulate the common professional associations in developed urban areas.

3.4 DESIGNING TELEMEDICINE SYSTEM DATABASE

Creating a 'blueprint' or 'conceptual model' of the new system database is vital before designing it. Hence, the model is designed to satisfy the proposed system's current and future information needs.

In designing a database of such, the conceptual model does not depend on the database model (hierarchical, network, or relational). More so, the model is independent of the application, software, and hardware used to build the system; this is to ensure that the required and correct information entered by an end user is stored correctly in the database.

There are several approaches to database design. But here, we will design our database on the Entity Relationship (ER) model, in which an ER diagram depicted below in Fig 3.13 represent the conceptual model of the database. The ER Model describes the database design. The ER Model views the entire system as composed of entities that are related to one another. The importance of this step is that at the end of the design process, we will be able to identify the various tables, the fields in each table, and the relationships between different tables.

Before we proceed further, we need to familiarise ourselves with the components of the ER Model. These components are explained below:

I. Entities

An entity is a person, place, thing, object, event, or even a concept which can be distinctly identified. This term covers a comprehensive spectrum. Take, for example, a medical patients' Mariam Yisah' whose hospital admission or card number is 'ABUTH10987354/08'. She was admitted for typhoid fever in clinical ward code FW/RM110/BD20 (female ward/room 110/bed number 20) at ABUTH (Ahmadu Bello University Samaru, Zaria). Patients and hospitals are all examples of entities.

II. Attributes

Each entity has a set of properties or characteristics. For example, the hospital card number and the hospital's name are attributes of the entity Hospital, as they defined the entity. Each attribute could further have properties attached to it. For example, the hospital card number could be assigned the 'Not Null' and 'UNIQUE' properties. This would imply that the hospital card number is mandatory and must be unique.

III. Relationship

A relationship can be defined as an association among entities. For example, 'Mariam was admitted to the Hospital' is an association between Mariam, Admitted and Hospital.

To better understand this model and its components, let us consider a patient- o n - admission case study. A patient is admitted to the hospital. The patient is first issued a hospital card, and the patient's medical history is taken. Then the case is attended to by a physician accordingly.
The nouns in the scenario mentioned above form entities. Thus, patient, card, history and physician are entities.
The patient would have a *Hospital Card*, a *name*, and perhaps *age* and *address*. These comprise the attributes or properties of the entity *Patient*. There could be many more attributes, such as the patient's *sex, tribe, unit number, etc*. The database designer and the end user thus decide which of these attributes are required.
In 'Patient on admission in a hospital', 'on admission' is the relationship between the entity's *Patient* and *Hospital*. Similarly, in 'A *hospital*, service is by *card*', 'consist of' is the relationship between *hospital* and *card.*

3.5 ENTITY RELATIONSHIP DIAGRAM (ERD)

The ERD is the culmination of the database design process. Once this is done, then we can start creating our database tables. Entity relationship diagrams graphically represent the entities, the attributes of an entity, and the relationships between these entities. The Patient, Hospital and Card are the entities in the previous case study. These entities, along with their attributes, are listed in Table 2:

Table 2: Entity Relationship Table

Entity	**Attributes**
Patient	Patient name, patient sex, patient age, patient tribe, patient occupation
Hospital	Hospital name, Hospital Code, Hospital Capacity, Hospital Location,
Card	Card Number, Card Name, Card Date, Card Age, Card Unit

The relationships between entities can be described as follows:
I. A '*Patient* admitted in a *Hospital*.'
II. In 'A *Hospita*l Access is by *Card.'*
With the above outline, we can then proceed to create an ERD. First, let us depict the Patient and Hospital entities, attributes, and relationships.
A patient can only be admitted to a hospital at a time, a hospital can recognise more than one patient at a time, and a patient can only own a card for a particular hospital. Hence the relationship between patient and hospital is of the 'One to One' type. Similarly, the relationship between Hospital and Card is a 'Many to Many' relationship. In this case, one hospital can have as many cards as possible for many patients.
Relationships can be of three types.
I. One to One (represented in the ERDs above as 1:1)
II. One to Many, or Many to One (described in the ERDs above as 1:N)
III. Many to Many relationships
Now that the ERD has been drawn, we can quickly create tables.

3.6 DESIGNING THE HEALTHCARE ENTERPRISE MEMORY

The Healthcare Enterprise Memory (HEM) can be characterised as a conglomerate Knowledge Memory architecture comprising functionally independent computing systems that provide the functionality to acquire, share, reuse and operationalise the various modalities of healthcare knowledge (for example, practitioners, healthcare-related documents, data, processes, workflows, experiences and lessons learnt). The technical realisation of Healthcare Enterprise Memory involves a confluence of data, information and knowledge management technology that aims to operationalise healthcare knowledge to realise a suite of strategic healthcare decision-support services. In summary, the healthcare knowledge base will be populated by the abstraction of internal and external healthcare information/knowledge based on specific content identification criteria. Finally, the emergent knowledge base undergoes a review or update process to ensure the extracted knowledge's validity and consistency (see Figure 3.14). The Enterprise Memory comprises four functionally distinct layers (see Figure 3.16):
I. Objective Layer: Consist of various healthcare information a n d knowledge sources such as data, document, knowledge and scenario bases. The authorities may have formal (mechanical-readable) or informal (human-readable) representations.
II. Knowledge Description Layer: Enables uniform and intelligent access to object-level resources. The primary purpose of this layer is to facilitate accurate specification and selection of relevant healthcare knowledge about the context. For this purpose, ontologies must reside at this layer to maintain a standard vocabulary to describe concepts and relationships between entities that attempt to share knowledge.

III. Application Layer: Models and executes processes and tasks. These include medical protocol models and healthcare work process management systems. The Enterprise Memory's service can be realised differently, ranging from dedicated programs (which perform a well-defined task) to flexible query interfaces.

IV. Service Layer: provides specialised services to healthcare professionals or the public through device applications—for instance, forecasting, knowledge and trend analysis, and best practice reporting services.

3.7 STRATEGIC HEALTHCARE DECISION-SUPPORT SERVICES

The effective delivery of healthcare services hinges on the ability to deliver appropriate, proactive and value-added services to different client segments on a timely basis. In general, healthcare services must be systematically determined based on needs; packaged according to usage patterns, demographics and behavioural psychographics; and delivered in a ubiquitous, proactive and continuous manner. These mutually interrelated constraints are hard to formulate, let alone satisfy, using conventional strategic planning techniques. Henceforth, for enhanced healthcare services efficiency and informed strategic planning and management, there is an imminent need to model and measure healthcare processes using definitive healthcare process models that are inductively derived from the collected healthcare data. It is, therefore, essential to propose that the controlled simulations of data-derived healthcare process models can be effectively used to derive 'knowledgeable' (strategic) insights about the intrinsic behaviour of the healthcare enterprise. The rationale of the approach is that by understanding what worked or did not, parishioners can identify areas for improvement and capitalise on past successful methods.

Strategic healthcare decision-support provided for the proposed system usage can best be seen as a suite of incorporated knowledge/data-driven, strategic, decision-support services derived from both healthcare data and the healthcare enterprise's knowledge base to improve the delivery of quality healthcare services. Typically speaking, SHDS may include trend analysis of disease/epidemic, treatment patterns, hospital admissions, drug patterns, etc.

Table 3: A Synopsis of the System SHDS

Main SHDS	Specific SHDS
1. Analysing trends in hospital admission	□ Spectrum of disease □ Seasonality in disease pattern □ Intervention measures to be instituted
2. Analysing treatment pattern	□ Comparison between hospitals and within hospitals □ Criteria for admission □ Investigations □ Therapeutic intervention
3. Analysing outcomes of treatment	□ Gauge standard and quality of care □ Highlight aberrations in treatment outcomes
4. Analysing the cost-effectiveness of healthcare	□ Audit expenditure and income □ Highlight areas of interest
5. Planning out-of-hospital (ambulatory) care	□ Assessing clients (patients and relatives satisfaction) □ Allows plan of care after discharge to be made □ Monitor treatment after release and patient management
6. Forecasting' new disease.' and strategising appropriate preventive measures	□ Allow appropriate preventive strategies to be recommended at the community level □ Better public education strategies

7. Forecasting complications of treatment	☐ Hospital-acquired infection ☐ Drug resistance pattern ☐ Iatrogenic diseases
8. Forecasting the spread of infectious diseases	

3.8 IMPLEMENTING THE SYSTEM DATABASE

The sole aim of designing a physical database schema is to prepare technical design specifications for a database adaptable to future requirements and expansions. The deliverability of this task includes the resulting database schema. A database schema is a structural model for a database. It is a picture or map of the record that depicts relationships to be implemented by the database in view.

IV. RESULTS AND DISCUSSION

4.1 SYSTEM IMPLEMENTATION

The system was implemented in four units: the initial unit, which covers security and privacy as regards administrative authentication rights and the confidentiality of the patient's electronic health record; the second and third units implement the end-user working sheets or interface for healthcare professionals and rural health workers alike and the fourth unit that constructs the database.

4.2 SYSTEM SECURITY AND PRIVACY

Developing an Internet-based system allows the exchange of patient data electronically among physicians and hospitals. This exchange makes security one of the highest priorities, enabling healthcare professionals to access patients' data while ensuring their privacy becomes a necessity. Security and privacy have different implications. Privacy is a policy decision, while security involves the tools to implement the policy. Internet security involves the applications of both non-technical and technical countermeasures. The non-technical measures for issuing Internet security include formulating a corporate security policy and educating and training users about that policy. Conversely, significant technical measures include access controls, authentication, data encryption, firewall, audit, anti-virus tools, and self-assessment. In recognition of the sensitivity of the patient data contained in the system, communication and the public network are protected with open_ssl

A library for data encryption and role-based authorisation is built into the system to specify access rights to the database system.

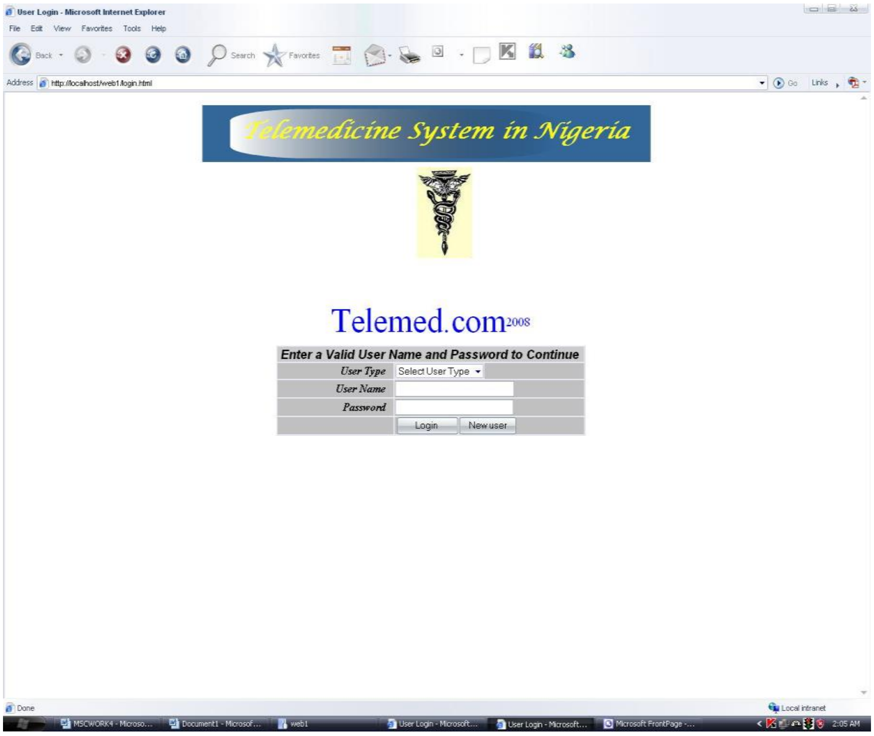

Figure 5: User Login

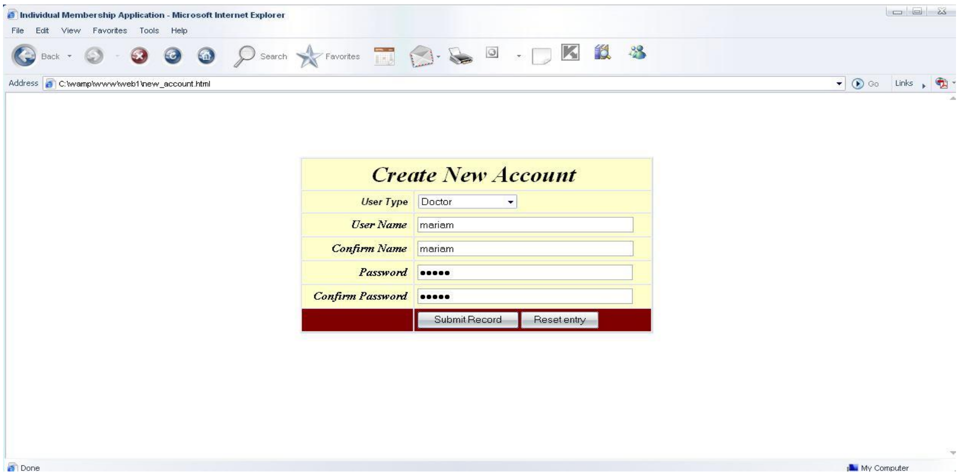

Figure 6: Creating a New User Account

4.3 SYSTEM INTERFACE

A web-based system contains patient-centric, electrically maintained information about an individual's health status and care, focusing on tasks and events related to patient care and optimised for use by clinicians. When designed correctly, it meets all of an organisation's clinical, legal and administrative requirements for the clinical process. The system's key role is to improve the delivery of healthcare services and quality outcomes by supporting physicians' needs. It is implemented in steps based on the return on investment that can be achieved within an organisation. Components include clinical workstations, data entry systems, templates or forms, communication (wireless, hard-wired and Internet-enable), security, master patient index (MPI), order entry results reporting and decision support.

Figure 7: Telemedicine System Home Page

4.4 TELECONSULTATION DATABASE RESULT

The consultation application database was designed to contain a broader range of medical records for the patient population it was meant to serve. To date, it has more than ten years of information ranging from laboratory, pathology, and radiology result and images, echo cardiology reports, cardiac catheterisation lab studies, nursing documentation of patient assessments and histories, discharge summaries, operative reports, history and physicals, medication lists, patient demographics, and electronic record documentation. This research aims to make this information available via a web portal for all physicians and remote rural health workers.

4.5 PERFORMANCE ANALYSIS

First and foremost, it is crucial to realise that this type of computerisation is often the most complex, costly and complicated that any healthcare organisation can deploy. It is often met with excellent resistance because of the nature and required level of change. It can take many years to implement fully. Without vision and leadership by a senior executive and medical staff leader of the organisation, a project of this nature can quickly fail. It is also one of the most, if not the most, crucial clinical computerisation projects that an organisation can implement.

4.6 SOFTWARE ANALYSIS

Software (required functionality) is one of the first things to consider when implementing an electronic health record. Electronic health record software is usually very complex and must be constantly maintained and updated. Hospitals and healthcare providers have difficulty recruiting and retraining talented information technology staff in many rural communities. Therefore, the new system implements some standard modules like those found in a vendor-developed product. Some of these modules are:

1. Results (a radiology report or laboratory values).
2. Ambulatory medical record (physician office record that contains chart notes, medications, patient problem list, and history).
3. Scanning (the scanning of various non-computerised documents into the software).
4. Documentation (the ability to type various types of notes and template notes).
5. Nursing (this could include items like Health History, Nursing assessments, and progress notes.).
6. Another care provider (charting from physical therapy, social services, dietary).
7. Physicians (this could include physician order entry, inpatient consults, progress notes, etc.).
8. Pharmacy information includes electronic prescribing, pharmacy profiles, decision-support tools, adverse drug-drug, drug-allergy, drug-food and drug-disease-checking modules, barcoding and drug administration.
9. Applications that allow access via the Web are becoming more and more popular and are considered easier to implement both from a technology standpoint as well as from the end-user training perspective.

4.7 HARDWARE ANALYSIS

Hardware is a significant implementation investment and can depend on the implemented product. It is essential to work with the vendor when selecting hardware. Often, hardware picked that a layperson would consider the same will not offer the same functionality as the hardware used/recommended by the vendor. The following are several options for use with a teleconsultation system:

1. Client Server applications typically use a personal computer as the interface for the end user. These systems can be cumbersome to support and maintain if the client device requires frequent updates. Again, each system is specific to vendor requirements and may or may not require extensive support and maintenance.
2. Terminal Based - Mostly, these systems are considered legacy systems that use dumb terminals. These are the least attractive to install today and have severe limitations for end-users. However, on the positive side, most of them work well, and once the user is accustomed to using the device and the system, the learning curve diminishes significantly.
3. Handhelds personal digital assistants (PDA) are becoming more and more popular. PDA is best used when much data does not need to be viewed on the device. Because of the limitations of the screen display, a good use for a device such as a PDA would be the entry of a patient's vital signs.
4. Wireless devices – Laptops and other types of computers can be deployed via a wireless network. This can be a significant expense for the organisation but can also have a rapid payback by creating an environment whereby the physician can document and review the patient information at the bedside.

4.8 TECHNICAL ANALYSIS

Technologies used in the implementation of teleconsultation systems are similar to those used in any other speciality that relies on clinical physical exams to diagnose and treat patients delivered via telehealth. Equipment is specific to the services provided. Transmission technologies are adequate if delivered at 128, 256, or 384 kbps. Full T-1 bandwidth interactive video is not required to provide consultations. In fact, many consultations are provided via low-bandwidth technologies due to the lower cost and wide-spread availability. In an activity based cost analysis of telehealth, a T-1 line may not be feasible from a cost perspective unless shared by other services that produce higher utilisation/revenue per case/value added expense reduction. The degree of physical exam becomes more difficult at the lower transmission speed but with digital capture and rebuild built into many of the current transmission technologies as well as cameras, lower frame rates are not a barrier to telehealth.

4.9 INTEROPERABILITY

A key to interoperability is the use and adoption of standards. Interoperability is the ability to "talk" from one information system to another and to share data. As more and more clinical information systems are installed in healthcare organisations across the country, it will be necessary for the system to talk to one another and to share data to provide the best in patient care. The proposed approach builds upon this standard communication network protocol and is expected to perform more effectively.

4.10 CHALLENGES AND IMPLEMENTATION BOTTLENECK

While the Internet-based teleconsultation system in Nigeria indeed has promised, there are several challenges and implementation bottlenecks which may hinder it from delivering its promise to the citizenry. Therefore, the following difficulties and bottlenecks must be addressed to implement and deploy the above system successfully.

4.11 ORGANISATIONAL AND CULTURAL INERTIA

Most government entities are unknown for their efficiency or willingness to adopt changes. Organisational bureaucracy and lack of clear communication channels or collaboration culture are some of the complex problems to resolve in which the system can become successful. Federal, state and local governments are known for being irresponsive, closed, secretive, arrogant, bureaucratic, and resistant to change. Organisational and cultural differences often are more complicated than technological change.

4.12 TECHNOLOGY AND INFORMATION CHANGE

Most government entities are not taking advantage of adjusting information technology opportunities, and most existing information systems are inadequate to meet the requirements of the new models of health being deployed in the context of health form initiatives. Besides the common perception among physicians that health information systems are primarily a source of scientific and technical information, often public health workers have a view of clinical administrative information systems that is obsolete and frozen, "a statistical-epidemiological" archetype designed for the collection of numerical data representing the counts of event and primarily generating only highly- aggregated statistical data and time series related to mortality, morbidity, and to service utilisation and coverage. Those information systems have little practical interest to healthcare professionals and unit managers. They are far behind in providing the logistical and longitudinal individual client-based data required to operate and manage the healthcare models developed in many countries.

Health has been conspicuously underrepresented in national technology-development policies and plans. Worse still, most public health authorities are oblivious to the broad variety of possibilities offered by modern information and communication technologies to manage client-based data, support operations, and large databases. Indeed, the health sector has not effectively applied the options provided by information and telecommunication technologies.

4.13 LACK OF IT FUNDING AND HUMAN RESOURCES

IT spending is often a priority, and the cost is one of the most significant barriers to telemedicine implementation. The maintenance costs for telemedicine in per-unit price over the last years, start-up investment and maintenance costs of a telemedicine network are still high. As well, technology becomes obsolete quickly. Some government bodies (local, state and federal) are affluent, but most are not. Pressure on the appropriate government will surely increase as more people realise the benefits of the teleconsultation system. This will prompt to set aside a large sum of money to implement the system. In addition, public teleconsultation centres could be located within urban cities where remote consultation and diagnosis between remote patients in the public telemedicine centre and the specialists take care of immediate and emergency healthcare cases. This approach could also be initiated in Nigeria's higher institutions to argue that institutional healthcare is delivered by allowing nurses to consult specialists. The system could also be created in correctional institutions, where the cost and danger of transporting prisoners to hospitals can be avoided. However, the system is very patient-ready, easy to follow and provides step-by-step instructions for the patient and requires the patient to have little competence to use the system and handle the medical equipment at his disposal.

4.14 TRAINING:

Training is one of the most critical issues in implementing the Teleconsultation system.

Research has found many health workers to be very computer literate, just as many have never used a computer before. When migrating to a personal computer-based system, it is essential to evaluate what percentage of your users will need computer training before you can begin implementing the training for the Teleconsultation system. Local high schools, colleges or universities are excellent partners for basic computer training because of their access to extensive training rooms with multiple computers and pre-designed introduction courses. Training sessions should be designed to meet the users, with a list of objectives and adherence to the schedule; the sessions should be held during times and in places that the trainees could attend. For example, it would be counterproductive to have a training session for physicians at 10 AM, when most physicians see patients in the office or attend to other patients' care needs.

4.15 PROS AND CONS OF TRAINING METHODS

One-on-one training

Sitting in front of a computer can be pretty intimidating for computer-literate people. Users at a basic computer skill level usually learn better in one-on-one training. This type of training allows the movement to proceed at speed comfortable for the trainees. Physicians or executives who are not computer literate are excellent candidates for this type of training. This type of training is very time and resource intensive for the success of the program this type of training should be considered. When implementing a system that requires little training and oversight, it is helpful to have the training group make rounds. The group visits the user areas – such as a nursing floor – and trains the physicians as they are available.

Lessons can be the most effective for users with essentially the same skill level. It is very effective to pre-screen or test the user in advance to place students with similar skills in the same class. At a bank computer, a trainer-to-trainee ratio of 1-2: 7-10 works best. The hands-on training is essential, allowing users to make mistakes and explore the program at their own pace. Classes usually contain trainees at a range of skill levels. Having the trainees Grouped by skill level is helpful, but this might not be easy to arrange because of limited training sessions. Less skilled users should be asked to identify themselves early in the class to obtain some individual help as needed.

Conferences: Training a large user group, such as a physician, in a short time is one of the most challenging obstacles when implementing a teleconsultation system. Research has found all-day training sessions during a conference to be most effective. Some corporate bodies offer Continuing Medical Education(CME) credits, speakers on related topics and a schedule that repeats all day long in a location on the hospital campus. This method is very staff intensive, from planning to fundraising and requires a team to design and staff the conference. This model also works well for large groups of nurses or other large groups needing training.

V. CONCLUSION

This project involved the development of a pilot internet and communication technology-based telemedicine system for primary community health care in urban and rural areas of Nigeria.

The research describes a telemedicine environment that could provide tools for overcoming the unequal distribution of medical experts and establishing meaningful consultation between remote rural healthcare practitioners and specialists typically located in urban medical centres. It also provides opportunities for healthcare practitioners to obtain access to information that can aid in diagnosing patients' health conditions or developing suitable treatment plans and for the patients to enjoy an enhanced level of healthcare service in remote rural areas. The system could also be used in urban medical centres as underground support for medical practitioners, allowing more accurate diagnosis, effective treatment, and enhanced healthcare services.

The proposed system is at its maturity stage. More contributions are still required from private or government healthcare institutions to make the system feasible and robust towards meeting the demand for quality healthcare from all ramifications of healthcare services. Apart from the stored and forward approach, as stated above, an interactive two-way remote consultation and diagnosis between patients in remote rural areas, remote rural health workers and specialists in urban cities could be supported using H.323 standard over a network in the future. Using video conferencing technology and specially adapted medical tools and devices interfaced with the computer. The remote specialist can see his patient, talk with the remote rural health worker, hear the heartbeat through the remote stethoscope, see images from the ear through the stethoscope, nose, and throat or skin conditions or make some other remote measurements of vital signs through a device such as Tandberg's Healthcare system III. Another area to be expected is the possible addition of data mining techniques to the system. This would allow the formulation of diagnostic behaviours and the building a knowledge-based approach to assist in medical diagnosis and treatment.

VI. RECOMMENDATION

This research aims to make this information available via a web portal for all physicians and remote rural health workers. Based on this, the following recommendations are made:

1. Government should try and adopt changes and define a communication channel.
2. Privacy, the government has to make decisive policy decisions to support privacy.
3. Most areas in Nigeria, especially the rural areas, have no electricity supply; for the system to be established in Nigeria, electricity must be provided.
4. Internet facilities have to be extended to rural areas.
5. An Internet-based distance learning system should be developed to extend educational capabilities to healthcare professionals throughout rural.

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