Communication of Medical Images, Text, and Messages in Inter-Enterprise Systems: A Case Study in Norway

Ilango Balasingham, Member, IEEE, Halfdan Ihlen, Wolfgang Leister, Per Røe, and Eigil Samset

Abstract—There is an increasing demand to discuss diagnostic images and reports of difficult cases with experienced staff. A possible solution besides physically transporting patients and material is to use high speed communication networks to transfer images and reports electronically. With the web application PACSflow we have developed a solution to transfer images, reports, and messages as a single package in one step procedure. The PACSflow is an interoperable and standard compliant web based application, which gives clinicians a user friendly user interface for their work on a daily basis. The solution assumes that the diagnostic images are compatible with the Digital Imaging and Communications in Medicine format. The department of cardiology at the Rikshospitalet University Hospital in Oslo and the department of internal medicine at the Sørlandet Sykehus in Arendal make clinical use of the system. Initial tests indicate that use of PACSflow reduced the time used to prepare and transfer data by a factor of 3.

Index Terms—HIS, PACS, teleradiology, work flow.

I. INTRODUCTION

The health reform adopted by the Norwegian government in 2002 will probably increase the tendency of hospitals to specialize in certain types of clinical procedures. Most hospitals in Norway are public and financed by the state. Since 2002, the hospitals are organized as so called “health regions”. There are five health regions (north, central, west, east, and south), where each region has at least one university hospital. The tendency within a health region is to organize its resources in an effective manner by increasingly identifying hospitals specializing in certain types of clinical procedures, even though they are geographically dispersed. This paper summarizes some of the results achieved in a project undertaken by the Rikshospitalet (the National) University Hospital in Norway in collaboration with the Norwegian Computing Center and the Sørlandet Sykehus (the Southern Hospital) in Arendal.

Most of the hospitals (over 95%) use advanced diagnostic imaging devices, Electronic Patient Record (EPR) system, Patient Archiving and Communication System (PACS), Radiology Information System (RIS), etc. All hospitals are interconnected by a broadband communication network at a bandwidth of at least 10 Mb/s. However, deployment of services based on teleradiology and telecardiology systems have so far been slow in Norway. Reasons may be that the reimbursement scheme does not cover such consultations, the organizational structure is missing, the management is not capable of utilizing the technology, the rules and regulations of public health care constrain the exchange of patient sensitive information, and the systems lack of important functionality. There are ample teleradiology solutions available in the literature. There are many commercial systems available in the market, which have a number of functionalities. The focus has lately been on clinical system usability, technical design and deployment [1].

A senior cardiologist at the Rikshospitalet faced the problem when his colleagues from other hospitals in Norway wanted his opinion whenever they had a difficult case. While having advanced diagnostic imaging devices the doctors requesting the second opinion were usually recently trained. To communicate with senior doctors, who are located in a geographically different place, the junior doctors copy diagnostic medical images from the imaging devices into appropriate storages such as magneto optical disk (MO-Disk), CD-ROM, or video cassette. Notes about the case are transferred using courier services. This is obviously a time consuming procedure, and the information sent often lacked important records from the EPR and imaging systems. Often the doctor performing the second opinion contacts the hospital to get more information about the patient. Obviously, difficult and emergency cases cannot be handled in this way. This means such patients are usually transferred to a specialty hospital immediately after imaging by ground or air transportation.

II. PROBLEM DESCRIPTION

At the Rikshospitalet University Hospital, the radiology department has installed an image transmission solution with limited success. The solution lacks several functionalities that seem vital to be used on a daily basis. The reason may be that the Electronic Patient Record (EPR), Radiology Information System (RIS), Patient Archiving and Communication Systems (PACS), laboratory systems are delivered by different manufactures where most of them lack standard-defined interfaces. Even for PACS delivered by two different vendors, compatibility problems have been reported.

The current routines for teleradiology include several manual steps both at sender and receiver sides, as shown in

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The department of cardiology at Rikshospitalet uses US scanners from GE Vingmed Ultrasound AS, Horten, Norway [2]. The scanners are connected in a separate private network, Echo-net, delivered by GE Vingmed Ultrasound. It has options for storage and disk back-up facilities. The workstations or PCs, running Microsoft Windows XP, are connected in the Echo-net. EchoPAC software, delivered by GE Vingmed Ultrasound, is used for accessing US data from databases, viewing and analyzing images and cine-loops, and creating examination reports.

EchoPAC also allows us to export and import US raw format data (a proprietary GE Vingmed Ultrasound format), available in DICOM in the JPEG (joint picture expert group) compressed format. Images that are exported to the PACS must have valid DICOM fields for UID (unique ID), name, person identification number, date of birth, gender, etc., preferably obtained from the hospital information system (HIS). In Norway, the personal identification number is unique nation-wide, consisting of date of birth and a five-digit number.

The department of radiology at the Rikshospitalet has a streamlined system where the PACS, RIS, and PIMS (Patient Information Management System, aka HIS) are interconnected. Their PACS was delivered by Sectra AB, Linköping, Sweden [3], the radiology information system (RIS) was delivered by Kodak Inc, USA [4]. Note, that the work procedures at the department of radiology differ from those in cardiology. Requirements regarding image formats (e.g., the use of raw format) are also different.

The Sørlandet Sykehus in Arendal uses the DIPS as the EPR system [5]. The PACS and DIPS are hospital-wide available, while the RIS is only accessible by the departments, due to security reasons. Therefore, each department (radiology, cardiology, etc.) has their own RIS implemented as a closed area of the HIS.

When images of a patient are acquired, the medical personnel need to enter the patient information, which must be a unique ID, e.g., in Norway the person identification number is used. The correct relationship among patient, medical data, reports, and images must be achieved, using the HIS. The RIS, which is connected to a part of the HIS generates a DicomID and the data for the work lists. Additionally, the technical parameters, e.g., compression methods, must be entered.

When medical images arrive from another hospital by other means than PACS to PACS transfer, the images are not attached to a valid DicomID, which must be generated manually. The routines include that a radiologist writes a referral, the radiology department registers the patient data in the RIS, manually attaches the data to the DicomID, fills out forms, and acknowledges the description in the RIS. For each examination, approximately 5-10 minutes are spent performing this procedure.

### A. Message and report formats

Images and associated examination reports containing various information about the patient are required for further investigation. At present, DICOM does not support such reports to be included. Although it is possible to include textual information using private tags, this has so far not been used since such a solution would be proprietary.

Commercial systems supporting DICOM Structured Reporting (DICOM-SR) [6], [7] are not yet deployed. Another solution within DICOM is to export any electronic text document as a DICOM image file. This may not be a good solution, as

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**III. Systems and Tools**

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**Figure 1.** Sketch of cardiology work flow at the project start. Note that PACS and RIS are very recently introduced (independent from the project), and data transport on CD, and manual routines for retrieving other information were employed just at project start.
the DICOM files would have many empty fields leading to cumbersome PACS administration. Therefore, scanned documents should be stored in a different system than PACS.

A list of different electronic patient record (EPR) systems used in Norway can be found in [8]. The documents and messages created by proprietary systems are difficult to incorporate in applications delivered by other vendors. Various organizations are working to find good solutions to address this issue [9], [10], [11], [12].

B. Data Transfer

Medical image data can have a resolution up to 16 bits per pixel, thus producing high-volume data. Within radiology the only acceptable compression standard in Norway has been a lossless scheme. This means typical file size reduction can be at a factor between 2 and 3.

A typical transesophageal echo US examination can produce several hundreds of mega bytes. A frame rate of 100–150 is common. Taking into account image resolution, bits per pixel, full color (RGB), and frame rate, it becomes evident that images need to be compressed prior to transferring on a bandwidth limited network.

Besides the medical images, administrative data and notifications must be transferred. These data contain information on the patient and descriptions of the medical case including diagnostic information. This type of information is confidential and sensitive, and security policies apply for the transfer between hospitals. According to Norwegian regulations this implies that sensitive medical data cannot be sent by email, and must be transferred encrypted.

The closed networks of the hospitals are interconnected by the national health care network [13] and operated by the respective IT-departments of the hospitals. Strict policies, controlled by the Norwegian Data Inspectorate and bodies of the European Union, must be applied when exchanging data between hospitals.

The hospitals in Norway are using the AMTrix [14] message broker system for both inter and intra hospital communication. Policies and rules defined by the AMTrix message broker are approved by the Norwegian health authorities.

IV. IMPLEMENTATION

This section describes the implementation of the PACSflow-application, which includes the implementation of a graphical user-interface for sending DICOM-images, the web application, notification of medical personnel, and the interface to the PACS.

A. Software Platform Choices

The hospitals in Norway prefer the Microsoft Windows operating system [15], and it is therefore essential that the PACSflow-application runs on a Windows platform. However, since Linux [16] is used to an increasing extent, we implemented the application to be system-independent as far as possible.

The Norwegian hospitals are developing portal solutions for providing information to their medical staff. Therefore, the PACSflow-application was implemented as a web based application. This implies that most parts of the user interface are handled in a web browser, while a web server handles the requests and interfaces the PACS, EPR, and the other infrastructure. The web application can later be integrated in a portal solution.

Web applications also have other advantages for maintenance and installation at other hospitals with different infrastructures. The configurations and interfaces to the PACS can be done at one central server, instead of on many clients. Since the communication between server and client (web browser) is within the secure zone of the hospital, the security issues are solvable.

We decided to base the implementation of PACSflow on the PHP: Hypertext Preprocessor (PHP) scripting language [17]. Note that the PHP is a recursive acronym. The PHP runtime environment can easily be installed on both Windows and Linux platforms. PHP applications can be run on both Apache and MS IIS web servers.

B. Implementation of the web application

The PHP scripts of the web application generate Hyper-text Markup Language (HTML) code that is viewed in the browser. Additional functionalities, which are required by the application to behave more dynamically, are implemented in JavaScript.

The application contains three modules; one module for sending image series and messages, one module for viewing received messages, and one module for the administration of user data.

Through the administration module, a database of users and locations are maintained. Information about sender and receiver is retrieved from these databases which are stored in files located on the web server.

The module for sending images mainly consists of handling a web-form. Patient ID and the ID of the image series are obtained from the PACS. The information of the user and user’s location are obtained from the user database. Additional documents can be uploaded to the web server and can be attached to the message, e.g., a report exported from the EchoPAC or data exported from the RIS. After the form is submitted, a C-MOVE request is issued to the PACS. Figure 2 shows workflow in the PACSflow-application. When the transfer is completed a file containing the message is generated and stored in the AMTrix output directory.

In the message viewing module, the user gets a list of messages generated by parsing all message files in the AMTrix input directory at the web server. From this list the user can display the individual messages.

C. PACS Interface

The medical images are stored in the PACS, and the transfer of images is implemented as a transfer of data between two PACSs. The Sectra PACS [3] supports transfer and decoding of JPEG-encoded DICOM files according to their conformance statement.
The images generated by the GE Vingmed US scanners are exported to the PACS using EchoPAC. Since the images are encoded in JPEG format, the PACS needs to support JPEG Baseline transfer syntax.

From the web application the user is able to search for records in the PACS, and to trigger transfer of images between two PACSs. To obtain this functionality the movescu and findscu programs enclosed in the DICOM Toolkit (DCMTK) [18] are executed from the PHP code running on the web server. We use FIND SCU and MOVE SCU to find and move examinations, respectively.

### D. Notification and Messaging Functionality

Medical personnel are notified by the PACSflow upon the arrival of a new medical case, i.e., the ultrasound images have been transferred. The doctors at the receiving hospital will also receive the description of the medical case and the attached diagnostic data. The security policy in Norway does not allow the use of email for transporting these messages. Therefore, we use other message handlers supported in the hospital infrastructure.

After the transfer of the image series has succeeded the web application stores a message in a dedicated folder on the web server. This folder is checked regularly by the AMTrix whether a new file has arrived. The AMTrix fetches this message using the file transfer protocol (FTP). The AMTrix then forwards this message according to header information to the installation that serves the recipient. The receiving AMTrix installation then uploads the message to the receiving web-server, again using FTP, and sends an email notification locally to the email addresses specified in the header.

For the sake of simplicity we represent the message as plain text, since Extensible Markup Language (XML) formats for this purpose have not yet been standardized.

Each message contains a header formatted in ASCII text, the message, and optionally an attachment. The “-” character is used as a separator between the different fields, which are interpreted by the AMTrix. Message header is defined as

```
SENDER"RECEIVER"RECV_EMAIL"ERECV_EMAIL"
TIMESTAMP"ID"TITLE"MESSAGE"["ATTACHMENT]
```

and is explained in Table I.

Based on the contents of the message, a notification is assembled by the receiving AMTrix. Since this notification is sent through e-mail it will not contain sensitive patient information. The notification contains the timestamp, sender department, message title, and message ID. Using the message ID it is easy to retrieve the correct message in the web application.

### E. Security

Transfer security is handled by the PACS for the image transfer and by the AMTrix for message transfer. The image communication between two PACS and the message communication between two AMTrix installations are handled by respective VPN tunnels.

Authentication in the web-application is by user name and password. This is handled in the PHP script. Furthermore, security policies can easily be added, since standard software and standard protocols are employed.

### V. PACSflow – A Proof of Concept

The PACSflow software consists of different parts that are explained in the following. The infrastructure of the hospital includes the PACS, message broker middleware, and telecommunication channels.

- The web application provides a user interface to the medical personnel, using a standard web browser. The doctor at the sending hospital enters the patient and study, including medical information on the case.
- The web application generates messages for the medical personnel, containing the ID for the study, and medical information on the case.
- The doctors at the receiving hospital use a browser to access the data. The application is controlled by the web application. The image viewing functionality is provided by the PACS software; alternatively other viewing programs can be used.

The web application implements the user interface and the control of the commands to the PACS, e.g., initiation of medical data transfer and messaging. The web application also contains functionality for lookup-tables, in order to hide unnecessary technical details from the medical personnel. These lookup-tables implement user data, departments, location of data, AE titles, ports, etc.

#### A. Workflow in PACSflow

In Figure 3 we show the overall data flow and control flow for the PACSflow-application. We assume that the diagnostic images from the imaging systems can be exported to the PACS. Images and patient records are available in the PACS and the EPR systems, respectively. When a doctor uses the PACSflow an electronic form is filled out including the diagnostic data. After the doctor at the receiving hospital is notified, he can access the images and perform a second opinion, which is sent to the requesting hospital.

When requesting a second opinion, an electronic form is completed and the information is sent to the PACSflow web application. The electronic form contains the following information, which partially are collected from the HIS/EPR:

- study ID of the DICOM images
Fig. 2. Workflow used in the implementation of PACSflow.

- sender (including phone numbers, department, etc.)
- address of receiver or receiving department
- details about the case and task to be performed by the physician

In the following some of the dialogues of the PACSflow are shown.

The “Send examination” page is shown in Figure 5. The doctor can retrieve an examination from the PACS belonging to a patient by providing either his personal number or name. Recipient coordinates can be chosen from a list of candidates. Sender information is automatically inserted from the user database. Patient reports generated from imaging software and databases can be included as attachment. Clinical problems and questions can be entered into the form.

After the data are transferred to the receiving hospital, the doctor there will receive the following data:

- a notification about a new case arriving,
- the DICOM object(s) transferred to the PACS at the receiving hospital,
- a message containing ID of the DICOM objects, together with patient information, and information about the case.

Once the second opinion is performed a message containing the report of the examination is sent to the hospital requesting the second opinion. This report can be included in the receiving hospital’s EPR.

Figure 6 shows the department database containing all necessary parameters to retrieve and send images, reports, and messages.

VI. DISCUSSION

We have developed a web based application called the PACSflow. The application requires that the images are in DICOM format and stored in the PACS or in a DICOM storage system. The application is generic in terms of DICOM-compatibility and interoperability on any operating systems.

The cardiac US scanner must be capable of converting digitally encoded heart images and image sequences into DICOM-format. Otherwise, a software application is required to convert data to DICOM-format. Since the cardiac US scanner at the Rikshospitalet was not directly connected to the PACS, we used the EchoPAC visualization software to convert and push the US images stored in a US database to the PACS. Automatic ways of importing and exporting data are not available from the manufacturer at the moment. This part has to be done manually by the user, unless the imaging scanners are directly connected to the PACS.

The PACSflow entries are filled out by a user, preferably by a doctor. Query-retrieve selections are used to identify the patient and examinations to be transferred to another hospital from the PACS. Cardiac diagnostic reports are generated by the EchoPAC software. At the Rikshospitalet most of the other diagnostic reports are created at the radiology department using the RIS. These reports are stored in separate folders.
which can be accessed by the PACSflow-application. The time required to fill out and dispatch the form with attachments was approximately 10 minutes. Cardiac US image sequences were compressed using lossy JPEG compression. This reduced the file size by a factor of 3. Initial tests indicate that an examination containing image sequences of 184 MB data required 8.3 minutes to transfer from Arendal to Oslo using PACS communication on an effective 3 Mbit/s channel.

The present national health care network in Norway lacks several services and protocols. To overcome these constraints, workarounds were employed. The Sectra PACS lacks functionalities such as the possibility to view real time cine-loops of heart US images and to calculate parameters like strain rates and velocity from image data.

The integration of third party middleware with the PACSflow-application has been complex and time consuming. It may be wise to choose solutions that are provided by at least more than one vendor.

Advanced diagnostic imaging devices produce large volume data. A typical example is ultrasonic examination of the heart. On-line transfer of high quality ultrasound images from the local hospitals to specialty hospitals will provide quicker and better diagnosis and will be a great help for very sick patients. Today on-line communication between hospitals is only possible using video-techniques. We consider high quality (diagnostics) of the recordings to have higher priority than online recordings at lower quality.

VII. Conclusion

A generic web application, PACSflow, was developed to create a message containing patient medical data that is sent together with any DICOM compatible images (US images, MR, CT, etc.) to the recipient hospital. The message, which is used to inform the recipient on incoming cases, contains patient name and ID, study UID, examination, problem, request, sender contact information, and recipient contact information. The web application used query-retrieve to choose correct examination and relevant images from PACS. The application moves the images to another PACS using a C-MOVE operation. The message part was encapsulated in an ASCII format and was sent using AMTrix. The patient sensitive information as well as US images were transferred in a secure, encrypted VPN. The web application triggered transmission of the message once it received an acknowledgment from PACS that C-MOVE was successful.

The prototype system has been tested technically. The department of cardiology at Rikshospitalet University Hospital and the department of internal medicine at the Sørlandet sykehus in Arendal have taken the system into clinical testing. A preliminary observation reveals that the average time required to prepare the reports, images, and messages to another hospital was approximately 10 minutes, thus effectively reducing the time spent by a factor of 3.

We expect the use of PACSflow will effectively reduce the cost in terms of man-hours and transfer time and increasingly provide better quality of services as the users become more
familiar with the system.

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