

An Approach to the Implementation of an Integrated Computerized Medical System in Nigeria

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Abstract Improvements in Information and Communications Technologies have driven innovations in computerized medical systems world-wide. Developed economies are quickly abandoning the paper-based medical record keeping and management systems for a more digitized approach. Nigeria and other developing countries, whose bulk populations reside in highly inaccessible rural areas, would also like to follow this trend. However, there are numerous and persisting obstacles and challenges that militate against such intentions. In this paper we discuss the issues associated with moving to a computerized medical system in the highly decentralized Nigerian medical sector and propose a workable three-tier integrated computerized medical system architecture which can re-integrate the rural health care centers to provide specialized care.

Keywords: computerized medical systems; 3-tier architecture

Introduction

Though there exists a higher prevalence of chronic illnesses among rural dwellers and populations when compared to city dwellers, it is predominantly the rural populations that enjoy the least access to available medical health resources in many countries [1]. In Nigeria, rural healthcare is typically provided by the local health centers and dispensaries. One major reason for this is the way in which patient data is managed. Healthcare is driven by the capturing and storage of Patient Health Information (PHI). PHI can be captured, tracked and stored using paper and physical files or in a digital format. The oldest form of managing patient information and data is on paper. Developing countries are gradually moving away from paper and towards digital formats which allow for an integrated computerized medical system. However, since a large number of Nigerians live in rural areas, there are numerous additional challenges that need to be overcome to realize an integrated computerized medical system.

In this paper we look at the current state of the Nigerian healthcare system and the various issues associated with the management of computerized patient data to achieve an integrated computerized medical system. To overcome these issues we propose a 3-tier architecture to realize an integrated computerized medical system for the Nigerian healthcare system. Our proposal will allow rural health care centers to be integrated with urban health care providers to provide specialized care to rural populations.

The structure of this paper is organized as follows: in section 2 we discuss the background to deploying an integrated computerized medical system; in section 3 we then discuss the key issues militating against an extensive introduction of a computerized medical system in Nigeria; section 3 presents our proposed technical model and solution to overcome the issues presented in section 2; section 4 discusses future work and final conclusions are given in section 5.

Background

Nigeria's Health Care Delivery System is systematically and fully decentralized. The country's health care delivery system is made up of a network of primary, secondary, and tertiary level facilities. Provision of health care at these various levels of care 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 and attention to patients is usually supported with referral treatments to the secondary level of health care.

The secondary level of health care usually provides some specialized services to patients who have been 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 testing, some improved diagnostic services, blood bank services, 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 medical colleges and universities.

This tertiary level of care consists of highly specialized services such as orthopedic, eye, psychiatry, maternity and pediatric cases by consultant medical specialists and personnel. The tertiary medical care facilities are not evenly distributed across Nigeria. For example the tertiary facility closest to remote rural areas may be located hundreds of miles away in a Teaching Hospital which, in turn, is located in an urban center or a state capital.

Apart from government owned primary, secondary and tertiary health facilities, there are a numerous private hospitals and health facilities distributed around Nigeria but they are still located in the vicinity of the few urban and semi urban centers. These facilities make up to more than 40% 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.

For millions of Nigerians, accessing urgent or specialized medical care usually means waiting for the occasional bi-weekly visits by designated specialists from the few specialist hospitals or travelling for two to three days to reach a specialist in the urban centers which can be haphazard. The ability to quickly link urgent patient cases in remote areas to specialized care workers still remains one of the biggest challenges that Nigeria faces because it can take days (even weeks) to wait for the return of paper-based patient data that was sent out by local health staff in the rural site as a referral to the more specialized hospitals.

Issues

There are several issues that need to be overcome if an e-based solution is to be realized in Nigeria to address the problems discussed in the previous section – we shall look at each of them.

There is a non-existence of a unified and unique patients' identifier. A single unique patient identification number, called the Patient Unique Identifier (PUI), is supposed to be assigned and used to track each patient's record. This is supposed to help differentiate between these records over a period of time. However, throughout Nigeria, the use of a unified PUI is still not possible owing to the non-existence of such identifiers despite efforts made by the Federal government to centrally initiate an identification scheme in the country. This situation is hampering the integration of any e-health system that would rather track patients digitally.

There is the non-existence of encompassing healthcare policies. Encompassing health policies are supposed to provide a cohesive framework and the necessary environment for e-health innovations to thrive. However, in Nigeria, there is no policy in place or any efforts being made to put such policies in place to guide and streamline the delivery of innovative health services like the one proposed by the authors. Without such a policy framework in place, the general distrust and attitude towards the security of patient medical data used in any innovative e-health endeavor is constrained to remain just at the prototype level.

There exists predominant security and confidentiality concerns regarding medical data. Emanating from a non-existent encompassing policy is the general concern about the confidentiality of the individual (personal) health records and data that would be digitally transmitted between different sites. Privacy, security and proper handling of such records in digitalized formats is of great concern to both the rural patients and their health care providers. There are apprehensions that the security of these forms of records may be

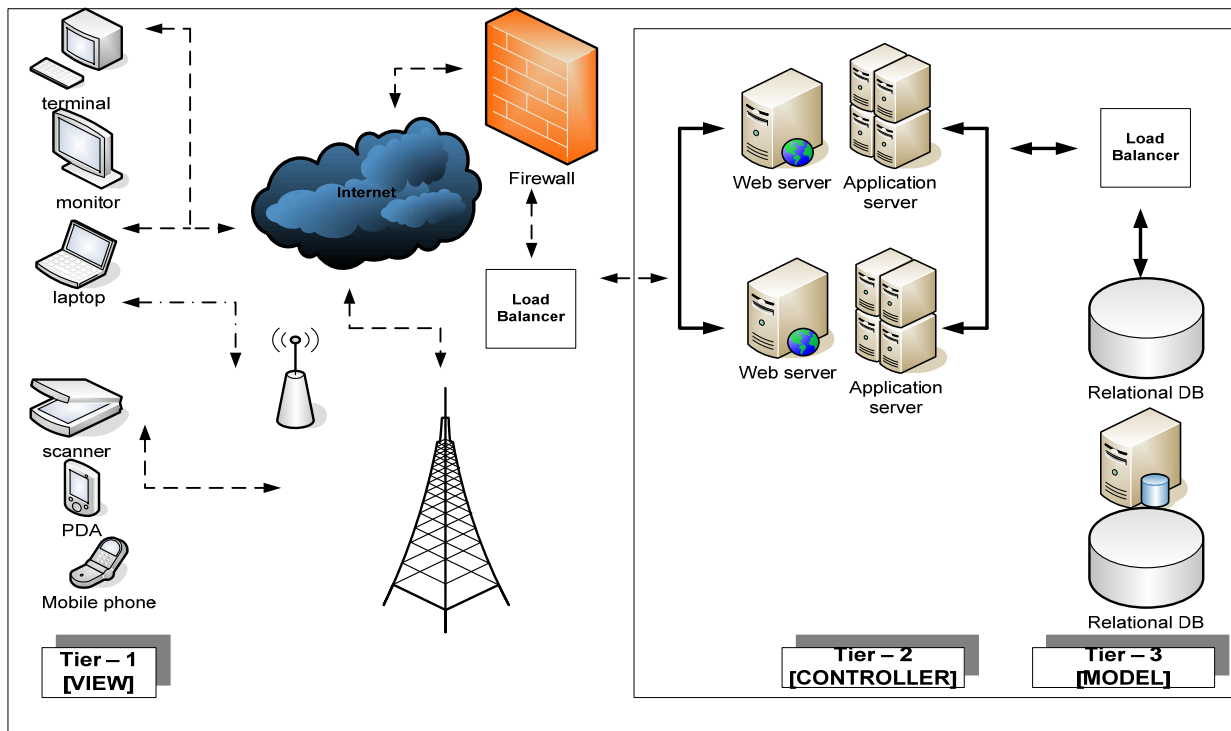
compromised unknowingly either internally or while in transit. There are still no strong safeguards around captured, communicated and transmitted patients' private health records. This situation constitutes a major challenge in the pilot rural areas investigated by the authors in Nigeria.

There is a consistent resistance towards e-health innovative solutions by medical personnel. A phobia and predominant fear exists among local medical staff and personnel towards abandoning their old paper way of capturing, transferring and storing patients' medical records. The authors observed their resistance towards adopting digitalized formats and more modern ways of tracking health records. Indeed we found that there was an abounding phobia and fear even among the computer literate university-trained medical doctors which may be emanating from fear of losing control over patient's medical records that come under their management.

There is absence of trained manpower and use of acceptable standards. Another nagging challenge unraveled by the authors emanate from the non-existence of trained staff who are abreast of established medical standards that would govern tracking, transfers, transmission and proper management of rural medical records belonging to the rural patients. There is virtually a zero security awareness and understanding of existing international medical and health care standards that exist among observed and interviewed health personnel in selected rural areas of study in Nigeria.

There is an absence of drive, low bandwidth and internet penetration. There is still a low rate of internet penetration throughout the remote rural areas of Nigeria. Bandwidths where and when available are very low. The majority of rural areas cannot support an e-based system using internet deployment because of poor infrastructure and unstable electric power generation. These challenges are attributable to the lack of drive and lack of enthusiasm that all the three tiers of healthcare in Nigeria have shown and demonstrated towards e-health innovations and endeavors. Local health centers and dispensaries also lack the funds and financial backbones needed to centrally put ICT infrastructures in place without the help of donors and their respective governments.

Figure 1: Proposed Architecture



Another problem of broadband in rural areas is the lack of telecommunication infrastructure which is mainly due to the capital cost for such deployment and associated operating or running costs. Consequently, bandwidth demand can easily outstrip the revenue realizable that is needed to pay for the network infrastructure investment [2, 3, 4]. As a result, rural areas generally have lower bandwidth than urban areas which, in turn, makes data transfer slow. Moreover, when operating in a rural multi-service environment such as a hospital a consequence of restricted bandwidth on access pipes is service contention at the customer site, even if core bandwidth exists to deliver the services. Contention for bandwidth within a customer site can arise if there are a number of devices at the site that can request services with aggregate bandwidth greater than can be delivered over the access connection [2, 3].

To address the challenges of deploying a medical system that uses broadband we also need to consider *Quality of Service* issues. In our case, Quality of Service refers to the collection of network technologies and techniques to guarantee a certain level of performance to the flow of medical data on a wireless network. The Quality of Service issues that concern successful medical system are delay, jitter, loss rate, throughput and network resource availability [5, 6]. Delay is the elapsed time for a packet to traverse the network from the source to the destination – we need to keep delay low. Jitter is defined as the variation in delay encountered by similar packets following the same route through the network and would affect real-time streaming applications such as transmitting continuous Intensive Care Unit monitor data - we need to keep jitter low. Loss Rate refers to the percentage of data lost among all the delivered data in a given transmission time interval - in order to reduce loss rate we need a decoder with high error resiliency. Throughput is defined as the rate at which packets are transmitted in a network – we need a system where throughput is high. Network resource availability is the infrastructure associated with the transmission of data e.g equipment, power, etc. In rural areas it is absolutely imperative in health networks to have good network resource availability because the generated traffic may be crucial for the patients' health and life.

Proposed Architecture

Our proposed architecture for an integrated computerized medical system in Nigeria was designed by the researchers to provide data linkage capability that will sit well among the three levels of care described in section 2 and addresses the issues described in section 3. Furthermore, a centralized medical data management system like ours will help solve the predominant problems that discourage efforts to convert paper-based medical records transmission into faster electronic data transmission processes. Our system was designed to manage medical data and information in clinical practice and diagnostics between levels of medical care giving.

Our architecture 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.

The proposed architecture of our integrated computerized medical system is shown in figure 1. Our 3-tier architecture 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 our proposed architecture in turn.

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. It will be enhanced to accommodate scanned paper forms with optical character recognition later on.

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.

The persistency and data model of our architecture 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 is designed to sit on an open source relational database. The concept of a 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. Our architecture's persistency is designed to accommodate data format conversions for easy analysis, interpretation, archiving and tracking of transmitted medical records and data.

Our architecture addresses each of the issues raised in section 2 – we shall look at each in turn.

Uniquely auto-generated patient identification numbers by the Model will be used to track patients and their health records in the proposed system architecture. This will enable each patient health record to be uniquely tracked.

An easily available open source database management system such as MYSQL forms the core/central component of the Model tier in the architecture. The robust security features of this relational database are leveraged to provide adequate security and confidentiality for all tracked, stored and transmitted patient health information and records. An accessibility matrix created for all the system actors is strictly adhered to and enforced by system components in the architecture.

Our architecture suggests and incorporates low-cost innovative mobile technologies such as Android-based phones, PDAs and easy-to-use devices for its presentation layer of the View component; these devices are relatively cheap and no specialized computer training or knowledge is required for medical personnel to know how to use them. Thus, the proposed architecture will provide a very simple and reliable way for health workers to key-in, enter and transmit written medical prescriptions, diagnosis and diagnostic imagery for immediate analysis and communication.

For all electronic transmission and processing of patient health records, the devices and computer systems within the architecture will be adhering to globally established policy and standards by Healthcare Level 7 International (HL7) for transmission of e-health information and data

Since users of the system can access the system using their own devices such as PDAs and mobile phones, there will be less contention on the system's bandwidth because users can use the bandwidth provided by their own devices rather than that of the system.

To address the issues of quality of service we propose in Tier 2 that access to data is strictly controlled. For example, if priority is given to specific users then delay and throughput will increase. We need high quality of equipment to address jitter, loss rate and network resource availability.

Discussion and Future Work

As a result of the present explosion and penetration of Information and Communication Technologies (ICTs), many developing countries can make the transition from paper to digital medical records using emerging information and communication technologies such as PDAs, Android-based phones, and laptops with blue tooth and internet capabilities.

There are various reported benefits of the adoption of an integrated computerized medical system to individual patients, hospitals, donors and governments. Real-time medical records management systems, telemedicine and other e-health systems allow system actors to send or receive medical data almost instantly [7]. These systems can allow underprivileged rural hospitals to share/leverage the equipments and

specialized human resources in real time with the well equipped bigger hospitals miles away in the urban centers [8, 9].

The specific benefits of an integrated computerized medical system therefore include the following: reduction in medical errors; speed in diagnosis; encouragement of the anywhere anytime diagnostic opportunities; improvement in physician-specialist-patient relationship and ratio; enhanced quality and speed of care; improved enablement empowerment for local health care centers; cost savings etc. Nonetheless, to reap these benefits, countries like Nigeria has to battle the militating challenges to a proper introduction of e-health and e-based systems.

Summary and Conclusions

Developing countries like Nigeria are gradually moving away from paper and towards digital formats that facilitates an integrated computerized medical system which can have numerous benefits. However, since a many Nigerians live in rural areas we have seen that there are numerous additional challenges that need to be overcome to realize an integrated computerized medical system.

To overcome these issues we have proposed a 3-tier architecture to realize an integrated computerized medical system for the Nigerian healthcare system. Our proposed architecture will make a bidirectional data transfer possible for the exchange of medical data, diagnosis, prescriptions and emergency alerts between the local health facilities and the specialized hospitals

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