Network Software for Picture Archiving and Communications Systems

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ABSTRACT
Realization of the full potential of Picture Archiving and Communications Systems in Radiology requires a well designed, flexible software architecture. The architecture must be well designed to accommodate high volume and short response times required of the system. It must be flexible to allow the software to be layered upon a variety of existing technologies and easily migrated onto emerging technology. As part of a joint research effort between the University of Arizona and the Toshiba Corporation of Japan, we have designed a software architecture for a prototype network. This software was originally intended to support communications across an ACR-NEMA Standard Interface. However, it has been designed according to ISO/OSI and most of the layers are completely independent of the physical communications media. This implementation has demonstrated the benefits of adhering to a well accepted standard. We are planning to migrate the software onto Ethernet and are looking toward ISDN.

INTRODUCTION
Picture Archiving and Communications Systems (PACS) represent the future of Radiology. In such a system the entire department becomes integrated through a very high speed network [1]. This network will connect three distinct classes of equipment: Acquisition, Archiving and Display. The Acquisition equipment consists of a variety of imaging equipment including Computed Tomography (CT), Computed Radiography (CR), Magnetic Resonance Imaging (MRI) and others. The Acquisition equipment for PACS corresponds directly with the imaging equipment existing in conventional film based systems. However, in PACS those systems capable of producing digital information directly will not require the generation of film. The various types of imaging equipment generate images in a wide variety of formats and sizes. Generally the image data ranges from 8 to 12 bits per picture element (pixel) in depth. The image sizes range from 128x128 pixels for some Nuclear Medicine images to as much as 4096x4096 pixels for certain film digitizers.

The Archival equipment in PACS will provide the database which stores the images. This equipment acts as a sink to the Acquisition equipment and a source to the Display equipment. The Archival equipment corresponds to the current film library in which clerks manage a room full of folders containing patient films. Archival storage is an aspect of radiology for which PACS holds great promise of improving the efficiency of the department. However, it also presents many problems because of the vast amount of data to be stored and the length of time that data must be maintained.

The Display equipment for PACS has been evolving for several years and consists of high resolution image display workstations. There is a wide diversity of host computers and operating systems in use, ranging from PCs to very powerful graphics systems. Generally, they have the common feature of one or more image display monitors with hardware and/or software image processing capabilities. Current display systems are used to a limited extent for primary diagnostic purposes due to limitations in resolution, responsiveness and connectivity.

These three components of PACS require a network to provide the communications path. A possible configuration of a PACS network is shown in Figure 1. However, there are several aspects of PACS which make the effective implementation of this network very difficult. Some of the difficulties arise from the nature of the information and the users of that information. The data flowing around a PACS network consists primarily of sets of images. For chest work, which comprises 85% of the work in an average department, the images may be on the order of eight Megabytes of data and a set will often contain four or five images. For other types of work, such as a Computed Tomography (CT), the images only a quarter of a Megabyte but there are dozens of images in a set. Compounding the problem of very large amounts of data is the requirement for very quick response times. Radiologists typically have very many cases to read each day. To be effective the PACS must support the throughput provided by the current film based systems and if possible increase the efficiency of the radiologists. Because of the case load on
the radiologists, they expect nearly instantaneous response from an imaging workstation. Processing or image manipulation which take too long, e.g. greater than 2 seconds, will generally find little use unless they provide some overwhelming benefit.

Connecting the components of PACS with a network also presents a standardization problem. Radiology departments often have equipment from a variety of vendors and this will undoubtedly continue to be the case in an all digital department. A successful networking strategy must allow the interconnection of equipment from many vendors. The interconnection problem was addressed in 1985 by the release of a standard for digital communications. This standard, published by the National Electrical Manufacturers Association (NEMA 1985-300), was the work of a joint committee of NEMA and the American College of Radiology (ACR) and is referred to as the ACR-NEMA standard. The standard describes a 16-bit parallel communications interface, applications level commands and protocols and a standard data format [2]. The standard has six layers loosely following ISO/OSI but with the Network and Transport layers collapsed. The ACR-NEMA standard was not intended to be a network standard but rather a point-to-point interface definition.

Figure 1. Example of a Possible PACS Configuration

At the University of Arizona a joint research program with Toshiba Corporation of Japan has been underway since 1983. As part of the research members of the University's Radiology Research Laboratory and Computer Engineering Research Laboratory have been working with engineers from Toshiba's NASU works in Otawara Japan to develop prototype communications software based on the ACR-NEMA standard. A major goal of this research was to evaluate the applicability of the ACR-NEMA standard in a networked system [3].

The first step in the work was the simulation of a PACS network based on the ACR-NEMA standard. This simulation was performed by members of the Computer Engineering Research Laboratory at the University of Arizona [4]. The simulation indicated that the 4096 Byte packet size specified by the standard should be increased to better utilize the bandwidth of the interface. In Japan a pair of Network Interface Units (NIUs) were constructed to provide the interface between ACR-NEMA and a Toshiba proprietary high-speed fiber-optic network [5]. The NIUs were brought to Arizona and connected between an image acquisition device [6] and an image display system [7]. This

**NETWORK SOFTWARE FOR A PROTOTYPE SYSTEM**

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system provided the prototype system for which ACR-NEMA compliant network software was implemented. Figure 2 illustrates the prototype network system, including the end nodes, the NIUs, and the star coupler. Figure 3 shows the ACR-NEMA interface between an end node and an NIU.

In planning the software development for this prototype system it was decided that the upper layers should be implemented following the ISO-OSI standard. This choice provided hardware independence and resulted in software which is largely independent of the ACR-NEMA standard. Further motivation for this approach arose from the ambiguous nature of the ACR-NEMA standard document in which the interlayer interfaces were completely undefined. The software was developed under the OS-9 operating system. Each of the layers from the Application to the Session Layer was implemented as an independent process. The hardware ACR-NEMA interface we had chosen from Matrix Instruments, implemented ACR-NEMA up to part of the Session Layer in onboard microcode. Between our OSI Session Layer and the hardware interface we inserted an additional process which translated OSI services into the appropriate command which the ACR-NEMA interface would accept. Figure 4 illustrates the relationship of the software processes.

The implementation of each layer as an independent process has proven to be very valuable. Each process was a manageable piece of code and much of the structure of the code was the same for each process. This allowed us to develop the code very rapidly. As we worked our way down the layers a simple piece of code provided a software loopback for the next lower layer so that all of the upper layers were almost fully debugged before communications.
through the hardware interfaces was attempted. The remaining debugging generally corrected unexpected interactions among the full set of processes.

The prototype system implemented a subset of the ACR-NEMA command set to allow SEND and GET commands. These commands allowed the display system to "get" and image from the acquisition system or the acquisition system to "send" and image to the display system. The completed system transferred data at 256 Kbytes/Sec. The effective throughput, including opening and closing channels, was a little more than 64 Kbytes/Sec. Much of the overhead can be attributed to the particular ACR-NEMA interface implementation which we used and the implementation of much of the function of the NIUs in software.

CONSIDERATIONS FOR PACS

The development of the software for this prototype system has brought to light many flaws in the ACR-NEMA standard and its approach to PACS networking. The standard was conceived to provide point-to-point connectivity between hardware from different vendors. This requires the inefficient use of separate network interfaces which connect the device to the network. This method causes many difficulties, especially with flow control. The result is that the receiving node has to try to exert ACR-NEMA flow control across two ACR-NEMA interfaces and the network.

Many of the problems of the ACR-NEMA standard are related to the physical interface definition and have been pointed out by others as well [8]. This portion of the standard has had the least success, while the data format and application command protocol has been widely implemented layered on various ethernet protocols. Our experience leads us to believe that a successful software architecture for PACS networking should not be tied to a physical interface such as that specified by the ACR-NEMA standard, but should be adaptable at the lower layers. This will allow the software to migrate to newer technology such as ISDN.

Our modelling and prototype work has convinced us that the current strategy specified by ACR-NEMA will not support totally digital radiology.
The important aspects of network communications which ACR-NEMA failed to capture especially include the definition of layer services and the interfaces between the layers. By standardizing these interfaces and removing any dependency on the old physical interface definition the upper layers of ACR-NEMA can be simply ported onto a variety of existing and/or future network technology. This will eliminate the inefficiency of a pair of NIUs between the nodes and the network.

SUMMARY

We have implemented an ACR-NEMA compliant prototype for PACS network communications. This experience has convinced us that the existing ACR-NEMA standard suffers from fundamental omissions which make its application to PACS network unnecessarily difficult and inefficient. A communications standard for networking in digital radiology should carefully define the upper three layers and their interfaces. The lower layers should be flexible to allow the use of a variety of existing transport technology, as well as the migration onto emerging, high-speed technology. Such a standard may be rapidly developed by using the data, format and applications command definitions from the existing ACR-NEMA standard, and bringing in the service and layer interface definitions from ISO-OSI. A standard which is portable, strongly based on a widely accepted existing standard and which allows migration onto new technology will provide a much more robust foundation for PACS networking.

REFERENCES


