Proceedings of the 29th Annual International
Conference of the IEEE EMBS
Cité Internationale, Lyon, France
August 23-26, 2007.

Development of an Electronic Medical Report Delivery System to 3G GSM Mobile (Cellular) Phones for a Medical Imaging Department

Eugene Y. Lim, *Member, IEEE* [1,2], Chiang Lee [2], Weidong Cai, *Member, IEEE* [2], Dagan Feng, *Fellow, IEEE* [2,3] and Michael Fulham[1,2]

[1]Department of PET and Nuclear Medicine, Royal Prince Alfred Hospital, Australia
[2]School of Information Technologies, The University of Sydney, Australia
[3]Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, China

***Abstract*—Medical practice is characterized by a high degree of heterogeneity in collaborative and cooperative patient care. Fast and effective communication between medical practitioners can improve patient care. In medical imaging, the fast delivery of medical reports to referring medical practitioners is a major component of cooperative patient care. Recently, mobile phones have been actively deployed in telemedicine applications. The mobile phone is an ideal medium to achieve faster delivery of reports to the referring medical practitioners. In this study, we developed an electronic medical report delivery system from a medical imaging department to the mobile phones of the referring doctors. The system extracts a text summary of medical report and a screen capture of diagnostic medical image in JPEG format, which are transmitted to 3G GSM mobile phones.**

I. Introduction

TELEMEDICINE is now widely used in medical practice [1,2]. One application of telemedicine is the fast and effective provision of communication between medical practitioners over the Internet. This type of communication can be a great benefit to medical practice because collaborative and cooperative patient care can be achieved through the exchange of knowledge, e.g. patients referred between general practitioners and medical imaging specialists [3].

Computer supported cooperative work (CSCW) has been applied within telemedicine applications [4]. CSCW is a concept of a computer-based system which supports a group-working environment. CSCW system can be divided into two different types based on the type of coupling - tight or loose [5]. Tightly coupled work involves two or more people whose work is directly dependent on each other and requires a number of interactions to complete the task. Loosely coupled work is where people are aware of the other's activity and decisions but no immediate clarification or negotiation is required. The practice of referring patients between different specialties can be described as loosely coupled. Fast exchange and availability of information can improve a loosely coupled work process by creating a tightly coupled environment [6].

The authors are grateful to the support from the ARC and UGC/PolyU grants.

As mobile technologies reach powerful modular and fast computation capabilities, fast message processing can be extended from a personal computer to micro devices such as mobile phones (name differs depending on regions e.g. cellular phone for US). Recently, telemedicine applications using mobile phone have been widely reported in the literature including [7-18]. The majority of them utilize mobile phone as a monitoring system [8-17] for biomedical signals. Not many of them have been applied to fast delivery of medical reports with medical images.

Faster delivery of medical report to referring doctors can improve patient care process by creating a tightly coupled environment. Currently, in our medical imaging department, email, fax, and paper-based reports are delivered to the referrers. Email and fax are fast platform in transmission time, but there is a possible delay of the transmitted report to reach the referrers. The report is expected to reach faster to referrers using mobile phones because of its mobility. This faster delivery can improve information availability to referrers.

In this paper, we developed a mobile medical report delivery system for a medical imaging department as a fast electronic delivery method. The system extracts a text summary from a medical report in an imaging information system (mainly used for scheduling and report generation) and transmits the data to referring medical practitioners' mobile phones. A selected key image of medical image visualizing the resulting diagnosis of the report in JPEG format is attached to the report.

II. Overview of System

The overall system flow is shown in Figure 1. The system consists of three components; medical imaging information system (MIIS), message generation system (MGS), and transmission gateway. MIIS is similar to a Radiology Information System (RIS) [19] customized for handling Positron Emission Tomography (PET) and Nuclear Medicine scans. The MGS extracts reports from the MIIS and initiates an image conversion process. A single frame of medical images in Digital Imaging and Communications in Medicine (DICOM) [20] format is converted to JPEG

format. The imaging specialist selects the frame number. This converted image is then transferred to the MGS for attachment. Transmission gateway is attached to a General Packet Radio Service (GPRS)/Global System for Mobile Communications (GSM) modem capable of transmitting Short Message Service (SMS) and Multimedia Messaging Service (MMS) to telecommunication service providers. The generated SMS or MMS message is transmitted to the GSM network to telecommunication service provider for transmission to the referring doctors.

The desired aspects of the profile using the newly developed system are as follows;

- Users are able to initiate message transmission from the MIIS.
- User can edit expected outcome of transmitted message.
- The system manages address book to prompt mobile phone numbers for selection.
- User can select single or multiple recipients.
- User can browse and select images converted from DICOM for attachment.
- User can select type of message to transmit: text only SMS or image attached MMS.

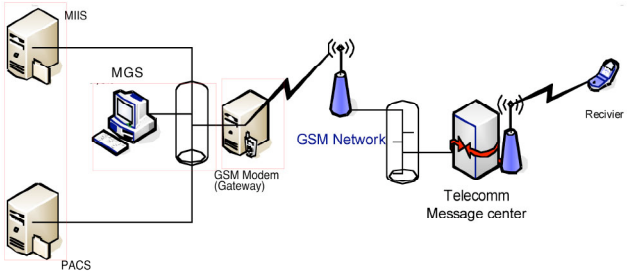

Fig.1 Overall system structure and flow of process.

III. System Development

MIIS is customized to the needs of the department using Filemaker Pro 8.5 (FileMaker, Inc. Santa Clara, CA), which has been developed for 10 years. The MIIS is based on client-server model that clients can access a centralized server over local area network (LAN). MIIS has a number of functions including scheduling patients, managing radioisotopes, and reporting. The server is on Mac OS X operating system. Clients are available in both Mac OS X and Microsoft (MS) Windows XP.

The scanned and reconstructed PET/CT and Nuclear medicine images are archived in a local archive (local picture archive and communication system (PACS)) in DICOM format. The platform of PACS is Siemens eSoft workstation (Siemens Molecular Imaging, Knoxville, Tennessee).

The MGS was attached to one of the client machine of MIIS dedicated for reporting in MS Windows XP. MGS was implemented in Java 2 Platform, Enterprise Edition (J2EE) platform (Sun Microsystems, Inc., CA) and is able to communicate with the MIIS using Java Database Connectivity (JDBC) for extracting text report. For control of the GSM gateway from MGS, M2U API package was used for the development (Mozat pte. Ldt., Singapore). M2U provides APIs for C++, Java, and Visual Basic (VB) [21]. MGS supports DICOM protocol for communication with PACS.

IV. System Process

Conceptualized data flow from MIIS to GSM gateway is shown in Figure 2. Firstly, MGS is initiated from MIIS and launches its interface in the MIIS workstation. Patient ID and Report ID number and the selected image frame number for conversion are parsed to MGS, which is then used by MGS to query to MIIS server to retrieve the medical report and patient demographic data including Patient Identification (PID), Medical Record Number (MRN), study date and date of birth. The patient demographic data are used to query to the local PACS. The DICOM image matches PID, Patient name, study date and MRN, is retrieved from PACS to MGS platform. A single frame of DICOM image with the parsed frame number is converted to a JPEG format image. The resolution is fixed to 128x128. The converted image, patient data and medical report are displayed on the interface of MGS for approval of transmission from the user. Once it is approved, the final message content goes through the message wrapper process encoding as message gateway job and transmit to on-site message gateway for sending via GSM network.

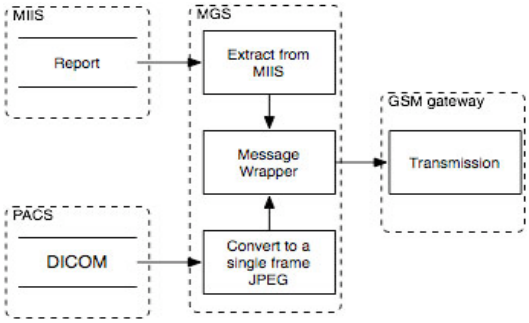

Fig.2 Data flow diagram: report from MIIS and a image from PACS are wrapped in MGS. The wrapped message is transferred to GSM gateway for delivery.

V. Results

Figure 3 shows the graphical user interface (GUI) of MIIS used for reporting. Patient demographic data is displayed on top of the MIIS interface. Text editable fields containing report and conclusion are located in the middle of reporting interface. A button called mobile phone is located on the bottom of interface, which can launch the MGS.

The message composer and address book of MGS is shown in Figure 4. Multiple recipients can be selected using check boxes as shown. The attach button is for attaching converted JPEG image to the message. As an option, the user can just transmit a text-only message. The preview window of MGS is shown in Figure 5 to display format of

message to be displayed on the recipients' mobile phones. The received medical report with attached image is shown in Figure 6. Left figure shows picture of the mobile phone with image display. As image resolution is slightly higher than the display capacity of mobile phone, scrolling is required for viewing. This depends on the display size of mobile phones; image can be displayed fully with mobile phones with large screen.

Transmission time of medical report is shown in Figure 7. Figure 7 (a), (c) show processing time for gateway to transmit from MGS to communication service provider for SMS and MMS respectively. Figure 7 (b), (d) show total duration of time to reach recipients' mobile phones using SMS and MMS respectively.

VI. DISCUSSION AND FUTURE WORK

The system successfully transmitted medical reports in the simulated settings. Based on the results from the simulated study, the finding is that this system can shorten delivery time of medical report to referrer. This faster delivery from medical imaging specialist to referrers creates a tight coupling between the referring doctor and the imaging specialist.

The processing and transmission time was major concern in the development stage. Transmission time normally depend on service providers. In this experiment setting, test results showed that successive processing and transmission of 40 text reports took 15.31 minute for sending out, and average arrival time was around 25 (24.72) seconds. For the 40 consecutive reports with image, the gateway processed each MMS job in average 51 (50.975) seconds. Total time taken was 34 (33.9833) minutes. The average MMS report received time was 74 (73.925) seconds. Above results may vary due to service provider's capacity, network traffic and signal strength.

Delivery of medical report in electronic form including email and fax is also fast in transmission time. However, time measure of reaching referring doctors is expected to be shorter in the mobile phones because of its mobility. The major advantage of the system is to improve information availability to referring doctors by reducing delivery time.

However, currently, the system has been only trialed in selected patient reports in a simulated environment to a predefined set of mobiles. The impact of faster delivery of medical report on patient care process can be measured in terms of CSCW, once the system is trialed in real clinical environment. Furthermore, usability of the system can be evaluated with large number of samples.

The system can be extended to more functions such as accessing PACS and manipulating images in real time. Capability of updating message feedback from referrers back would be desirable for reliable communication which can detect accidental disclosure of patient information. Even more, a videoconferencing function can be built via 3G network services to achieve a seamless health care environment.

VII. CONCLUSION

In this study, we developed a medical imaging report delivery system and explored the advantages of mobile phone as a fast report delivery platform in telemedicine. The system is expected to improve quality of care and efficiency of patient care process thanks to fast delivery of medical reports. The system design is expandable, and further improvement is feasible. We believe that this system is a valuable next step forward in the development of state of the art telemedicine applications in clinical practice.

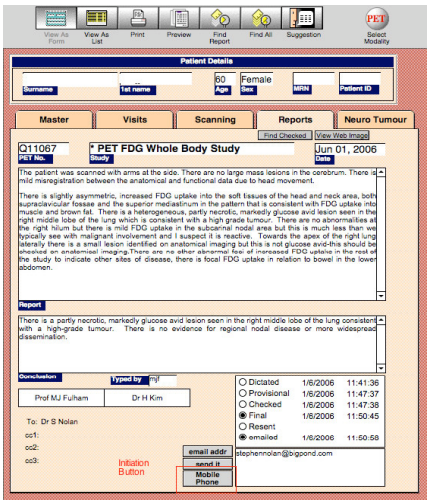

Fig.3. GUI of MIIS for reporting containing a medical report. Marked button in red for initiating MGS process.

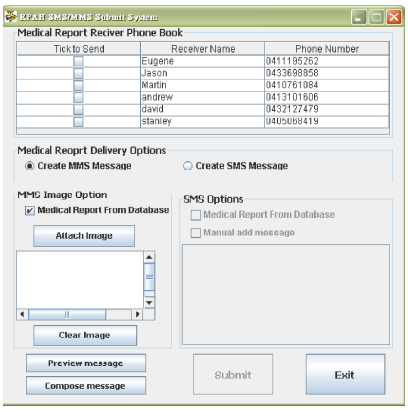

Fig. 4. Interface of message composer and address book.

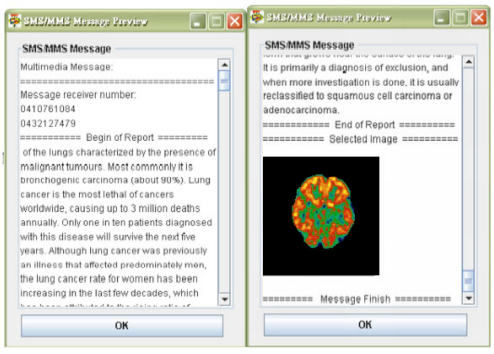

Fig.5. Preview window of SMS and MMS messages.

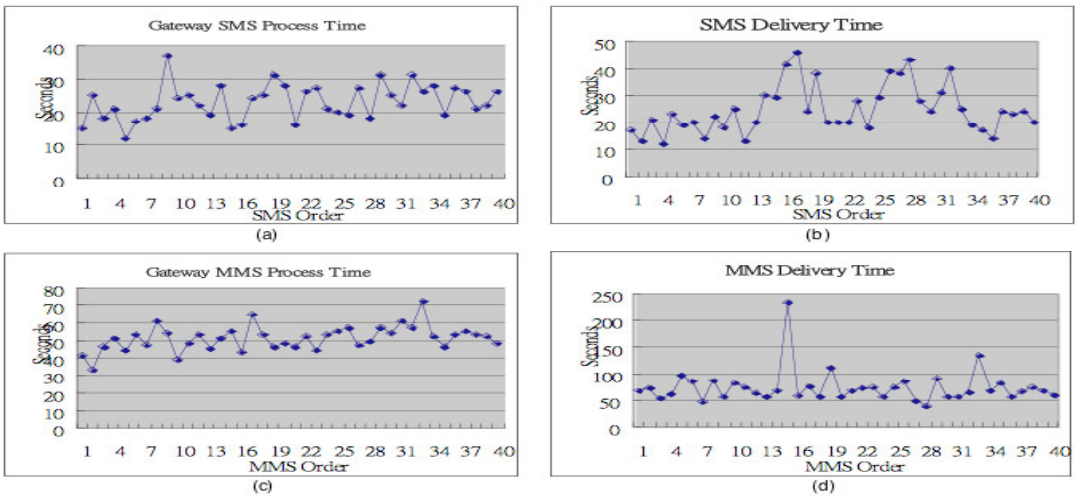

Fig.7. Time measure (a) gateway processing SMS (b) total delivery time for SMS (c) gateway processing MMS (d) total delivery time for MMS.

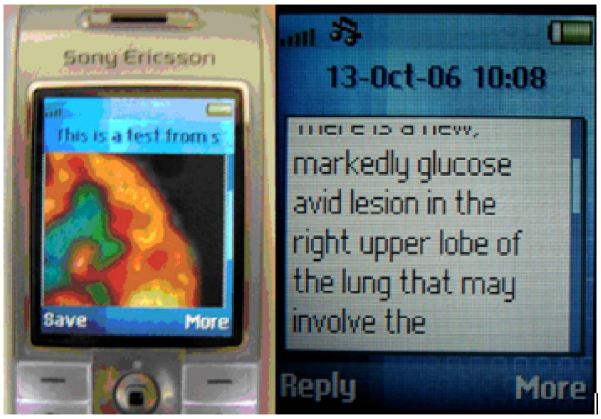

Fig.6. Transmitted reports and image displayed on mobile phone.

REFERENCES

[1] Maglaveras, N., Chouvarda, I., Koutkias, V., Gogou, G., Lekka, I., Goulis, D., Avramidis, A., Karvounis, C., Louridas, G., Balas, E., *"The citizen health system (CHS): a modular medical contact center providing quality telemedicine services,"* IEEE Transactions on Information Technology in Biomedicine, 2005, vol. 9(3) pp. 353-362.

[2] Whitten, P. S., Mair, F. S., Haycox, A., May, C. R., Williams, T. L., and Hellmich, S., "*Systematic review of cost effectiveness studies of telemedicine interventions",* British Medical Journal, 2002, vol. 324, pp.1434-1437

[3] Bardram, J. E. and Bossen, C., "The spatial dimension of collaboration at a hospital," Comput. Supported Coop.Work, 2005, vol. 14, pp. 131-160.

[4] Ellis, C. A., Gibbs, S. J., and Rein, G., *"Groupware:some issues and experiences,"* Commun. ACM, 1991, vol. 34(1), pp. 39–58.

[5] Olson, J. and Teasley, S., *"Groupware in the wild: Lessons learned from a year of virtual collection,"* In Proc. of CSCW, ACM press, 1996, pp. 419–427.

[6] Erickson, T. and Kellogg, W., *"Social translucence: an approach to designing systems that support social processes,"* ACM Transactions on Computer-Human Interaction (TOCHI), 2000, vol. 7(1), pp. 29–83.

[7] Kafeza, E., et al., "*Alerts in mobile healthcare applications: requirements and pilot study,"* Information Technology in Biomedicine, IEEE Transactions on, 2004, vol. **8**(2) pp. 173.

[8] Kovacs, F.; Horvath, Cs.; Torok, M.; Hosszu, G., *"Fetal Breathing Transmission in Phonocardiographic Monitoring Telemedicine Systems,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2006, pp. 5226 – 5229.

[9] Maby, E.; Le Bouquin Jeannes, R.; Faucon, G., *"Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 3751 – 3754.

[10] Gollol Raju, N.S.; Anthony, J.P.; Jamadagni, R.S.; Istepanian, R.; Suri, J.; Laxminarayan, S., *"Status of Mobile Computing in Health Care: An Evidence Study,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 3274 - 3277

[11] Chu, Y. and A. Ganz, *A mobile teletrauma system using 3G networks.* Information Technology in Biomedicine, IEEE Transactions on, 2004, vol. **8**(4): pp. 456.

[12] Kogure, Y.; Matsuoka, H.; Kinouchi, Y.; Akutagawa, M, *"The Development of M3S-Based GPS Navchair and Tele-Monitor System,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 4052 - 4055

[13] Kovacs, F.; Horvath, Cs.; Torok, M.; Hosszu, G., *"Fetal Breathing Transmission in Phonocardiographic Monitoring Telemedicine Systems,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 5226 - 5229

[14] Kroc, S.; Delic, V., *"Personal wireless sensor network for mobile health care monitoring,"* In Proc. Telecommunications in Modern Satellite, Cable and Broadcasting Service, 2003, vol. 2, pp. 471-474.

[15] Yi-Hui Wu; Bing-Yuh Lu; Heng-Yin Chen; Yao Ou-Yang; Jin-shin Lai; Te-Son Kuo; Fok-Ching Chong, *"The Development of M3S-Based GPS Navchair and Tele-Monitor System,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 4052 – 4055.

[16] Kogure, Y.; Matsuoka, H.; Kinouchi, Y.; Akutagawa, M., *"The Development of a Remote Patient Monitoring System using Java-enabled Mobile Phones,"* In Proc. Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005, pp. 2157 – 2160.

[17] Goh, K.W.; Kim, E.; Lavanya, J.; Kim, Y.; Soh, C.B.,*"Issues in Implementing a Knowledge-based ECG Analyzer for Personal Mobile Health Monitoring,"* In Proc. Engineering in Medicine and Biology Society, 2006. IEEE-EMBS 2006, pp. 6265 – 6268.

[18] Byeong-il Lee; Jeong Min Ham; Ki Soo Park; Su-Ho Ok; Jong Min Kim; Heoug Kook Choi, *"Development of the investigation scheduling system using mobile phone utilization of the department of nuclear medicine,"* In Proc. Enterprise networking and Computing in Healthcare Industry, 2005. pp.325-326.

[19] Honeyman JC., *"Information systems integration in radiology,"* Journal of Digital Imaging, 1999 May;12(2 Suppl 1):218-22.

[20] Huang, H. K., *"PACS and Imaging Informatics: Basic Principles and Applications,"* John Wiley & Sons, inc. 2000

[21] *M2U White Paper.* [cited 2006 12/10]; Available from: http://www.mozat.com/resources/M2U_whitepaper.pdf.