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Rich Internet Application System for Patient-Centric Healthcare Data Management Using Handheld Devices

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***Abstract*—Rich Internet Applications (RIAs) are an emerging software platform that blurs the line between web service and native application, and is a powerful tool for handheld device deployment. By democratizing health data management and widening its availability, this software platform has the potential to revolutionize telemedicine, clinical practice, medical education and information distribution, particularly in rural areas, and to make patient-centric medical computing a reality. In this paper, we propose a telemedicine application that leverages the ability of a mobile RIA platform to transcode, organise and present textual and multimedia data, which are sourced from medical database software. We adopted a web-based approach to communicate, in real-time, with an established hospital information system via a custom RIA. The proposed solution allows communication between handheld devices and a hospital information system for media streaming with support for real-time encryption, on any RIA enabled platform. We demonstrate our prototype's ability to securely and rapidly access, without installation requirements, medical data ranging from simple textual records to multi-slice PET-CT images and maximum intensity (MIP) projections.**

I. Introduction

TELEMEDICINE is advancing rapidly, as are the capabilities of mobile and handheld wireless devices. Telemedicine solutions can now access, exchange and manipulate digital image data, medical documents, patient records and other medical information for a range of purposes including research collaboration, emergency diagnosis, management of chronic disease and medical education (amongst others). A wide variety of hardware are used in this context - server, desktop, mobile and purpose-built medical systems [1-2]. It is clear that digital communication has the potential to transform the way patients and practitioners interact, collaborate, share and use medical information [3-5]. However, the uptake of telemedicine solutions has been slow, fragmented and limited by infrastructure, financial, security and compatibility issues [6]. The concept of personalized medicine and demand from stakeholders (patients, practitioners and referring doctors alike) for improved access to and control over medical data herald efforts to democratize the delivery of healthcare information [7]. Many telemedicine solutions are web-based, which allows for rapid design and deployment, reduced cost, greater convenience and compatibility [8, 9]. Web-based systems, however, are limited in the ability to provide a comparable user experience and processing ability to traditional desktop applications.

Rich Internet Applications (RIAs), however, have changed this dynamic [10]. RIAs incorporate a richer user experience with rapid access and responsivity to multi-media data [10]. They were initially developed for e-business and entertainment use, but have since been enhanced by a variety of major software developers and contain a variety of advanced security and graphics technologies in addition to all of the capabilities and protections enjoyed by secure web-based software [12-16]. There has also been recent application of RIA technology to the storage and retrieval of health records [17-19]. Our aim was to apply RIA technology in telemedicine and mobile health (m-health). Our proposal introduces a RIA-based Content Management System (CMS). This system was motivated by our previous research into mobile medical data delivery [20], and forms a part of our long-standing project to deliver components of a hospital medical IT infrastructure to handheld devices [9, 21]. Our aims were to develop a system that could: a) enable access to medical data in emergencies, or for teleconsultation, presentations, education, collaboration and out-of-office review; b) serve as an installation-free, platform- and hardware-independent, dynamically configurable Internet-based framework for retrieval of

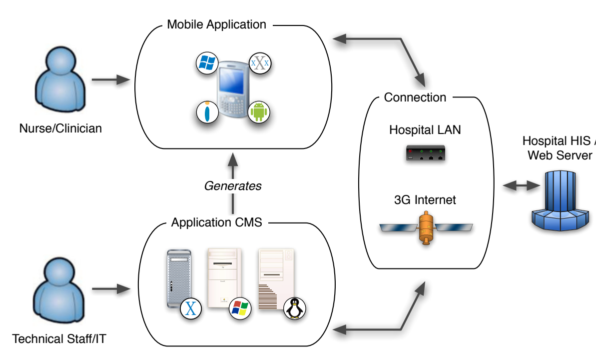

Fig. 1. The overall architecture of our mobile RIA.

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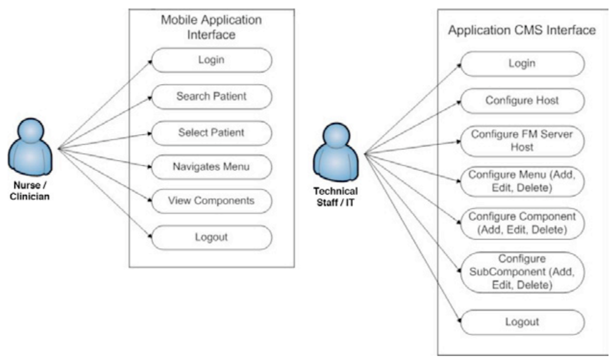

Fig. 2. Use-Cases for the Mobile and CMS interfaces.

medical data and multimedia, c) contain encryption sufficient for the transmission of sensitive medical data and d) allow the real-time conversion of medical data formats to web / mobile formats for display and review through RIA-friendly media streams.

II. Architecture and Implementation

Our RIA is designed around: i) a Mobile Application layer that is fully compatible with mobile and handheld devices in addition to desktop, server and tablet devices and, ii) the Application CMS layer that runs on non-handheld operating systems only. The overall architecture of the system presented in this paper is given in Figure 1. Both layers are accessible over the network and interact directly with one another. The chief data source for both is the server layer storing the requisite medical data. This server layer is not a part of the RIA itself, and may be any Hospital Information System (HIS), Picture Archiving and Communication System (PACS) or other such server or combination. The limiting factor is that the CMS layer is able to communicate with the server and transcode the relevant data to a mobile format. In our approach the server layer consisted of our hospital's Department of PET and Nuclear Medicine Information System (IS). The IS contained patient, appointment, patient reports and scan image data, as well as a separate PACS server storing a series of image slices and pre-rendered rotational Maximum Intensity Projection (MIP) as video (cine) files.

A. *Mobile Application*

The mobile application component can be broken down into parts. Figure 2 shows the main use-cases of the Mobile Application layer. There are a small number of standard views for performing common tasks such as searching and authenticating to the system. A generalized notation is adopted to allow doctors and other non-technical users to customize the components, menus, etc., that they want to see on the mobile device screen, and where in the requisite data may be found in the server layer. The mobile layer is adaptive in that it detects the graphical and technical capabilities of the device, and displays content as appropriate. This is achieved by implementing tabbed panes, scaling down graphics and using simple view controllers, as well as adapting to limited text input capabilities and navigation limitations, when run on particularly small devices (such as clamshell phones).

The components available in the mobile layer include all the standard components expected within an application (buttons, menus, text boxes, scrollbars, lists, etc.), as well as components for displaying compressed or lossless medical images, and interactive video.

B. *Mobile Application Technology Overview*

We used the Flash Lite platform to build the Mobile Application layer. Use of the Flash Lite platform, in addition to providing consistent behavior on a major and growing percentage of mobile devices [22], provides full access to the entirety of Flash Lite's extensive suite of optimized functionality and advanced application behaviors. This allows improvements in networking, streaming, compression, memory management, security and runtime speed. We also applied a number of PHP-based server-side scripts, Java applications and native binaries to convert data to suitable formats for mobile display. Image series were converted to streamable video data, using the FLV format and Sorenson H.263 codec, through the open-source ffmpeg command-line video conversion script [25]. Communication between the Mobile and CMS layers was done via a localized TCP/IP connection using the RIA platform itself, whereas Server layer communication was handled by XML-based callbacks over a security-capable channel.

C. *Application CMS*

Within the CMS, users can easily select, add and configure components and views within the mobile layer application, and control their bindings to and from the server layer data sources. This allows the CMS to open up and share particular data items from within the hospital IS

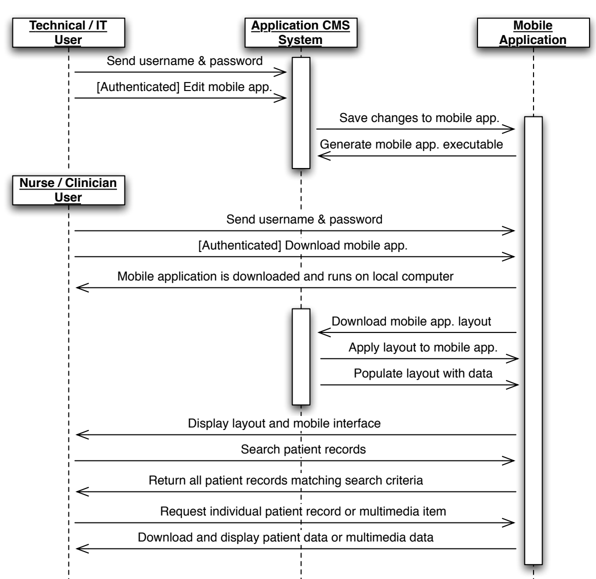

Fig. 3. Sequence diagram of simplified system use.

immediately for mobile use, allowing a mobile application to be rapidly tailored to the needs of a particular situation or user.

An example of an Application CMS layer is shown in Figure 4 alongside the mobile application interface. In this figure, the CMS is shown editing a mobile application containing a MIP navigation component that is concurrently in use on the PDA device and streams live data from an image server. This illustrates a primary feature of our CMS: the ability to make changes to data structure, interface and capabilities on-the-fly. The CMS consists of one main interface, and may be run inside any web browser in the same way as the mobile layer interface. Unlike the mobile layer, however, it does not support smaller handheld devices. Figure 5 displays a mobile application that contains numerous record, image series and MIP navigation components. This was assembled and bound to HIS and MIP data using the CMS, and then can be executed as a standalone application or via a web browser on any RIA-capable handheld device.

D. Application CMS Technology Overview

The CMS layer was built using Adobe Flex [23] technology and used an MVC (Model View Controller) model. This allows the user interface and underlying medical data bindings to be modified independently, without either affecting the other. As with the mobile component, the CMS uses a series of server-side scripts for data conversion. It handles data storage and transmission via a mixture of XML-based data and TCP/IP networking. The mobile application preview displayed within the CMS is an active instance of the mobile layer, and can be dynamically manipulated at runtime by the CMS via a TCP/IP-based or local connection as noted above.

III. Results and Discussion

Our prototype telemedicine HIS, CMS and multimedia medical data viewer application for handheld devices, using RIA technology, is a simple, secure, and effective approach to access medical image and textual data over the Internet. Our system can convert an existing HIS into a multi-platform, device-independent web service with benefits in performance, security and scalability.

A. Performance

Our RIA platform approach overcomes the limitations of a web-based solution through a callback communication model that avoids the redundancy of reloading the page after each operation, and wait times. Size of transmitted data varied by connection type, ranging from 300 to 400 bytes for search queries to 200 Kb or higher for rotational MIP. PET images were transmitted at the full resolution of the scan, namely 256 x 324 pixels. We found that less network traffic to and from the device was needed using the RIA approach, which increased the performance and usability for end-users. Table 1 shows our RIA's performance measured during routine HIS operations, on a commonly available PDA (the Dell Axim X51v), which is used as the base platform for every connection type. All operations complete in under half a second - indicating real-time, lag-free data access and user interaction.

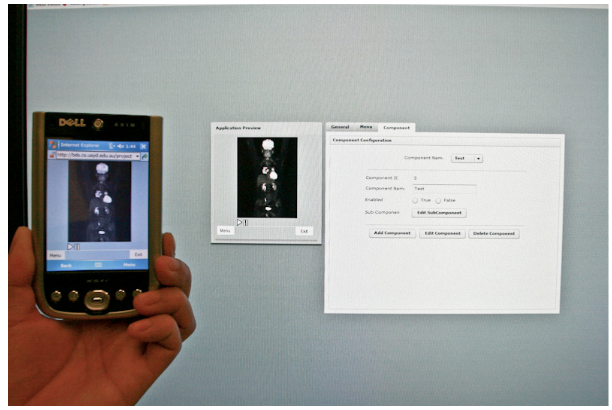

Fig. 4. The Content Management System, showing a mobile application in the process of being edited. The PDA pictured is running the same application.

B. Security

Our RIA addresses security at three levels. As a web-based system, and due to the use of standard web protocols for communication, our application is capable of running over a secured web-channel in the same way as any HTTPS website, providing security equivalent to that of the certificate used to sign the transaction. HTTPS is the protocol used for internet banking, and supports a high level of encryption. Further, our application also supports encapsulating all medical data that passes through the open Internet in an RFC 4251 tunnel, providing a second layer of industry-standard encryption [24]. Such encryption creates a protected datastream between the sender and receiver, preventing unauthorized eavesdropping. Finally, user authentication is incorporated into our CMS and mobile layers, requiring a valid hospital user ID and password for access. Such authentication forms a last line of defense, and enhances auditability, by requiring a unique login for each system user. Password information is stored on the hospital servers, is verified by means of a hashing algorithm (meaning it is never transmitted to the user), and is protected

TABLE I
Average* RIA Performance by Clients Served

Connection Type	1 Client	4 Clients	8 Clients
Rotational MIP Series	51.44 ms	94.52 ms	147.96 ms
PET Image Series	46.3 ms	50 ms	70.5 ms
HIS Authentication	92.88 ms	129.4 ms	147.08 ms
HIS Search Query†	21.76 ms	32.52 ms	38.72 ms
Patient Textual Data	10.08 ms	10.8 ms	11.16 ms

* Averaged over 5 iterations. Results accurate to within 1/100 ms.

† Time to obtain result-set for simple string query (eg. Patient name search), displaying up to 25 results.

by firewall and file system barriers.

These forms of security are available on the vast majority of internet-capable devices, including most SmartPhones, PDAs and other mobile computing devices, and provide additional protection on top of (not in place of) the encrypted Wi-Fi (or 3G internet) signals these devices already use to access the internet or LAN via their browser.

C. Scalability

Finally, a telemedicine system needs to scale well to a large user base, and avoid interruption in high-load situations. Again the discrete communication model, reduced traffic and increased capability for client-side processing, etc., of the RIA platform serves to reduce the load on infrastructure and improve scalability. Coupled with existing safeguards and network/streaming optimizations inherent in server software and the RIA platform itself, our system displays a high level of scalability as shown in Table 1 for 1-8 users. The system scales in the same ways as a typical web-service, indicating that the only limitation on potential performance and simultaneous user count is the performance level of the enabling server hardware.

IV. Conclusion and Future Work

We present a RIA approach to the distribution of multimedia medical data via a handheld device. Our solution facilitates web-based access in an easy-to-customize application for a variety of purposes.

In future, we aim to investigate this system's effectiveness for presenting study findings to patients. It is also being extended via the incorporation of a fully interactive control interface for collaborative remote 3D PET/CT review [26], and due to undergo clinical trials.

Fig. 5. Mobile app created within our CMS, running on a Dell Axim X51v PDA and a Nokia N82 mobile.

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