SESSION IV: Picture Archiving and Communications Systems: Archives and Networks

The Strategic and Operational Characteristics of a Distributed Phased Archive for a Multivendor Incremental Implementation of Picture Archiving and Communications Systems

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The long-term (10 years) multimodality distributed phased archive for the Medical Information, Communication and Archive System (MICAS) is being implemented in three phases. The selection process took approximately 10 months. Based on the mandatory archive attributes and desirable features, Cemax-Icon (Fremont, CA) was selected as the vendor. The archive provides for an open-solution allowing incorporation of leading edge, "best of breed" hardware and software and provides maximum flexibility and automation of workflow both within and outside of radiology. The solution selected is media-independent, provides expandable storage capacity, and will provide redundancy and fault tolerance in phase II at minimum cost. Other attributes of the archive include scalable archive strategy, virtual image database with global query, and an object-oriented database. The archive is seamlessly integrated with the radiology information system (RIS) and provides automated fetching and routing, automated study reconciliation using modality worklist manager, clinical reports available at any Digital Imaging and Communications in Medicine (DICOM) workstation, and studies available for interpretation whether validated or not. Within 24 hours after a new study is acquired, four copies will reside within different components of the archive including a copy that can be stored off-site. Phase II of the archive will be installed during 1999 and will include a second Cemax-Icon archive and database using archive manager (AM) Version 4.0 in a second computer room.

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THE MEDICAL INFORMATION, communication and archive system (MICAS) is a multimodality image management system that seamlessly integrates the radiology information system (RIS). The first phase of MICAS,^{1,2} a multivendor, phased implementation of a picture archiving and communication system (PACS) was installed in 1997 and did not include a permanent archive, nor was it Digital Imaging and Communications in Medicine (DICOM)-compliant.

The primary objectives of the second phase of MICAS was to select a long-term (10 years) multimodality, distributed phased DICOM archive solution for MICAS and demonstrate "plug and

play" DICOM compliance for all MICAS components.³⁻⁵ The selection process was initiated in June 1997 and the archive was to be installed in three or more phases over a 3- to 5-year period.⁶ The first phase was installed in August 1998.

The archive solution selected is media-independent and provides expandable storage capacity, redundancy, and fault tolerance, while minimizing cost in the second phase. Some of the required attributes of the archive include scalable archive strategy, virtual image database with global query—ie, the archive manager (AM) knows the location of each copy of the data set, and object-oriented database. Other requirements include fully automated workflow, which includes fetching, routing, and compression, seamless integration with the RIS, automated study reconciliation using modality worklist manager, clinical reports available at any DICOM workstation, and studies available for interpretation whether reconciled or not.

The economics of this archive strategy dictated that the capacity of the first phase of the archive accommodate 12 to 18 months of images (≈ 1.7 TB lossless compression). Only computed tomography (CT), magnetic resonance (MR), computed radiography (CR), nuclear medicine, and film-digitized images will be stored in the first phase, with ultrasound being added during the second quarter of 1999. A relatively small archive was selected, since archive speed and capacity are rapidly increasing and price is decreasing with time. A fundamental policy in the development of MICAS is to purchase no more than what is currently needed,

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since prices will decrease with time and performance will increase.

The critical component in the selection of an archive system is the AM, which provides the "brains, nerves, and heart" of the archive. The "brains" to know when and where to move data and how to protect the data; the "nerves" to sense in a timely manner when data must be delivered to a user and moved or stored for future use; the "heart" to ensure that data move rapidly and reliably from point to point and to ensure that there is enough reserve capacity to handle the variation in workload.

PHASE I ARCHIVE SOLUTION

The Cemax-Icon (Fremont, CA) Version 3.5 AM was selected with a written agreement that it would be upgraded to Version 4 and beyond as soon as it is released. This DICOM archive provides for an open, scalable solution allowing incorporation of leading edge, "best of breed" hardware and software. The Cemax AM provides for future expansion as the enterprise-wide PACS grows and offers maximum flexibility and automation of workflow both within and outside of radiology. The Cemax-Icon AM is independent of jukebox and media as long as the company has validated these components. Mixed media can be managed by the AM, eg, various generations of digital linear tape (DLT), other tape-based storage solutions, and magneto-optical disks (MOD). One of the reasons for selecting the Cemax archive was it was the only AM that provided an automatic backup of the acquired images in the form of a bit file that can be stored remotely for disaster recovery.

Before awarding a purchase order to Cemax, they performed a site survey, agreed upon the acceptance test protocol, and provided a written guarantee of connectivity between their archive and the imaging modalities, ImageLabs (Bedford, MA) DICOM study cache, and DICOM viewing software. As part of this agreement Cemax agreed to update the acquisition interfaces if the modality vendors revised their software as long as 60 days' notice was given and a maintenance agreement with Cemax were in place.

MICAS required that the Cemax-Icon Version 3.5 AM be configured as follows: a SUN (Mountain View, CA) Enterprise 450 with two processors and 1 GB of RAM, the ATL (Milipitas, CA) jukebox with two DLT 7000 drives and 28 tapes and DEC

(Nashua, NH) 450 redundant array of inexpensive disks (RAID) 5 with 162 GB. The jukebox provides 1.7 TB of storage (lossless compression) plus four tapes are used to generate bit files of the images. The archive is seamlessly integrated with the RIS (IDXrad) using IDX (Burlington, VT) PACSlink and the Mitra (Waterloo, Canada) PACS Broker. ImageLabs Storage Works Microsoft (Redmond, WA) Windows NT-based DICOM study caches were selected to increase bandwidth and add redundancy to the system. The hardware (DEC 500/400 Alphas with DEC StorageWorks RAID 5) for the study caches were converted from the UNIX-based temporary archives used in the first phase of MICAS to NT using RAID 0. The MR and CT study caches have 54 GB each, ultrasound 24 GB, and nuclear medicine, CR, and the film digitizer share a 24-GB study cache.

The AM or the Mitra Relay,⁷ a modality worklist manager, acquires the images and header data from the modality, the Mitra PACS Broker communicates with IDX PACSlink for the demographic data in the RIS, and validation takes place in the AM or Relay. The study is moved to the AM's RAID 5 and then routed to the designated study cache and then to the designated workstation. The AM has already fetched prior studies and sent them to the AM's RAID 5 and then to the designated study cache. The ImageLabs workstations query their respective study cache or the Cemax archive for the current and prior studies to be interpreted. Reports are available at the workstation via PACS Broker and IDXrad.

PHASE II ARCHIVE SOLUTION WITH FAULT TOLERANCE AND REDUNDANCY

The second phase of the archive will be installed in 1999. This will include AM Version 4.0, a second Sun Enterprise 450 or equivalent, the expansion of the ATL jukebox to 52 DLT 7000 tapes with 3.4 TB of storage (lossless compression), and two additional tape drives. A second jukebox will not be added at this time. The AM will run on both Sun Enterprise 450s—one will be the master; the other the slave. The AMs will be located in separate rooms and interfaced for fault-tolerant operation. If one fails, the other can maintain system operations at reduced efficiency until the failed AM becomes operational. The two rooms are on different power grids and fire zones.

Each AM will have a RAID that contains the

entire demographic database. These databases will be mirrored and maintained concurrently so if one fails, the identical information is available on the other. Each RAID will be large enough to limit fetching of previously performed studies from DLT that are required for interpretation of current studies by approximately 75%. This will significantly enhance the speed of operation of the archive and eliminate the need for faster and significantly more expensive jukeboxes, as well as faster and additional tape drives or the equivalent for other media. The studies stored on RAID will be distributed between the two RAIDs. The study caches also will be distributed between the two computer rooms so if CT studies are stored on the RAID in room 1, then the CT study cache will be located in room 2 (see Fig 1). As a result there will always be adequate studies available for interpretation in either computer room should the equipment fail in one.

The RAIDs are currently being sized based on the department's workflow. Depending on when the system is installed either 32- or 64-GB hard drives and the latest SCII technology and/or fiber-ready RAID systems will be used. The current DEC 450 RAID will be either traded in or used as one or more study caches. The AM eventually will be able to discard studies from the RAIDs based on any field in the DICOM header. For example, CR studies performed in the intensive care units will be

discarded from RAID, 2 weeks after the last study was performed, while the last study performed will be kept for 6 months.

When a study is acquired, it resides on a RAID in one of the two computer rooms and then will be routed to the study cache assigned to that modality which is located in the other computer room. Within 24 hours, the master AM will write the study to DLT and generate a bit file of that study. Thus, within 24 hours of acquiring a study, four copies of that study will exist, three in the main computer room and one in the other. When a bit file DLT is filled, it is removed from the computer room and stored in a secure location.

Figure 1 illustrates this distributed and phased archive strategy for a redundant, fault-tolerant operation. The infrastructure to implement this fault-tolerant, redundant PACS is currently being designed.

PHASE III AND BEYOND

When the DLT 7000 jukebox in the computer room approaches its capacity, a second jukebox will be purchased and located in the second computer room. The master AM will put the new studies on this jukebox, while it will continue to generate the bit files on the first jukebox. The jukebox and media to be selected will be dependent on what systems have been certified by Cemax and current technology. Based on current information,

Fig 1. Proposed configuration of the phase II archive. Currently, all 4 study caches are located in room 1. AM #1, the master, and AM #2, the slave, are to be networked in a fault tolerant configuration.

if the jukebox were to be purchased in 2000, it would probably be a jukebox capable of supporting DLT 12000 with four drives and 52 or 100 tapes. For DLT 12000, based on present information, this would provide lossless storage of at least 10 to 20 TB assuming 100 GB per tape uncompressed.

If necessary, the AM can copy studies from the initial jukebox with DLT 7000 to the second jukebox with whatever media it may use.

When additional modalities and study caches are interfaced to MICAS, one or more slave AMs and Sun Enterprise 450 or equivalent can be added. Assuming the most recent version of the Sun Enterprise 450 is the fastest and has the most computing power, it can be designated as the master AM and the original would become a slave AM.

CONCLUSIONS

The phased approach of archive implementation provides obsolescence protection while minimizing costs by building the archive in phases, rather than buying a 10-year solution at one time. Technology improves and costs decrease with time. The distributed phased approach of archive implementation provides increased performance, as well as the opportunity to incorporate redundancy and fault tolerance at minimal cost.

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