A Bidirectional ACR-NEMA Interface Between the VA's DHCP Integrated Imaging System and the Siemens-Loral PACS

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ABSTRACT

There is a wide range of requirements for digital hospital imaging systems. Radiology needs very high resolution black and white images. Other diagnostic disciplines need high resolution color imaging capabilities. Images need to be displayed in many locations throughout the hospital. No current system can completely cover all of these needs. Different imaging systems within a hospital need to cooperate in order to show the whole picture.

At the Baltimore VA Medical Center, the DHCP Integrated Imaging System and a commercial Picture Archiving and Communication System (PACS) work in concert to provide a wide-range of departmental and hospital-wide imaging capabilities. An interface between the DHCP and the Siemens-Loral PACS systems enables patient text and image data to be passed between the two systems. The interface uses ACR-NEMA 2.0 Standard messages extended with shadow groups based on draft ACR-NEMA 3.0 prototypes. A Novell file server, accessible to both systems via Ethernet, is used to communicate all the messages. Patient identification information, orders, ADT, procedure status, changes, patient reports, and images are sent between the two systems across the interface. The systems together provide an extensive set of imaging capabilities for both the specialist and the general practitioner.

INTRODUCTION

The Department of Veterans Affairs has recently opened a 324-bed replacement medical center in Baltimore, Maryland. The new hospital is expected to handle 6800 admissions and 220,000 outpatient visits this year.

The facility will use several new imaging technologies for patient care. The VA's internally developed DHCP Integrated Imaging System will support high resolution black & white radiology images, true color imaging for Pathology, Endoscopy, and other diagnostic procedures, ECG tracings, and document imaging capabilities. The Department of Radiology is installing a Siemens-Loral Picture Archiving and Communications System (PACS) and in several months will begin operating in a film-less all digital mode. An interface between these two systems permits high-speed transfer of both text and image data.

DHCP Imaging System

DHCP is the standard Department of Veterans Affairs Decentralized Hospital Computer Program that is installed nationwide at 168 Veterans Administration medical centers. The DHCP Integrated Imaging System is an integral extension to the standard DHCP hospital information system [1, 2]. It is designed to provide a wide-range of image capture, retrieval, and display capabilities (see Table 1). The DHCP

Imaging System records clinically significant diagnostic images selected by medical specialists. Images are incorporated into the patient medical record along with associated report text. The DHCP Imaging System is well suited for the general practitioner and for communication across disciplines (e.g., bronchoscopists viewing pathology findings).

Approximately 40,000 imaging studies per year are expected to be performed at the new facility.

DHCP Imaging Workstation Capabilities

Image Type	Spatial Resolution	Bits per pixel
24-bit color	1024 x 768	8-bit RGB
16-bit color	756 x 486	5-bit RGB
12-bit b/w	1448 x 1272	12-bit grey
8-bit b/w	2048 x 1800	8-bit grey
8-bit b/w	756 x 486	8-bit grey

Table 1

The DHCP Imaging System consists of a network of workstations, magnetic file servers, scanners, printing devices, and long term optical disk image storage integrated with a hospital information system. The DHCP Imaging System is based on off-the-shelf hardware and software components. The workstation consists of an IBM-compatible 386/486 PC, a Truevision Vista true color image acquisition and display board, an Ethernet card, a VGA monitor, and a RGB monitor. The imaging workstation runs MS-DOS 5.0 and MUMPS. Image files are stored on Novell file servers and are accessed via NetWare over Ethernet. DHCP HIS software with imaging enhancements runs on the PC, and uses the Micronetics/Digital DDP protocol over Ethernet to reference patient data stored on the main hospital VAX computers.

The DHCP imaging system capabilities have recently been tested in a two-year pilot project [3, 4]. Baltimore VAMC is the second test site for the DHCP Imaging System.

Siemens-Loral PACS

The Siemens-Loral PACS supports image acquisition devices that transmit digital images to a 40 GB magnetic working storage unit. A VAX 4000 host processor with a Sybase relational database controls all image acquisition, storage, and retrieval. Long-term storage is provided by a 1.02 terabyte Kodak optical jukebox. PACS workstations are Motorola 68040 Apple MacIntoshes with black and white image display capabilities. High speed PACS image transmission is provided via a 100 mb/s FDDI (fiber optic network), in parallel with a 10 mb/s Ethernet for control communications. The PACS workstations are designed to provide rapid access to very high resolution black and white images [5].

Similar Siemens-Loral PACS systems are being installed over the next three years at Department of Defense medical centers where they will be interfaced to the CHCS HIS (a commercial derivative of the DHCP hospital information system) [6].

Baltimore VAMC Configuration

The Baltimore VAMC has installed twenty-two PACS workstations and over fifty DHCP Imaging Workstations. DHCP images are stored on file servers with 24 GB of magnetic disk storage. Long-term storage is provided by a 327 GB optical jukebox. At the Baltimore VAMC the Siemens-Loral PACS workstation is a facility primarily for radiologists, while the DHCP Imaging System provides the radiology images to clinicians. The DHCP Imaging System acquires radiology images from the PACS and provides color imaging capabilities for other diagnostic disciplines. All of these images will be displayed together throughout the hospital.

Radiology currently performs about 200 exams per day, generating about 3500 images per day (see Table 2).

Radiology Image Workload

Type	Image Size	daily	images /exam	images /day
MRI	256 x 256	16	80	1280
CT	512 x 512	21	72	1512
CR	2048 x 2560	141	2.5	353

Table 2

INTERFACE REQUIREMENTS

The Siemens-Loral PACS requires several different kinds of HIS text data in order to operate properly. Current patient identification and order entry information are needed to process the order. Accurate tracking of patient demographic changes are necessary to prevent patient mismatch and duplicate patient registration. The PACS needs radiology reports so that they can be displayed in conjunction with the images. Changes in reports (that is, amendments) and changes in exam order information are also necessary. Patient tracking information is needed for display of patient information by ward. Clinical scheduling information is also needed. All of this data is supplied to the PACS by DHCP.

The PACS must supply DHCP with status information and radiology images. Examination completion notification must be sent to DHCP in order to update the order status. The PACS must also send to DHCP a list of the images associated with each completed order.

DHCP must be able to retrieve any PACS image for display on its imaging workstations. The PACS images are transferred across the interface and stored in the DHCP image file servers. They are then retrieved from the DHCP file servers and displayed on the imaging workstations. In a similar fashion, DHCP images must be able to be transferred, stored, retrieved, and displayed on the PACS.

Image rendering may be required when the images are transferred between the two systems. DHCP color images need to be converted into black and white for the PACS. Some PACS images may need to be reduced in size when sent to DHCP.

INTERFACE DESIGN

The interface between DHCP and the PACS uses ACR-NEMA 2.0 Standard messages extended with shadow groups based on draft ACR-NEMA 3.0 prototypes [7]. A Novell file server, accessible to both systems via Ethernet, is used to communicate all the messages. Each ACR-NEMA message is stored in a separate file on the server. The files are processed in a sequential first-in-first-out order. After each message is processed, the ACR-NEMA response message is stored on the file server in a similar manner.

Patient identification information, orders, ADT, procedure status, changes, patient reports, and images are sent between the two systems across the interface. The interface follows the "ancillary service-to-hospital information system" model successful for over a decade [8, 9].

The following message types are sent across the interface:

DHCP to PACS
- Order Entry
- Get PACS Image Request
- Patient Demographic Change
- Report Transfer
- Examination Change
- ADT (Admission Discharge Transfer)
- Examination Pull
- Send DHCP Image

PACS to DHCP
- Examination Completion
- Get PACS Image Reply
- Clinical Subfolder Update

When DHCP processes a request for a radiology examination, an Order Entry message is sent to the PACS. This message contains all of the essential patient demographic and radiology order information, and triggers the examination processing on the PACS. When the images have been acquired by the PACS, an Examination Completion message is sent back to DHCP. This message contains status information and a list of all the image identifiers that are part of the examination. The status information and list of image identifiers are stored in DHCP with the radiology exam. The DHCP Imaging System uses the image identifiers to retrieve images from the PACS so that they can be moved to DHCP and viewed at the DHCP Imaging workstations. The Get PACS Image Request and Get PACS Image Reply messages are used to retrieve images from the PACS.

The PACS also has a feature which allows radiologists to group together each patient's clinically significant images. The list of these image identifiers is sent to DHCP in the Clinical Subfolder Update message, and is used to mark the "clinically significant" radiology images in DHCP.

The radiology report is entered and edited on the DHCP system. Released and verified reports are sent to the PACS via the Report Transfer message. Patient demographic changes and admission information is sent from DHCP to the

PACS in their respective messages. Outpatient scheduling information is sent to the PACS in the Examination Pull message.

Images collected on the DHCP system can be sent to the PACS with the Send DHCP Image message.

The anticipated daily volumes of transactions for the Baltimore VAMC consists of about 2,300 text messages per day, with an average size of one kilobyte each, and about image 3,600 messages, of much greater size (see Table 3).

Number of ACR-NEMA Messages per Day

Message Type	Number per Day
ADT	400
Clinical Subfolder Update	200
Examination Change	10
Exam Complete	200
Exam Pull Request	400
Exam Pull Reply	400
Get Image Request	200
Get Image Reply	200
Get Image Data	3,472
Order Entry	200
Patient Demographic Change	50
Report Transfer	400
Send Image Request	20
Send Image Reply	20
Send Image Data	100
Text Messages Total	2,700
Image (Data) Messages Total	3,572

Table 3

Internal HL7 - ACR-NEMA Protocol Conversion

The VA requires the Siemens PACS to communicate using ACR-NEMA, the standard for the radiology hardware imaging industry. The DHCP Radiology Package supports the HL7 protocol for interfacing to external systems, the standard for health care software. The DHCP-PACS interface bridges the two environments, and converts one protocol to the other when using HL7 for communicating with the interfaces to DHCP packages, and ACR-NEMA for communicating with the PACS.

PACS IMAGE SELECTION FOR TRANSFER

In order for a radiology PACS image to be displayed on a DHCP Imaging workstation, the image must be retrieved from the PACS and stored on the DHCP Imaging File Server. Approximately 500 radiology images are produced per day at the Baltimore VAMC. There are many considerations in determining which of these PACS images need to be transferred to DHCP, and how long should they be kept on the DHCP Imaging System.

General design considerations include:

1) Images should be displayed as quickly as possible. This will require the storage of some radiology images on the DHCP system for some period of time.

2) Some staff members in some clinical services have access to PACS workstations and will not use the DHCP Imaging workstations for viewing radiology images. Others rely heavily on the DHCP Imaging workstations.

3) Some images are viewed more frequently than others.

4) Clinicians frequently want to display certain sets of images in making decisions, for example, the previous two or three chest xrays with the current chest xray.

Several strategies are possible, for example:

1) DHCP could retrieve all images immediately, thereby making them available to users rapidly upon request. Storage and network requirements will be high. Images would be held on DHCP for a predefined period, such as during a patient stay, or based on access history.

2) A number of radiology images do not need to be viewed by the clinician; these include normal studies, in many cases, or those images in a CT, MRI, or ultrasound study which do not present the abnormality seen. These images may not need to be displayed on DHCP.

The second strategy is to request only select images immediately. Other images would be requested across the interface when a user needs to access them. Images would be held on DHCP as above. This reduces storage and network requirements, however users will have to wait longer to view some images. Selection strategies can be developed and modified based on experience.

3) Another strategy is not to move any PACS images across the interface until they are requested. Images would be held on DHCP as above, once they have been moved. Storage requirements are low; interface traffic and network usage may be high at peak image viewing times, such as before rounds, and user wait times will be high.

The Examination Completion message contains all the information needed to retrieve the images. The Clinical Subfolder Update message identifies those images that a radiologist considers "clinically significant" when reading the study. The DHCP system knows the ordering service, the ordering physician, whether or not he/she would be using an imaging workstation, what radiology procedure was ordered, and how many times the image has been displayed.

A PACS image can always be requested and transferred to DHCP on demand. Based on system experience, PACS images for transfer to DHCP will be selected and retention times set in order to provide the best service to the VA staff.

RESULTS

The interface is currently being implemented. The ACR-NEMA message specification has been completed and prototype messages have been exchanged. The DHCP Imaging System can read and generate ACR-NEMA messages. It can also convert and display images in ACR-NEMA format from the PACS.

The system is scheduled to be ready for testing during the winter, be completely installed in the spring, and be operational in the summer of 1993.

DISCUSSION

The DHCP software is written in ANSI Standard MUMPS which generally deals with character string data. The ACR-NEMA messages contain binary fields which are handled by single byte read/write operations and byte arithmetic. The processing of image data is performed by C routines using block i/o. The ACR-NEMA dictionary is mapped in straightforward fashion to a MUMPS global using the group, element, and owner as the first, second, and third subscripts.

The generation and parsing of ACR-NEMA messages requires access to the file positioning functions of the host file system. It is necessary to obtain the value of the current file position and to set the file position for subsequent read or write operations. Different MUMPS implementations vary in their ability to provide this capability. The MUMPS Development Committee is developing a binding to the ANSI C library *ftell()* and *fseek()* functions to standardize this capability in the future.

The interface is designed to be "loosely-coupled" and permits relatively complete separation between the PACS and the DHCP Imaging System. This approach allows each side of the interface to be completely tested in the absence of the other using a known input stream. It also permits each system to be operational (for a short time) without the other, and allows one system to "fall behind" the other and then "catch up". In addition, it provides an audit trail of all transactions. A "tightly-coupled" interface using a remote procedure call to transmit messages directly between systems might give quicker performance, but would be harder to implement and lacks these features.

CONCLUSION

The interfacing of the Siemens-Loral PACS and the DHCP Imaging System provides the HIS text data transmission necessary for the operation of the PACS and high speed image transfer. It allows the DHCP Imaging System to provide very high resolution black and white radiology images for radiology needs, as well as high resolution color imaging capabilities for other diagnostic disciplines.

It underscores the usefulness of a general purpose HIS imaging system. The PACS workstation provides very high performance for radiology images, but at a very high cost. The DHCP Imaging Workstation provides high resolution black and white and color capabilities for a variety of medical images in many locations throughout the hospital at a much

lower cost.

This bidirectional image and text interface is the first using a standard ACR-NEMA interface between a hospital information system and a PACS. It should provide valuable experience for others who may need this capability in the future.

ACKNOWLEDGEMENTS

The authors wish to recognize Frank T. Bradshaw, Information and Control Technology, Inc., Beachwood, Ohio, and Fred Prior, Penn State College of Medicine, Hershey, Pennsylvania (formerly with Siemens Gammasonics, Inc.), for their work on the design and development of the PACS side of the interface.

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