Interactive Telemedicine Solution Based on a Secure mHealth Application

Ayman M. Eldeib-*IEEE Senior Member*

***Abstract*— In dynamic healthcare environments, caregivers and patients are constantly moving. To increase the healthcare quality when it is necessary, caregivers need the ability to reach each other and securely access medical information and services from wherever they happened to be. This paper presents an Interactive Telemedicine Solution (ITS) to facilitate and automate the communication within a healthcare facility via Voice over Internet Protocol (VOIP), regular mobile phones, and Wi-Fi connectivity. Our system has the capability to exchange/provide securely healthcare information/services across geographic barriers through 3G/4G wireless communication network. Our system assumes the availability of an Electronic Health Record (EHR) system locally in the healthcare organization and/or on the cloud network such as a nation-wide EHR system. This paper demonstrate the potential of our system to provide effectively and securely remote healthcare solution.**

I. Introduction

The ultimate goal of health care is to provide timely medical resources of high quality to all who need them whenever it is needed [1 -2]. Therefore, any patient, especially in a medical emergency, needs an immediate medical attention that can be provided in two main steps. First, to reach the best medical staff available for any particular case. Second, to provide that medical staff with the patient medical records to be able to prescribe the right treatment. These two steps require two different types of connectivity. Therefore, there is a need to have one system that provides these types of communications [3 – 9].

This paper proposes an easy to use and affordable solution that utilizes the Information and Communications Technology (ICT) to facilitate and integrate these types of communications interactively and securely in one system. In addition, our system enables the administration of a healthcare organization effectively manage the need of patients and medical staffs especially in emergencies.

II. Existing Methodology

Let us look into the different ways of communications to first and simply find a medical staff even within a healthcare organization. In many developing countries, such communication ways are lacking mainly because of the high cost and/or missing necessary IT infrastructure. In our case, we did a survey and found mainly three types of connectivity used in three big hospitals. The first hospital (Children Cancer Hospital) bought an expensive but complete hardware and software VoIP solution with 30 IP phone handsets that cost about $1000 each. The limit number of handsets is because of limited budget and of course does not cover everybody. This system has the paging capabilities. The second hospital (International Medical Center) solved the communication problem partially in a different way by having a monthly contract with one of the local wireless communication provider to provide 300 mobile SIM cards for more than 10 k L.E.. The main issue with this solution is that the wireless communication is prohibited in several areas in the hospital to avoid negative impact on biomedical equipment [10]. The third hospital (Galaa Family Hospital) utilizes an ordinary pager system with limited number of pagers.

Now, medical staff is available and needs access to the patient medical history records to provide the right treatment when it is needed. Access to a patient's EHR became the key of delivering and ensuring high quality healthcare. EHR is the primary medical history of a patient stored in digital format, which allows vital medical information to be easily and securely exchanged between different health care providers, such as medical practitioners, specialists, pharmacists and hospitals. An EHR may include a range of data, including medical history, laboratory test results, radiology images, vital signs, medication and allergies, immunization status, demographics, and personal data. In many countries, especially developing countries, access to EHRs is limited within the healthcare facilities such as hospitals. There is no doubt about the benefits of having a remote but secure access to EHRs especially in case of emergency.

III. Proposed Solution

Our proposed solution is comprised of two main logical parts: a server that provides services/data and a client that requests services/data from the server. However, our client can provide data to be added to the EHR of a patient as needed. The following two sub-sections provides more descriptive details of our proposed solution.

A. The Server

Our server is a modular and scalable software for healthcare organization of all sizes based on a highly available open source Session Initiation Protocol (SIP) routing core integrated with a growing suite of

Resrach supported by Cairo University, Egypt.

A. M. Eldeib is with the Systems & Biomedical Engineering Department, Faculty of Engineering, Cairo University, 12613 Giza, Egypt, phone: +020-106-121-3450; fax: 928-563-9591; e-mail: eldeib@ieee.org.

communications services designed for healthcare needs. All services are managed through a unified web based management and configuration application. The native SIP used in our server is sipXecs [11]. It provides traditional Private Branch Exchange (PBX) telephony services including all common calling features, messaging, voicemail, conferencing, and call center capabilities. Our server is deployed on standard Linux machine CentOS.

On top of the sipXecs, we developed additional features/services specific for healthcare needs. Our server is integrated with internal health information systems such as Hospital Information System (HIS), Radiology Information System (RIS), and Picture Archiving and Communications System (PACS). Integration with external system is currently limited to affiliated physician offices with certain services mainly to retrieve/update EHRs. The integration possibilities are unlimited with the ultimate goal of having direct access to all information/data needed for our healthcare services.

Our server utilizes the capabilities of MySQL, which is the world's most popular and widely used open source Relational Database Management System (RDBMS), to manage users' connectivity to the server and their access permission to each piece of information/data and services/features. The database holds the necessary rules, policies, and relation between main entities; e.g. the relationship between patient and his/her EHR, physician, nurse in each shift, medications with their schedule, appointments, and mobile unique identification data; i.e. phone number and Media Access Control (MAC) address. Another example is the relationship between a nurse/physician and his/her duties, patients, and mobile data.

B. Clients

Our client is a web-based application [12] that has two versions. One version runs on any PC and/or laptop while the other version is a mobile application that can run on an ordinary phone as well as a smart phone depending on the type of user and associated services/features. The default way of communication between the server and its clients is wireless communication to manage the cost. Local clients connect to the server via Wi-Fi connection assuming the availability of a local wireless network. Remote clients are connect through internet, if internet connection is available, or via public 3G/4G mobile wireless network, if needed. The connectivity between the server and its clients is secured by applying strong password policy for each user, limiting access to registered MAC address, and encrypting all data exchanged. In addition, RSA SecurID software tokens are deployed on the recipient's mobile/tablet/laptop devices. A proven algorithm is utilized to produce every minute a unique One-Time Password (OTP), which is coupled with a Personal Identification Number (PIN) to generate a combination, which is nearly impossible to be hacked.

The PC-based version of our client runs on any Microsoft® Windows supported browser. It is mainly tested using Google Chrome. The system requirements of the PC that holds our client is minimal but varying based on the user allowed functionality; e.g. retrieving medical images vs. plain text data. Simply, our client's system requirements of the PC is typical requirement to browse the internet.

There are mainly four different versions of the mobile-based clients depending on the mobile Operation System (OS). The four-supported mobile OSs are Android, Windows Phone, Symbian, and iOS [13 – 14] that are chosen to cover the most popular mobile OSs used in our area.

Our client functionalities are enabled based on pre-defined Role-Based Access Control (RBAC); i.e. role-based security, in our database to restrict certain services/features/data to authorized users. RBAC is a known approach in computer systems security. Within a healthcare organization, we define roles for various job functions and/or user type such as patient, physician, nurse, and admin user. The permissions to perform certain functions are assigned to specific roles. Members or staff of certain user type are assigned particular roles. In order to simplify common operations, such as adding a user or changing a user's department, permissions are not assigned to users individually; instead, they are assigned through the users' defined role(s). Hence, the management of any given user's authorizations would be a matter of simply defining the appropriate roles to the said user.

C. Pager Capabilities

There is no way to know whether a page reached a physician's pager, for example, when a nurse pages that physician using ordinary paging system. The nurse has to wait for a while before trying to page again. Such waiting time could seriously influence patient care [15]. Our system can solve this main disadvantage of any ordinary paging system and provide more benefits such as:

a) The administrator have the benefit of real-time reporting/status on all pager alerts
b) Improve the response time especially in case of emergency since physician can send back an immediate feedback.
c) Wi-Fi support delivers pager alerts to Wi-Fi enabled mobiles without using the mobile carrier public networks to reduce cost.
d) A page in our case is actually a test message that can include important information related to the case, which the page is sent for.
e) If the pager alert includes a phone number, the client can initiate a call back with a single click.
f) If the pager alert includes a patient ID, the client can retrieve a summary of patient medical history with a single click or detailed EHR in few steps.
g) All pages/alerts are logged with powerful reporting engine capabilities.

TABLE I. A COMPARISON BETWEEN DIFFERENT COMMUNICATION METHODS WITHIN HEALTHCARE FACILITIES

		Option A	Option B	Option C	Option D
Brief Description		Regular wireless mobile connectivity	ordinary pager system	complete hardware and software VoIP solution	Our proposed solution
Cost	Initial Cost	Cost of purchasing the mobile phones for each healthcare giver plus the initial cost of the Mobile network company SIM cards.	Cost of purchasing the pager for each healthcare giver plus the initial cost of pager activation.	High cost to buy both the hardware and the software	Software development cost
	Running Cost	Monthly contract bill	Monthly contract bill	Maintenance	Maintenance and upgrade
Medical Data Transferred		No actual medical data exchange takes place, just a way of communication between healthcare givers within the healthcare facility.	None. Just a page with phone number to call.	No actual medical data exchange takes place, just a way of communication between healthcare givers within the healthcare facility.	All medical data as well as personal data.
Method of medical data transfer		None	None	None	Wireless
Required training		None	None	Minimal	Yes.
Device set		Regular mobile phone for regular calls	Pager	IP device set	Regular mobile phone with Wi-Fi capabilities. Smart phone is needed for some users such as physicians.

D. Service Oriented Architecture (SOA)

Our web-based client is designed based on SOA, which is a set of methodologies and principles for designing/developing software in the form of interoperable services. These services are well-defined business functionalities that are built as software components related to each user type's role permissions. Rather than defining an Application Program Interface (API), SOA defines the interface in terms of protocols and functionality. Here are few examples of different access/scenarios:

i. Physician logs in and gain access to EHRs of patients under his/her supervision. Physician retrieves vital signs and DICOM images. Physician sends his/her evaluation and writes prescription.

ii. Nurse logs in and gain access to EHRs of patients under his/her supervision. Nurse retrieves scheduled medications of each patient. Nurse inserts vital signs of each patients at schedule plan.

iii. Patient logs in and gain access to his/her own EHR. Patient retrieves scheduled medications should be taken and recently inserted vital signs. Patient will be informed with any scheduled lab test or radiology scan.

E. Statistics Module

All transactions between clients and server are logged with time stamp. Our server has a statistics module that can help healthcare service providers systematically, quickly, and easily identify and correct operational problems that are hard to find out without using our system. This module enhances monitoring and research in improving healthcare and clinical quality.

F. Processes Enhancement and Polices Enforcement

Our system automates and enhances the process of healthcare delivery. Having immediate access to complete and accurate information can improve patients' outcomes and reduce, even prevent medical errors. In case of emergency, our system can automatically page a second

physician, if the first one is not available or not responding to the pages/alerts.

IV. Discussion

As thousands of healthcare-related processes are enhanced from paper to electronic format, the focus is primarily on the PC, neglecting the potential of wireless devices. Yet, the majority, if not all, of the healthcare workforce is mobile. Our solution provides a simple and easy to use method that allows data collection and database synchronization with the healthcare workforce mobile supporting several main objectives such as:

1) Guarantee the notification of the appropriate medical staff within seconds of the occurrence of an emergency.
2) Guarantee that all the needed/available information reaches key emergency responders to perform their roles.
3) Guarantee that all up-to-date information available is accessible to healthcare personnel.
4) Guarantee alerts to reach doctors despite any system outages that may occur.
5) Enable system administrators to overrule personal device settings to guarantee that an alarm sounds on the recipient's mobile in all cases.
6) Guarantee that administrators and medical professionals have the necessary up-to-date contact information on their mobiles in order to reliably send documents while away from the desk.

Our system is unique in providing communication capability with the ability of medical data transfer with one application. Table I provides a comparison between our solution and the other three systems we found during our survey in three big hospitals in our area. Our System provides comprehensive picture by having reliable access to patient's complete health information at point of car that can help healthcare providers diagnose/handle patients' problems sooner. It also enables evidence-based decisions at point of care.

For future work, we are working on adding more services such as integrate with billing system, patient appointment scheduling/reminder, adding Mac support, and support different browsers. Almost any process can be mobilized with our system such as:

- Accuracy of clinical and billing information is increased by allowing home care personnel to submit reports upon patient visits from the field.
- Dispatching of maintenance tickets and submission of work orders by of medical facilities personnel can be completed on the go.
- Building inspections and repair requests can be recorded/sent by medical facilities personnel while on-site.
- Medical equipment can be easily scanned in and tracked throughout its lifecycle.

V. Conclusion

It is recognized that it is in everyone's best interest, including healthcare insurance companies, to provide immediate medical care once it is needed. The cost of managing the long-term consequences of delaying treatment in some case especially emergency ones far exceeds the cost of a software solution such as ours. Our system is designed and developed based on open source to reduce it cost while maintain its ease of use and its great healthcare services and features. We believe that the usage of our system will enable administration staff in any healthcare organization to accurately measure healthcare quality indicators that will definitely improve the healthcare delivery process.

References

[1] "Hospitals Using Technology To Advance Patient Care", http://www.10tv.com/live/content/local/stories/2010/08/31/story-columbus-hospitals-using-technology-stay-connected.html?sid=102

[2] Jovanov, E. ; Dept. of Electr. & Comput. Eng., Alabama Univ., Huntsville, AL, "Wireless Technology and System Integration in Body Area Networks for m-Health Applications", The 27th Annual International Conference of the Engineering in Medicine and Biology Society, IEEE-EMBS, PP 7158 – 7160, 2005.

[3] "Concord Hospital Expands Its Trapeze Networks Wireless LAN, Improving Patient Safety and Quality", http://www.fox44now.com/Global/story.asp?S=12882204&nav=menu660_8_10

[4] "Hospital using new technology for improved clinical communication", http://www.lcni5.com/cgi-bin/c2.cgi?151+article+Business+20101019171802151151013

[5] Book: Telemedicine Technologies: Information Technologies in Medicine and Telehealth, Author: Bernard Fong, A.C.M. Fong, C.K. Li , ISBN: 978-0-470-74569-4 - October 2010

[6] "Mobile Telemedicine System for Home Care and Patient Monitoring", Proceedings of the 26th Annual International Conference of the IEEE EMBS, San Francisco, CA, USA, September 1 -5, 2004.

[7] Mobile health application market to explode to 500 million within five years : http://news.techworld.com/applications/3249091/mobile-health-application-market-to-explode-to-500-million-within-five-years/

[8] Annals of The Royal College of Surgeons of England, "Mobile Phones, in Combination with a Computer Locator System, Improve the Response Times of Emergency Medical Services in Central London", http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2443303/

[9] "Mobile Telemedicine: A Computing and Networking Perspective", Xiao, Yang, CRC Press, ISBN-10: 1420060465, ISBN-13: 978-1420060461, 2008

[10] Cohen T, Ellis WS, Morrissey JJ, Bakuzonis C, David Y, Paperman WD., "Safe use of cellular telephones in hospitals: fundamental principles and case studies, J Healthc Inf Manag. 19(4):38-48, 2005

[11] Cloud Based Unified Communications for the Enterprise, http://www.sipfoundry.org/

[12] "Beginning Web Development for Smartphones: Developing Web Applications with PHP, MSQL, and jQTouch", ISBN-10: 1453831053, 2010

[13] "Beginning iOS 4 Application Development", Lee, Wei-Meng, ISBN-10: 0470918020, First Edition, 2010

[14] "Beginning Android Application Development", Lee, Wei-Meng, ISBN-10: 1118199545, First Edition, 2012

[15] The Longstreet Clinic: Replacing Pagers, Supercharging Communications with WIC Pager", www.wallacewireless.com/healthcare