Managing Medical Data in Clinical Practice and Diagnostics in a Developing Economy

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Abstract— **In developing economies there are still no dependable, assured, and networked health care systems which utilize the improved ICT technologies to fight and combat the scourge of increasingly deadly and dilapidating diseases such as malaria and HIV. In this paper we propose an Integrated Health Records Management System (IHRMS) which is web-based collaboration/integration system to allow tracking of patient medical history and prognosis and to manage medical data and information in clinical practice and diagnostics. Using a case study, we will show that IHRMS is a flexible system whereby medical departments can be integrated seamlessly.**

Keywords- Integrated Health Records Management Systems (IHRMS), ICU, development, ICT

I. INTRODUCTION

In the states of Anambra and Adamawa of Nigeria, little had been done to use improved communication technologies to network health care givers, hospitals and patients to date. There exists little or no effectively integrated electronic medical recordkeeping and networked medical data transmission and management between health care givers, health dispensaries, general hospitals and specialist hospitals.

In many countries with developing economies such as Nigeria, though there are huge strides in innovation and development of information and communication technologies, there are still no dependable, assured, and networked health care system which is poised to leverage the improved technologies to fight and combat the scourge of increasingly deadly and dilapidating diseases like malaria, diabetes, human immunodeficiency virus (HIV), TB, polio, heart failure, ovarian cancer etc.

Up to date, in the above regions of study, paper-based medical record keeping is still predominantly the prevailing mode of communicating and transmitting urgent, crucial and very important medical data among health facilities and hospitals even in life threatening situations. To compound this trend and apathy, majority of the population live in remote inaccessible rural areas far from the few semi urban towns.

It should be noted that with the exponential growth of accessibility to computers, hand-held mobile phones and PDA gadgets, business entities from other sectors like the banking sector had successfully incorporated electronic digital data transformation and interpretation in their decision making processes and use cases.

Very little of such improvements can be witnessed in the health sector, where exchange of medical data, information and feedbacks between health providers, hospitals, test centers, test depots and the beneficiaries are still extremely slow, difficult and sluggish, especially in the inaccessible remote areas of the country. Sometimes it takes weeks to get an expert opinion on very simple diagnosis and health conditions. Patients are still required to travel many miles from their remote villages to urban medical centers to manually submit their test results to more advanced hospitals, and wait to obtain results and then to travel back to their local health dispensary locations.

Despite greatly improved internet connectivity and accessibility to mobile electronic gadgets and PDAs by a great number of rural Nigerians, medical records are still kept in physical files, printed forms and graphs which are manually collated, carried and copied here and there, Rural Nigerians are PDA-literate and shockingly enough, a majority of them are also increasingly becoming electronically and digital computer literate.

One therefore wonders what is keeping the health sector and its managers from utilizing this vast and improved digital literacy, potential and possibility. In the regions of study, among the problems and obstacles observed and recorded by the researchers which may be militating against the integration of digital recordkeeping, transfer and exchange of medical data are the following:

- Health providers, including the computer/internet literate medical doctors are reluctant to let go of their entrenched paper-based ways of doing things and transmitting health records and data. Most previous attempts made to change and transform manual medical data tracking/management into digital processes stopped at the prototype levels; at local hospitals there is a lack of commitment at the

strategic management levels to covert prototypes into real health recordkeeping and management systems

- In the region of study, most health facilities and locations do not have computer terminals, WAN networks, communication channels and good bandwidth; there is predominantly an absence of internet-based information systems requirements
- There is still a misplaced priority on how important the speed of medical data transmission across spatial distributions of health givers is among health managers; existing health care information systems are mainly geared towards the need to report statistics for funding agencies. Efforts are not to help and support diagnostics and clinical case management
- There are no centralized medical record repositories; there are no central relational medical databases and data centers
- There are no centralized health management systems which can be networked together
- There is lack of low-cost clinical information systems; available open source variations and offerings which are out there are themselves expensive to procure and maintain for most of the health providers and local hospitals observed; the requirements and skill to customize/maintain such packages are still non-existent
- Power and steady electric energy supplies are still very unstable and unpredictable in the regions of study; attempts to build computerized medical data repositories and network systems in the past have been unsuccessful which have resulted in huge shrinkages and data corruption or loses

The researchers looked at the problems and hitches enumerated above, and decided to design/build a working model for the regions under study. The working model is called the Integrated Health Records Management System (IHRMS).

The remainder of this paper is as follows. In section 2 we will describe the current structure and challenges in Health Care Delivery Systems in the selected regions of study in Nigeria. In section 3 we describe the Integrated Health Records Management System (IHRMS) and its associated components to address the problems described in section 2. To demonstrate the flexibility of IHRMS we show in section 4 how a clinical department can be integrated seamlessly into the architecture of IHRMS. Section 5 describes related work. A discussion of future work is given in section 6 and final conclusions are given in section 7.

II. HEALTH CARE DELIVERY SYSTEM IN SELECTED REGIONS OF STUDY IN NIGERIA

The Health Care Delivery System in the selected regions of study is completely decentralized. Nigeria is one of the few countries with a developing economy that systematically and fully decentralized the delivery of its basic health services.

For the observations and research for this paper, the researchers chose two states of Nigeria namely, Adamawa State in the north and Anambra State in the southern region. The health care delivery system within these two regions of study consists of a network of primary, secondary, and tertiary level facilities. Provision of health care at these levels of care giving is the responsibility of Local Governments, State Governments and the Federal Government respectively. At the primary health level, care is given at the general hospitals and dispensaries. This level is where the bulk of rural Nigerians obtain their medical care. Facilities at this level of care are not well equipped. Attention to patients is usually supported with referral treatments to the secondary level of health care.

The secondary level of health care provides some specialized services to patients referred from the primary health care level through out-patient services of hospitals for medical, surgical, pediatric and community health services. At these secondary level facilities, patients receive supportive health services such as basic laboratory, some improved diagnostic, blood bank service, rehabilitation and physiotherapy services. Serious cases are referred from the second level facilities to the tertiary levels of health care, which are usually the teaching hospitals attached to the medical colleges and universities.

This tertiary level of care consists of highly specialized services by consultant medical specialists and personnel for specific diseases such as orthopedic, eye, psychiatry, maternity, and pediatric cases. The tertiary medical care giving facilities are not evenly distributed across Nigeria. For example the tertiary facility closest to Anambra State is located at the Enugu Teaching Hospital which is approximately seventy kilometers from the state capital. Likewise the closest tertiary facility closest to the Adamawa State capital is located at the University of Maiduguri Teaching Hospital, which is more than four hundred kilometers away.

Apart from government owned primary, secondary and tertiary health facilities, there are a good number of private hospitals and health facilities sprouting up here and there in the last decade. These make up to more than forty percent of the whole health care delivery system in the regions of study. These private care givers also depend on the more specialized tertiary level facilities at the teaching hospitals for referrals of serious cases.

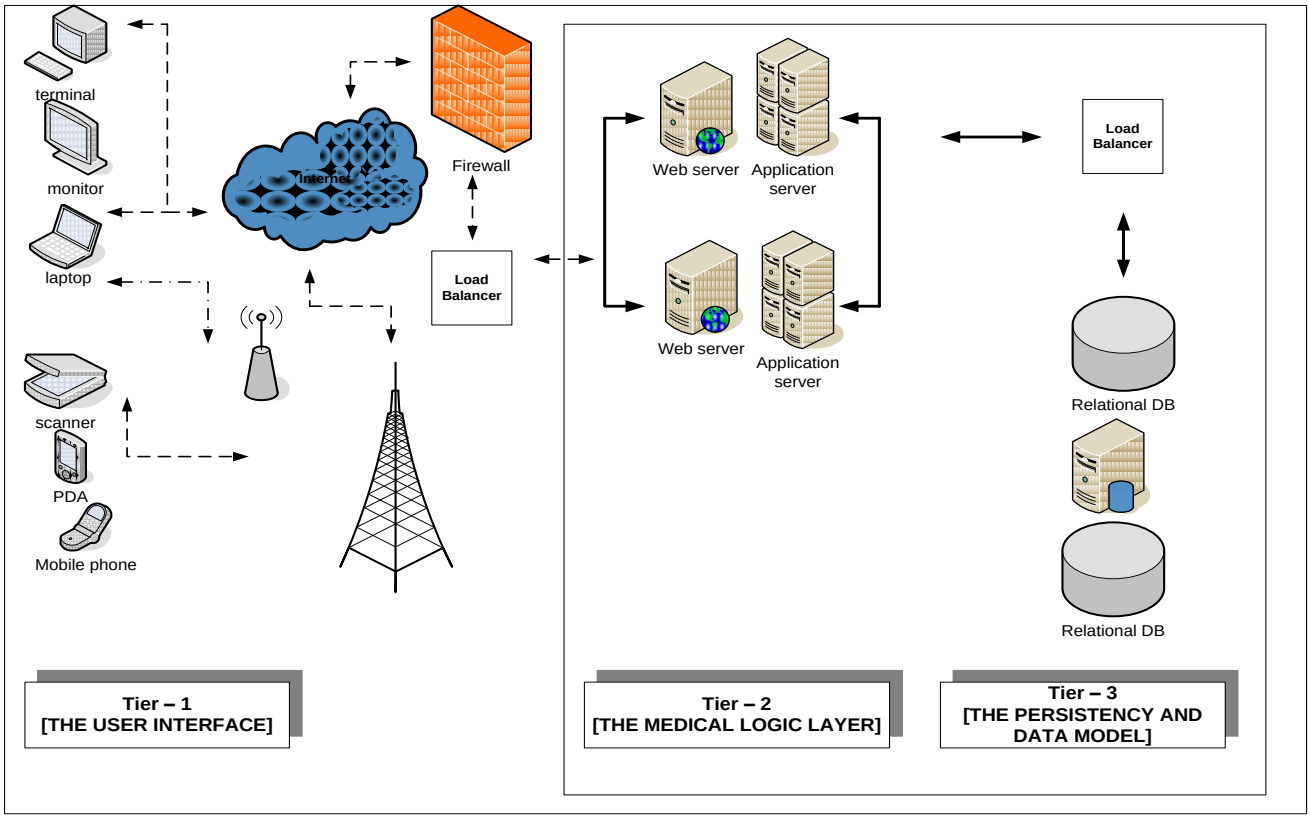

Figure 1: IHRMS Architecture

III. The Integrated Health Records Management System (IHRMS)

Our Integrated Health Records Management System (IHRMS) was designed to provide data linkage capability that will sit well among the three levels of care described in the previous section in the regions of study. Furthermore, a centralized medical data management system like ours will like help solve the predominant problems that discourage efforts to convert paper-based medical records transmission into faster electronic data transmission processes. IHRMS was designed to manage medical data and information in clinical practice and diagnostics between levels of medical care giving.

IHRMS is a web-based collaboration/integration system which allows tracking of patient medical history and prognosis; it allows data sharing for remote specialist consultation. It will be used to extensively support diagnosis, prognosis and treatment decisions. The system will also make possible some checks and balances of diagnosis outcomes and treatment regiments between local hospitals and more equipped / more specialized health facilities; local health care givers and health dispensaries will have the opportunity to easily consult with specialist doctors and counterparts.

IHRMS is a proprietary low-cost system designed by the researchers. It is located at the School of Information and Communications Technology (SITC), American University of Nigeria, Yola, Nigeria.

The architecture of IHRMS is shown in figure 1. The IHRMS is designed and built on wireless thin client architecture with a single very powerful central application server and web server. To connect to the system, the client health facilities, hospitals, health dispensaries, specialist hospitals, patients will only need a web browser. They do not need to install any client application system. We shall look at each of the tiers of the IHRMS in turn.

A. Tier 1 – The User Interface

The IHRMS tier 1 is the user interface and is designed as a separate component. The system provides a structured interface to transfer data and information from and to the client user interface. This provides for extensibility and increased portability to all remote client machines, laptops, monitors and even mobile hand-held PDAs down the line. At the onset, the system is designed to use browsers, emails and web forms for transfer and transmission of medical data, graphs, images and other patient information among system actors. Later on the system will be enhanced to accommodate scanned paper forms with optical character recognition.

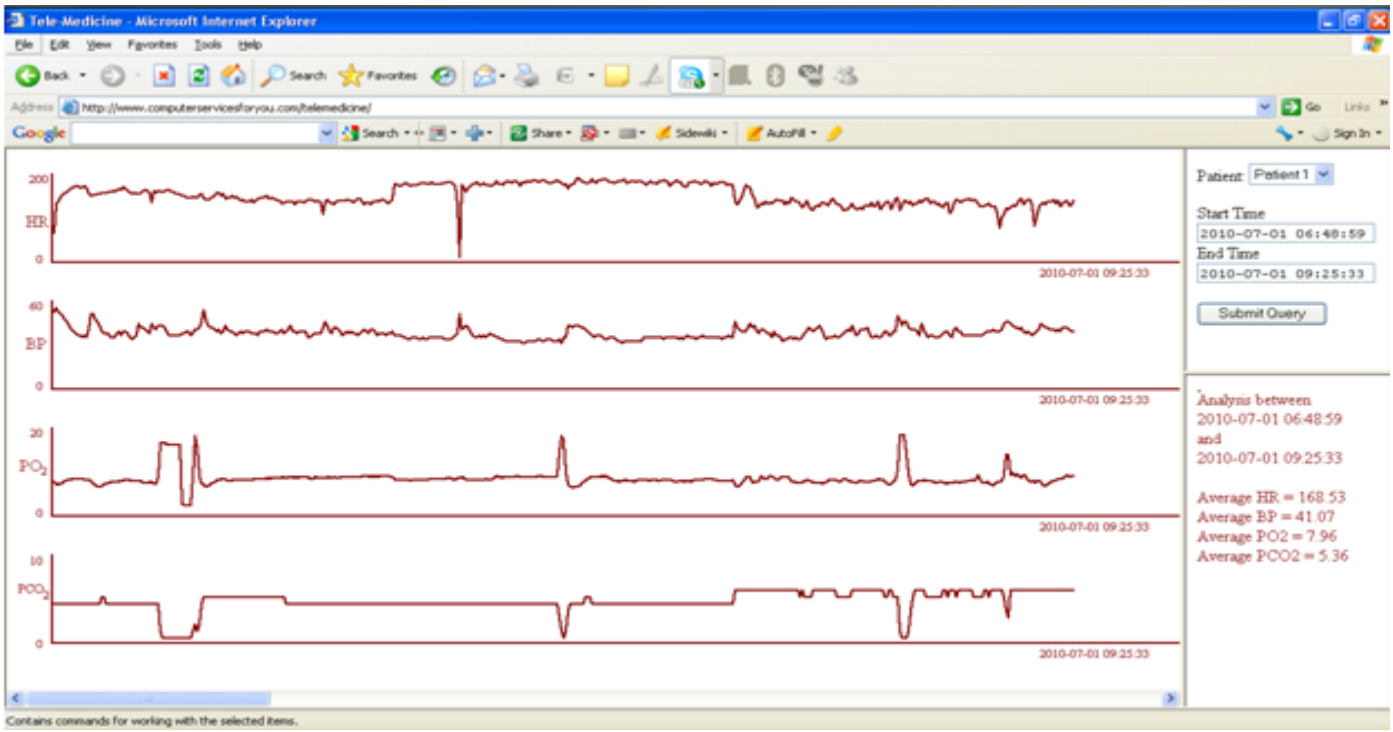

Figure 2. Output of TICUM

B. *Tier 2 – The Medical Logic Layer*

The IHRMS tier 2 is the medical logic layer and acts as the interface between tiers 1 and 3. Tier 2 interprets the commands entered by staff in tier 1 and formulates commands to execute on tier 3 to access data. Tier 3 will then return the required data to this tier and formats it for the appropriate user interface (PDA, Laptop etc) to return to tier 1 to be presented and viewed.

C. *Tier 3 - Persistency and Data Model*

The persistency and data model of IHRMS is designed and built on relational tables in order to accommodate the future multifunctional needs of the system. The persistency is a coded database and was designed to sit on an open source relational database, MYSQL. The concept of data dictionary was employed in the design in order to make sure that validation rules are supported for all sensitive data and information transmission and transfers remotely by system actors across the regions of study and focus. IHRMS' persistency is designed also to accommodate data format conversions for easy analysis, interpretation, archiving and tracking of transmitted medical records and data.

IV. CASE STUDY: INTERPRETING ICU DATA

To show the flexibility of the IHRMS we will demonstrate how a clinical department can be integrated seamlessly into our architecture. The clinical department chosen is the Intensive Care Unit which could benefit from telemedicine for remote assistance.

The Intensive Care Unit (ICU) is a specialist ward in a hospital where critically ill patients reside for the management of their severe illnesses. These patients are connected to monitors to display their vital physiological signs - this data enables medical staff to assess the state of the patient. The monitors typically record and display cardiovascular data (e.g heart rate and blood pressure) and respiratory data (e.g partial pressure of oxygen and partial pressure of carbon dioxide) data produced by the monitors. The ICU monitors generate large quantities of high-frequency and noisy data which must be analyzed to inform clinical decisions. However, in rural areas, particularly in a developing economy, there is shortage of trained ICU medical staff to interpret the complex data generated by the monitors.

We therefore believe that medical staff in rural ICUs in areas of study could benefit from remote assistance in the interpretation of ICU monitor data to decide which interventions are appropriate, particularly if such a decision has to be made in the absence of more senior staff.

TICUM is a low-cost multi-media telemedicine system for receiving and transmitting data from the monitors of a rural ICU in areas for purposes of remote assistance. Telemedicine is the use of telecommunication networks for the delivery of healthcare and medical education across a distance to mitigate issues of misdistribution of healthcare resources [1]. The goal of TICUM is to provide a multi-media tool to receive rural ICU monitor data and to display the data graphically and to

provide a textual analysis of the data to enable remote clinical decision support.

The real-time data generated from the ICU monitors (the user interface) are received by the medical logical layer and SQL statements are used to store this data in the persistency and data model. Using a transceiver in a modem, the data is transmitted by the medical logical layer accessing the persistency and data Model using a VSAT (Very Small Aperture Terminal) antenna to an orbiting satellite for a client anywhere in the world to receive. Using the transceiver in their modem, the client will receive the data, using the internet, through their VSAT antenna and present it on a browser for remote assistance. The advantage of this wireless network architecture is that distance will not hamper data transmission.

Figure 2 shows the output of TICUM. The interface is partitioned into 3 frames: a main frame to display the rural ICU monitor data in graph form (note that in the graphs *HR* represents the Heart Rate, *BP* represents the mean Blood Pressure, PO_2 presents the Partial Pressure of Oxygen and PCO_2 represents the Partial Pressure of Carbon Dioxide); an input frame (top right) for specialize staff around the world to choose the patient and the range of data points to view on the main frame; and an analysis frame (bottom right) to output a textual analysis of the data displayed in the main frame.

V. Related Work

A potential architecture for managing clinical data is the *blackboard*. A blackboard system consists of a set of independent modules, called Knowledge Sources (KSs) that contain the domain-specific knowledge in the system and a blackboard which is a shared data structure to which all the KSs have access. When a KS is activated it examines the current contents of the blackboard and applies its knowledge either to create a new hypothesis and write it on the blackboard, or to modify an existing one [2]. The blackboard is not suitable for our application because it is a way for the different modules to contribute to the blackboard to solve a particular problem – in our case our architecture is used to integrate the various medical departments into a single network.

Another approach to managing clinical data is to have a distributed architecture. A distributed architecture for managing clinical data is TSNet (Time Series Network) [3]. TSNet's architecture involves researchers at a number of sites putting their client data on to their server. Each site maintains a TSNet database containing data originating from their site. These site databases are visible to all other collaborating sites. The TSNet architecture is designed for research collaboration in order to interpret Intensive Care Unit data. Like our architecture, no results have been published.

Another potential approach is the *Service Oriented Architecture* (SOA) such as that used by ICAP (Intensive Care Agent Platform) [4]. SOA defines how to integrate vastly disparate applications for a web-based environment and uses multiple implementation platforms. SOA allows interoperability between different systems and programming languages and provides the basis for integration between applications on different platforms through a communication protocol. The SOA is similar to our IHRMS in that numerous unconnected applications written in different programming languages and running on different platforms can be integrated into a single network to allow interoperability.

VI. Discussion and Future Work

It should be noted that the quality of health care and safety greatly depends on having "clean" patient health data and information available at the right time when needed to support accurate diagnosis and treatment routines by care providers, irrespective of distance.

The researchers' next stage of work will lay emphasis on data management and sanitization. Accurate data transmission and interpretation by the IHRMS system will depend very much on this effort. The system will therefore be extended to incorporate built-in data filtering and checking mechanisms. Also initial training sessions will be planned for remote data entry nurses and ICU staff.

Secondly, owing to the incessant power outages and interruptions prevalent in the regions of study, an offline data entry/temporary storage capability will be researched and incorporated for the remote stations to include some simplified semblance of some IHRMS core functions to enable data to be temporarily held on remote laptops or user terminals; this temporarily held/stored data will be automatically transmitted immediately on to IHRMS as soon as network connectivity becomes available and remote staff accesses the internet.

VII. Summary and Conclusions

In developing economies such as Nigeria there are still no dependable, assured, and networked health care system that utilizes the improved technologies to help fight and combat deadly and dilapidating diseases. In this paper we have proposed the Integrated Health Records Management Systems (IHRMS) which is web-based collaboration/integration system to allow tracking of patient medical history and prognosis and to manage medical data and information in clinical practice and diagnostics. The IHRMS consists of 3 tiers: the user interface; the medical logic layer; and the persistency and data model. This architecture is flexible and we have shown that medical departments can be integrated seamlessly.

The next stage of our work is to test the IHRMS architecture at the School of Information and Communications Technology (SITC), American University of Nigeria, Yola,

Nigeria then evaluate the results before deploying it in the two chosen states of Nigeria namely, Adamawa State in the north and Anambra State in the southern region.

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