IMPLEMENTING THE DIGITAL IMAGE AND COMMUNICATIONS FOR MEDICINE (DICOM) PROTOCOL IN M

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ABSTRACT

DICOM is the Digital Imaging and COmmunications in Medicine standard developed by the American College of Radiologists and the National Electrical Manufacturers Association. The DICOM standard brings open systems technology to the previously proprietary medical imaging market. Commercial pressures require DICOM to be universally supported by all radiology imaging equipment vendors. It is also being adopted as a standard by other non-radiology medical imaging bodies.

The U.S. Department of Veterans Affairs has begun an ambitious project to develop a set of DICOM capabilities in M as part of the Decentralized Hospital Computer Program (DHCP) Imaging System. This work will be based upon the considerable M experience accumulated with ACR-NEMA Version 2.0, the predecessor to DICOM. The interface will allow DHCP to interface directly to commercial medical image equipment, for example, to download patient study information and to obtain digitized images.

The effort is important to the M medical information systems community because virtually all future medical imaging applications will require the use of DICOM.

INTRODUCTION

In 1994 the American College of Radiologists and the National Electronic Manufacturers Association (ACR-NEMA) standards organization approved the third version of its protocol for Digital Image and COmmunications in Medicine (DICOM).[1] The DICOM standard describes all communication aspects of digital image production, storage, retrieval, transmission, and display in a medical environment, and how these functions are related to various information systems.

The DICOM standard is bringing open systems technology to the previously proprietary medical imaging market. While earlier versions of the ACR-NEMA standard were originally developed for radiology imaging, this version of the DICOM standard is being adapted and extended to other medical imaging modalities. Currently the American College of Cardiology, the American Society of Gastrointestinal Enterologists, and the College of American Pathologists are working to include cardiology, endoscopy, and pathology images in DICOM. It is anticipated that commercial and political pressures will require the DICOM standard to be universally supported by all medical imaging modalities.

Public domain versions of DICOM have been produced in C and C++, and most commercial implementations are currently in those languages.[2,3] Since the M community is so heavily involved in the medical information systems market, it is also highly desirable for DICOM to be supported in M. The U.S. Department of Veterans Affairs (VA) has begun a project to develop a set of DICOM capabilities in M as part of the Decentralized Hospital Computer Program (DHCP) Imaging System.

BRIEF DESCRIPTION OF DICOM

DICOM is the first of a new generation of medical information standards that uses an Entity-Relationship (E-R) model, is object oriented, is based on International Standards Organization (ISO) information processing and communications standards, and has user conformance statements. By comparison, the previous version of the standard (ACR-NEMA Version 2.0) had a limited data dictionary and message acknowledgement protocol, but lacked the E-R model, the object orientation, and ISO information processing and communications standard foundation. The additional standard specifications are required to make medical imaging an open systems technology with good interoperablility.

The E-R model is a graphical technique for representing information interrelationships that is very popular within the database community.[4] An entity is used in an E-R model to represent a real-world object. A relationship defines how entities are related. There may be one-to-zero, one-to-one, one-to-many, many-to-one, and many-to-many relationships between entities. "A patient makes visits to institutions" is an example of a one-to-many relationship, while "patients see doctors" is an example of a many-to-many relationship.

The Entity-Relationship model for DICOM defines the following entities as *Information Object Classes*:

- Patient
- Visit (admission)
- Study
- Result (interpretation)
- Image

Each information object class is defined to have similar properties (*Attributes*), common behaviors (*Operations*), common relationships to other objects, and common semantics. (For an example of the patient information object attributes, see Figure 1.)

Different types of images (computer tomography, magnetic resonance, endoscopy, pathology, etc.) are treated as different subclasses of the image information object class. Each image subclass inherits all the image class characteristics and have additional ones of their own.

The set of information object definitions are the nouns of DICOM. The verbs of DICOM are the *Service Group Elements* that define the set of operations that can be performed upon the information objects. For example, service group elements perform the following operations:

- Create an object
- Get the value of an attribute of an object
- Set the value of an attribute of an object
- Communicate event information about an object
- Copy an object
- Print an image

The information object definitions together with the service group elements form the *Service Object Pair Classes*, the sentences of DICOM.

DICOM uses a service provider/user paradigm in which the service provider "owns" the information object and notifies the service user of changes to it. All communications between the service provider and the service user are via the service object pair classes.

DICOM is layered on ISO standards. The DICOM standard specifies how the provider and user communicate socket-to-socket over an ISO stack and a TCP/IP stack.

The DICOM standard completely specifies the information objects, the legal operations on them, and the semantic relationships of each operation. A DICOM implementor must write a user conformance statement that states in detail exactly how each part of the implementation supports DICOM.

The keys to DICOM interoperability are its layering on ISO standards, its user conformance statement, and its information objects and service classes that are well specified and have well defined semantics. Health Level Seven (HL7), the other major medical information industry communication standard, lacks this foundation. As a result, HL7 classically has poor interoperability and wide differences exist between the different vendors' implementations.

Tag	Name
(0008,1120)	Referenced Patient Sequence (with Unique Identifier for the patient)
(0010,0010)	Patient Name (in LAST, FIRST, MI uppercase format)
(0010,0020)	Patient ID (VA uses the patient's social security number)
(0010,0021)	Issuer of Patient ID
(0010,0030)	Patient Birth Date (yyyy.mm.dd format -- VA uses imprecise birthdates)
(0010,0032)	Patient Birth Time
(0010,0040)	Patient Sex
(0010,0042)	Patient Social Security Number (999-99-9999 format)
(0010,0050)	Patient's Insurance Plan Code Sequence
(0010,1000)	Other Patient IDs (VA uses quick PID, "K6789", not unique)
(0010,1001)	Other Patient Names
(0010,1005)	Patient's Maiden Name
(0010,1010)	Patient's Age
(0010,1020)	Patient's Size
(0010,1030)	Patient's Weight
(0010,1040)	Patient's Address
(0010,1060)	Patient's Mother's Maiden Name
(0010,1080)	Military Rank
(0010,1081)	Branch of Service
(0010,1090)	Medical Record Locator
(0010,2000)	Medical Alerts
(0010,2110)	Contrast Allergies
(0010,2150)	Country of Residence
(0010,2152)	Region of Residence
(0010,2154)	Patients's Telephone Number(s)
(0010,2160)	Ethnic Group (race of patient)
(0010,2180)	Occupation
(0010,21A0)	Smoking Status
(0010,21B0)	Additional Patient History
(0010,21C0)	Pregnancy Status
(0010,21D0)	Last Menstrual Date
(0010,21F0)	Patient's Religious Preference
(0010,4000)	Patient Comments

Figure 1 -- DICOM Patient Attributes

VA'S PLAN FOR SUPPORTING DICOM

Previous Experience with ACR-NEMA

The VA has accumulated considerable M experience with ACR-NEMA Version 2.0, the predecessor to DICOM. The VA developed a bidirectional text and image interface to a radiology Picture Archive and Communication System (PACS) at the Baltimore VA Medical Center that has been operational since October 1993.[5] All admission, discharge, and transfer transactions, patient demographic changes, radiology orders, and reports have been sent from the DHCP Hospital Information System/Radiology Information System (HIS/RIS) to the PACS, and all images have been sent back (see Figure 2 and Figure 3).

The text-only portion of the interface was ported to a second PACS vendor at the Houston VA Medical Center. It was subsequently modified to work with the Department of Defense Composite Health Care System (CHCS) HIS/RIS and was installed at three DoD sites (Madigan Army Medical Center, Wright Patterson Air Force Medical Center, and Brook Army Medical Center/Wilford Hall Air Force Medical Center).

DICOM Project Goals

DICOM is a very versatile standard that has several possible uses by the DHCP Imaging System:

1.) Image Capture Modality Interfacing -- allow DHCP to send patient study information to a commercial modality and acquire images from this image source.

2.) Image Display Interfacing -- allow DHCP to send image data to a commercial display system for viewing.

3.) Image Server -- allow DHCP to store and retrieve images from a commercial image server and allow DHCP to act as an image server.

4.) PACS Interfacing -- bi-directional communications between commercial PACS systems and DHCP.

5.) TeleMedicine -- allow a remote examination site to have images read at a central site; provide transfer of patient, study, and image data from the remote site to the central site, and transfer of result data back. The goal is to provide seamless integration of image and text data at both sites (peer-to-peer system communications).

The goal of DHCP is to be a fully compliant DICOM Service Class Provider or User of many of the DICOM Service Classes.

METHODS

Queue-Driven Network Architecture

The VA's earlier ACR-NEMA version of the HIS/RIS-PACS interface used a shared file server accessible to both systems for the network communications. The messages are stored on the file server in high, medium, and low priority first-in-first-out queues, and are later available for use as an audit trail. This approach has worked well.

For the DICOM version of the interface, the VA will use TCP/IP network sockets to communicate with the PACS. The shared file server will remain with the prioritized message queues and the transaction log. M TCP/IP processes will access the file server and transfer DICOM messages directly to and from PACS processes (see Figure 4).

HL7 - DICOM Gateway

The HL7 standard is the almost universally supported communications method for M-based medical information systems. The VA's DHCP/CHCS PACS interface will contain a HL7-DICOM Gateway to translate between the two protocols. The characteristics of each protocol need to be considered in the design of the gateway.

HL7 is traditionally envisioned as a uni-directional event-driven protocol, where all the information necessary to process an event is presented at one time. DICOM, on the other hand, is a session based protocol with bi-directional communications supported between a service class provider and a service class user. Event notification in DICOM is object oriented and is normalized (contains information about only one object). A service class provider can only pass information to a service class user about one object at a time. The service class user must ask the service class provider for

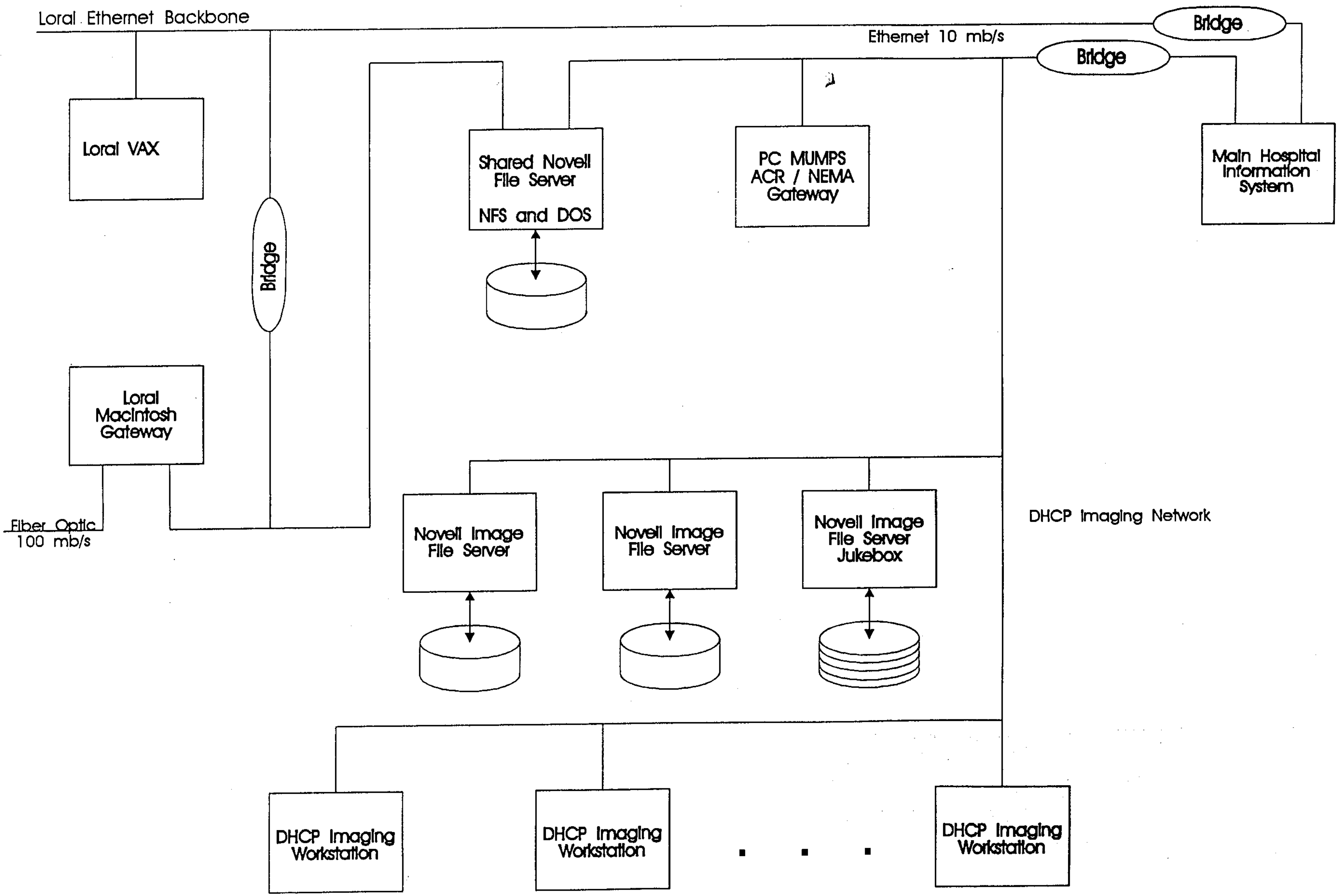

Figure 2 -- DHCP / PACS Interface

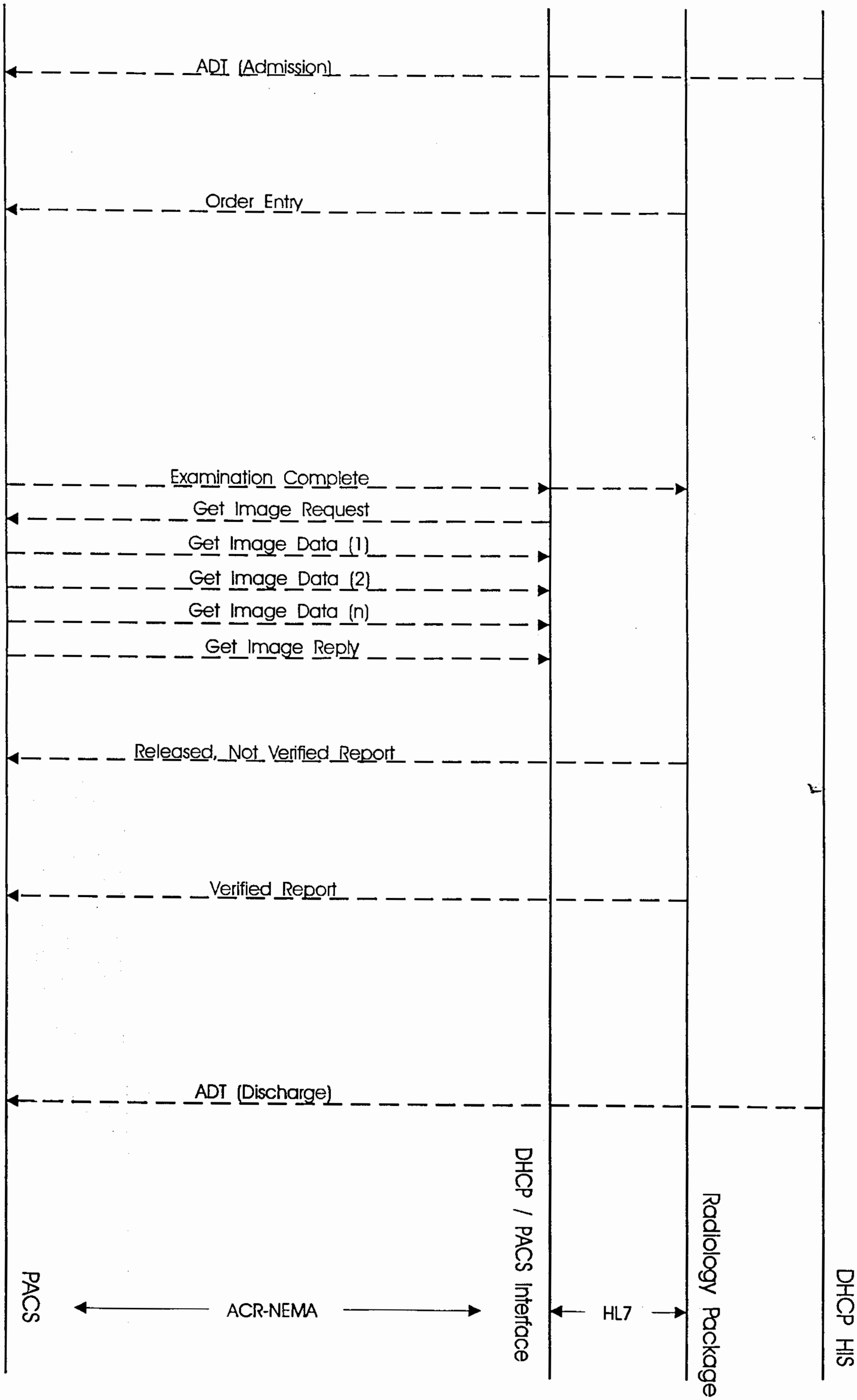

Figure 3 -- DHCP - PACS ACR-NEMA Message Flow

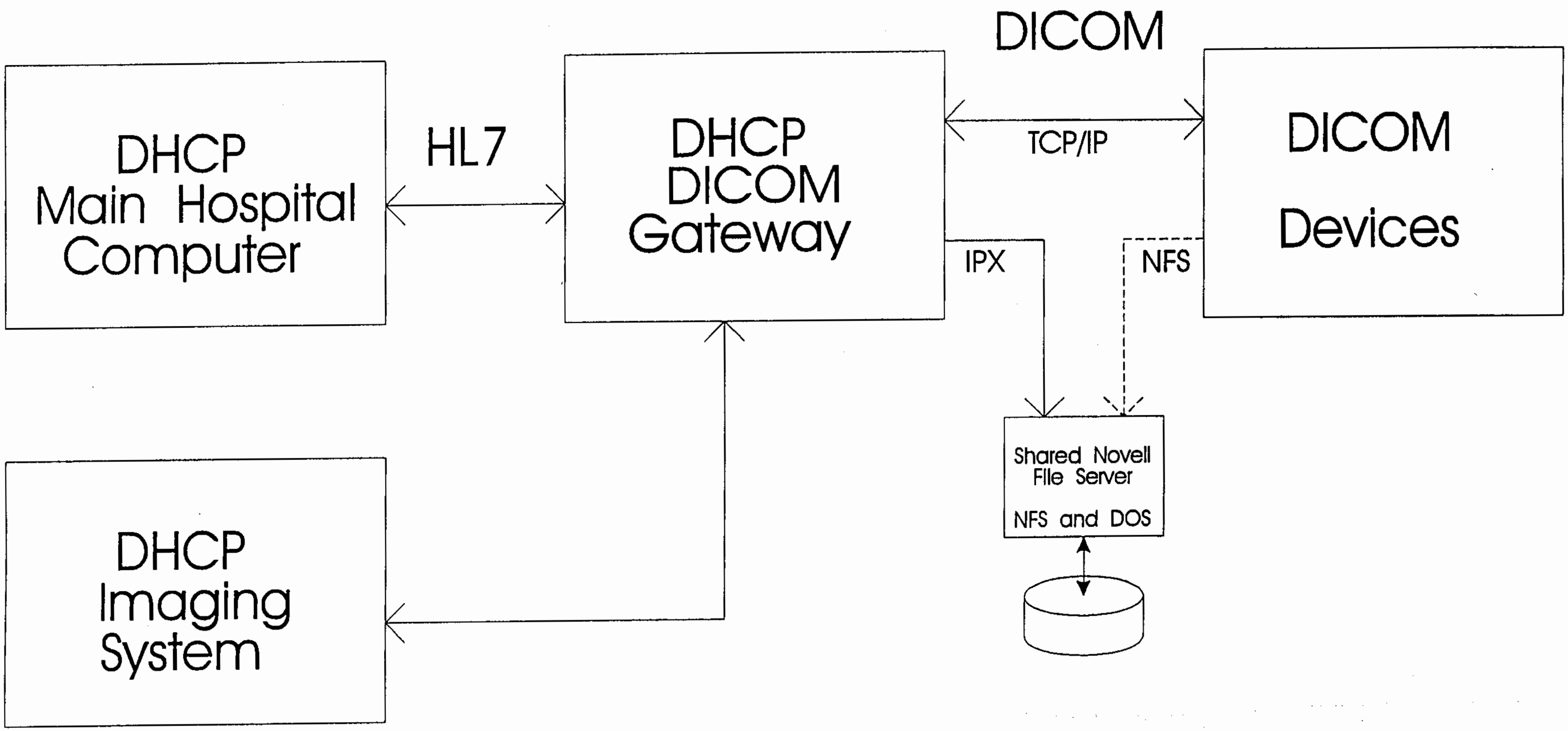

Figure 4 -- VA's HL7 - DICOM Gateway

information about other objects as needed. This is awkward to support with HL7 implementations that lack query capabilities. The VA plans to use the standard extension mechanisms of DICOM to pass all the information necessary to process an event in one message to avoid this query requirement. A one-to-one mapping between HL7 transactions and DICOM messages can be achieved in this fashion.

Implementing DICOM in M

DICOM data consists of nested sequences of binary tagged fields. It is relatively easy to handle the tags and data with binary arithmetic and byte I/O in M. The tags map to M subscripts that are used to index a DICOM dictionary and to store DICOM textual data in a global.

M TCP/IP will be used to support DICOM in the socket-to-socket mode.

DISCUSSION

Writing a DICOM interface in M is an ambitious goal. Just learning the DICOM standard can be a formidable task for the uninitiated. DICOM messages are encoded in binary, not in ASCII, and raw DICOM messages are not easily readable. DICOM requires socket-to-socket interprocess communications over TCP/IP.

Fortunately, the VA has a successful experience with ACR-NEMA Version 2.0 on which to build. In many respects, implementing DICOM will be very similar. The use of TCP/IP for M interprocess communications was first suggested by the author just over a decade ago, and is now readily available.[6]

CONCLUSION

This effort will be very significant for the M community. First, any medical imaging application will require the use of DICOM. Second, it is important to demonstrate interprocess communication between M and non-M applications. Third, since joint ACR-NEMA / Health Level Seven committee activities are underway to merge HL7 and DICOM, this work may become the foundation for supporting the next generation of standards, in the years ahead.

ENDNOTES

1. Digital Imaging Communication in Medicine (DICOM), NEMA Standards Publication PS3.1(1992) - PS3.9(1993), National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, DC 20037.

2. S. M. Moore, D. E. Beecher, and S. A. Hoffman, "DICOM Shareware: A Public Implementation of the DICOM Standard," *Medical Imaging 1994: PACS Design and Evaluation*, R. G. Jost (ed.) Proceedings SPIE, Vol. 2165, p. 772-781, The International Society for Optical Engineering, Bellingham Washington. 1994.

3. Public domain C++ code, University of California at Davis.

4. P. P. S. Chen, "The entity-relationship model - toward a unified view of data", *ACM Transactions on Database System 1*, 1 (March 1976).

5. P. M. Kuzmak and R. E. Dayhoff, "A Bidirectional ACR-NEMA Interface Between the VA's DHCP Integrated Imaging System and the Siemens-Loral PACS," *M Computing* 1:3 (June 1993 Proceedings) p. 62-68.

6. P. M. Kuzmak, "A Proposal for the MUMPS Standard Interface to Local Area Network Technology," R. E. Dayhoff (ed.), *MUG Quarterly* XIV:1 (June 1984 Proceedings), p. 128-132.