

Automated DICOM Pre-fetch for Legacy Applications using *UltraPREFETCH*



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Abstract—Automated pre-fetch of DICOM data is discussed and its impact on radiology and related fields. Two use cases are examined; a.) pre-fetch from near-line PACS devices that have a need to receive relevant prior patient information and b.) DICOM push from retired or legacy near-line systems to on-line systems in PACS environments.

Index Terms—PACS, Pre-Fetch, DICOM, HL7

I. INTRODUCTION

PACS, (Picture Archive and Communication System) has undergone significant growth and changes over the last 10 years, and continues to expand beyond the radiology specific implementations originally developed. This whitepaper discusses the role and attributes of DICOM pre-fetching as organizations expand and add functionality to their PACS. This expansion may take two forms: 1.) Addition of specialized workstations and/or incremental reading sites not directly integrated with PACS (near-line workstations). 2.) Replacement of PACS architecture thereby transforming online and integrated archives into near-line PACS devices.

The term near-line is chosen since these devices, although integrated using the DICOM standard, may not necessarily have the capability of fully integrating to modern PACS. Many modern PACS systems utilize a client-server architecture rather than peer-to-peer. To achieve desired and optimal workflow the client-server architecture requires tightly coupled applications, where DICOM alone loosely couples applications across the imaging domain.

Two use cases are examined: 1.) Near-line specialized PACS workstations receiving relevant priors from PACS 2.) Near-line archives pushing to online PACS. In both cases, the DICOM image transmission (C-MOVE) can be triggered by either an HL7 message or DICOM header information.

II. PRE-FETCH TRIGGERING

A. Triggering Logic

When radiologists are reviewing studies, relevant prior patient information is critical in making accurate diagnoses. [1]Pre-fetch rules define when prior studies are relevant to a study being interpreted. In order for this process to function, prior studies must be defined; for example, if a chest radiograph is sent to a workstation or is being viewed by a radiologist, would that radiologist prefer to see only chest studies that are also radiographs, or would they also want to see any chest studies from other imaging modalities?[1] Once this logic is defined, we can then focus on the specifics of where and how to derive the information about a recently performed study, how to locate its prior studies and when to push or pull this data.

B. HL7 Triggering

HL7 is a standard method by which medical information systems transfer and share information about patients and their associated medical records. For example, in radiology informatics the radiologist may dictate reports into electronic transcription software, which receives patient demographic information from a billing or scheduling system. Once the report has been completed and signed, the results could be sent back to the radiology information system (RIS).

In radiology applications, HL7 frequently makes use of three basic message types: ADT (Admission/Discharge/Transfer) which contains global information about a patient such as their name, medical record and account numbers, insurance information, and other demographic details.[7] ORM (Request for Observation) would typically contain information about a procedure or exam a patient has been scheduled for. In radiology this might contain information about what imaging modality, body part, CPT, and accession number.[7] Finally, an ORU message contains results, such as a report dictated by a radiologist.[7]

HL7 could be generated by a system managing and scheduling patients, billing for services, or providing results. In pre-fetch workflows, it is especially useful to be aware of a patient prior to their arrival to allow ample time to traverse the logic chosen and move the study to online systems before the current study being performed is online for interpretation. In this way, ADT and ORM messages originating from a radiology management system are most useful for pre-fetching studies.

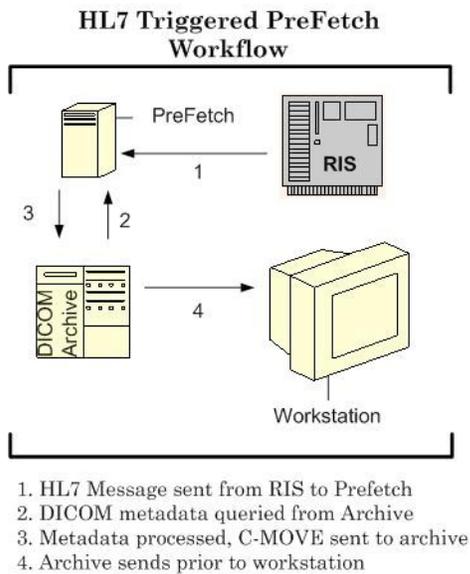


Figure 1

Both ADT and ORM message types will provide information about a patient, which would allow for pre-fetching relevant studies based on the medical record or account number. However, an ADT contains no information on what type of study is being performed, making study level logic impossible.[7]

Although pre-fetching all studies can be useful in some cases, in many cases there will be large amounts of image data for a single patient. For example, a yearly mammography study's relevant priors may only be the previous year of data, as well as a baseline. This may be only 3 studies totaling 12 images. However, this patient may have been admitted as an inpatient in the past, and had 20 anterior-posterior chest x-rays. In this example, the pre-fetch process would not be aware of the ordered procedure, and would pre-fetch over 40 images including irrelevant mammography studies.

ORM messages contain patient information as well as the ordered procedure data. This information can be cross referenced to allow more precise pre-fetching. In the mammography follow-up, the CPT or procedure code would identify the scheduled procedure as a mammography screening, which would then follow a rule set and transfer only those images relevant to the study being reviewed.

C. DICOM Triggering

DICOM is a standard format for storing and transferring medical images, and is the foundation on which most PACS communicate with external devices. A DICOM file's payload not only includes the image data (such as an x-ray or a single CT slice) but also includes the patient and study information in much the same way the ORM HL7 message described above.[6]

Although pre-fetching need not process the image data in the DICOM transaction, it can use the DICOM header information to perform the same logic as in the HL7 messages received prior to the study.

Since extracting information about an event using DICOM implies the event has already occurred, frequently users would experience delay before realizing the benefit of pre-fetching.

In the mammography example, a patient arrives for an exam, the procedure is performed and the study transmitted to a review workstation. Priors are sent the workstation after which they are visible to the radiologists, requiring a delay by the radiologist to ensure all prior exams have arrived on the workstation. Depending on the network conditions, this delay could be only a few seconds to several hours.

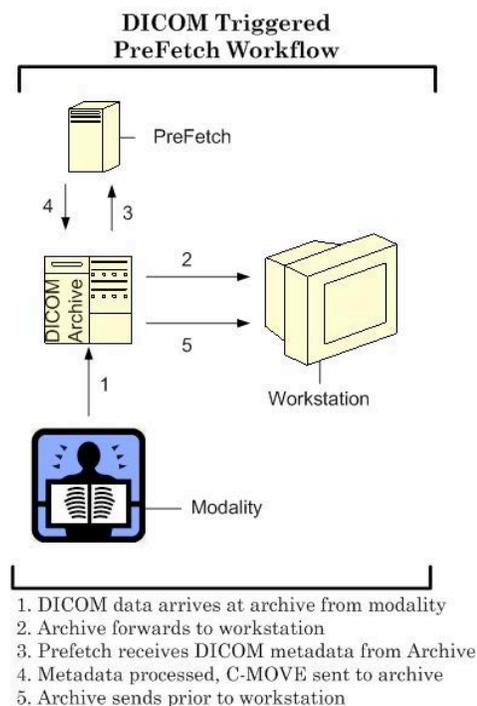


Figure 2

In addition to acquiring patient demographic data by extracting from a DICOM header, this information can also be obtained using a DICOM C-FIND message on a DICOM modality work list. Typically a DICOM modality work list is a DICOM accessible list of studies queried from a modality in order to automatically populate the DICOM demographic information at the imaging modality.[6] Pre-fetch can obtain

information on scheduled patients in much the same way, performing a similar DICOM modality work list query.

Although not optimal, DICOM is an acceptable alternative to HL7 triggered pre-fetching when the HL7 is not available.

D. Triggering a Pre-fetch Event

Information derived from HL7 or DICOM would typically be stored in a SQL database, in a standard format. For example an HL7 message describing a mammography screening ordered for a given patient will have its metadata stored in a database of orders. Similarly, DICOM information is stored in the same database.

Periodically, a process parses the order database, and any orders matching its predefined trigger will be parsed. For example, the mammography study will be checked to see if it is for the current date, or some date in the future. The pre-fetch process may skip procedures not scheduled within 24 hours, but act on those where the study is scheduled within 24 hours.

E. Finding Prior Studies

In some cases, prior studies are expected to reside on a single near line or online DICOM archive device (depending on the use case described further in section 3-5). In other cases, multiple archive devices may have relevant prior studies. To locate studies, the pre-fetch system queries all associated DICOM devices using a C-FIND DICOM message.

C-FIND messages in DICOM allow a DICOM device to query for a list of DICOM metadata based on criteria supplied by the requesting DICOM device.[7] Typically, the DICOM device requesting information is referred to as a Service Class User, while the device responding to the request is referred to as the Service Class Provider.[7] In the case of pre-fetch, the pre-fetch process queries DICOM archives as an SCU which is supported on most archiving platforms.

In the mammography example, pre-fetch might query a DICOM archive for all studies for the patient with a medical record number that matches that of the ordered procedure. However, in some cases there may be no unique identifier for patients. In this case, some other logic would be used, such as patients where the date of birth, last name, and other identifying data that adhere to JHACO recommendations [2] are found.

Once a comprehensive list of prior studies has been accumulated, pre-fetch can identify those meeting the logic set forth for the study type ordered. For example, in the case of a mammography screening, pre-fetch may be instructed to push only the most recently performed procedure, with a baseline that could be either 3 years old, or the oldest available if the history is less than 3 years.

F. 'Moving' DICOM Data

The actual fetching of DICOM data matching the defined logic to a workstation or archive is accomplished using a C-MOVE DICOM message. Many DICOM and PACS administrators are familiar with the term "DICOM

Query/Retrieve" whereby DICOM archives can be queried by DICOM devices, then requested data can be retrieved to their workstation. This is made possible using a combination of C-FIND and C-MOVE DICOM messages.[6]

First, a C-FIND is issued as described previously. A C-MOVE message is then sent to the archive identifying the study by "unique identifier" (an identifier that is globally unique) and the device name (Application Entity [AE] Title) to send the study. Although in a typical DICOM Q/R use case the C-MOVE AE Title is that of the SCU (requesting system) this does not always have to be the case.[6]

In the example of the mammography case, the C-MOVE AE Title would be that of the workstation that is the final destination. In this way, pre-fetch essentially sends a DICOM command to the archiving device instructing it to send a DICOM study to another DICOM device.

Although pre-fetch does not typically handle the actual DICOM transfer, it initiates the transfer of data using the C-MOVE DICOM command containing a study UID, and AE Title.

III. NEAR LINE ARCHIVE USE CASE

A. Retiring an Archive

Typical computer and software solutions have a life expectancy and return on investment (ROI) of approximately 3 years.[3] PACS archives generally have a lifecycle of approximately the same timeframe. When an archive nears retirement, the data stored in that archive is typically still needed, and must be accessible. Although users in some scenarios can either manually or automatically 'pull' the archived data using the DICOM Q/R process described in section 2.f, this is not always the case nor is it an optimal workflow.

B. Client/Server vs. Peer-to-peer PACS

In the early days of computing, users typically used "dumb terminals" to access computing power on more powerful mainframe systems. As the price of computer hardware and software reduced dramatically over time with Moore's Law [4] the power of mainframe computers could be harnessed in a desktop PC. As PACS became more prevalent this paradigm shift in the late 1990's was at its peak. [5] Many PACS systems adopted the workflow of implementing image viewing on workstations where images would be 'sent' using DICOM. Priors could either be pulled in real time from archives, or archives may have been configured to push relevant priors upon receipt of studies (similar to the pre-fetch logic described in the mammography example).

However, many PACS have since migrated to a client/server architecture where studies residing on an archive are accessed and viewed from a client workstation. Although web technology may be used as a transport in this client/server topology, other methods may also be used and are most likely to be proprietary in nature. In this context, the term proprietary is used to describe a transport that is not explicitly "DICOM" (although DICOM data may be the payload of the

transport from server to client.) This methodology is the predominate topology of most commercial PACS environments at the time of this writing.

When migrating to a new PACS environment, data residing in the old PACS cannot easily be accessed from the new PACS. The data must be resident on the new PACS in order to be efficiently accessed.

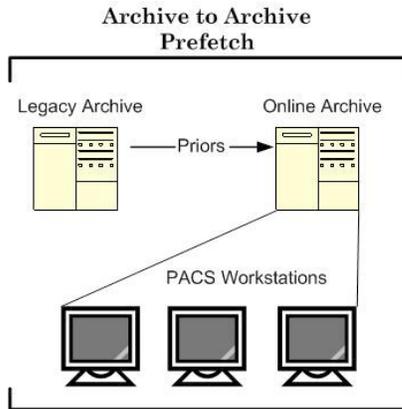


Figure 3

C. Pre-fetch vs. Migration

Organizations implementing new PACS have two choices for accessing prior data: 1.) Migrate their existing data, in it's entirety, to the new PACS/Archive. 2.) Only push relevant prior data on demand. Pre-fetch provides an automated method to achieve the later.

Although the case can be made for migration from the old PACS to the new PACS, this is a costly, time consuming and inefficient process.

First, considering the amount of data that will actually be needed compared to what will be moved shows a large amount of data (thus time and effort) is migrated that will never be used. An archive with 5 years of data will typically only use about 18% of that data that is less than 18 months old., while the remaining data may see under 1% usage. In an archive that contains millions of images, this is a tremendous amount of unused data migrated.

A recent article in an industry publication outlines one such migration example; a PACS administrator in a large hospital environment claimed that using DICOM query retrieve would have taken his hospital 10 years to complete for all the data. He goes on to say that paying to migrate this data would cost about \$.50 per study. In this case, the hospital reports they complete 300K studies per year. For five years data, this migration costs \$750K, and moved about 1.4 million cases that may never be needed. In addition, the PACS administrator goes on to claim that 10-15% of the data is not usable. [6]

When migrating DICOM data from one system to another, the risk of data loss is far greater than if the data was sent DICOM. However, the overhead in migrating the entire dataset is diminished by the returns realized in time and utilization of that data.

If the hospital in the example above had used a pre-fetch workflow to migrate the data as needed from an HL7 data

source, they would have realized a significant savings over the data migration in both time and effort.

IV. NEAR LINE WORKSTATION USE CASE

A. Dedicated and Specialized Workstations

Most of the DICOM data generated by imaging modalities can be interpreted by radiologists on an integrated PACS client. However, there are some cases when this data cannot be read for diagnoses within the PACS environment. One example is mammography, where only approved specialized workstations may be used for diagnoses. Other workstations may be advanced 3D volume and reconstruction, and PET/CT workstations among others.

The challenge in this scenario lies in integrating a workstation that may require prior data into a client/server PACS that does not natively support pre-fetching the relevant priors.

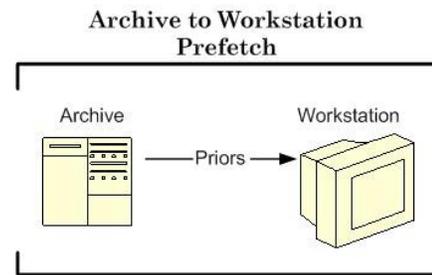


Figure 4

In this case, studies must be pushed from an online DICOM archive to a near-line dedicated workstation. Typically, this pre-fetch would occur prior to the current cases arrival to the workstation.

Although this process can be accomplished manually, pre-fetch automates this process saving significant time and resources. In addition, the automated pre-fetch application allows for data movement over wide area networks, (where bandwidth utilization is critical during business hours), to take advantage of bandwidth usage during off-peak hours.

V. ATYPICAL PRE-FETCH APPLICATION

The scenarios described thus far have been common throughout radiology points of care. However, pre-fetch can also be used in specialized workflows not typical to the industry.

One such example is a regional healthcare authority in Oklahoma. With 5 regional healthcare centers and only limited bandwidth between each facility a centralized PACS can not offer the performance required in each localized facility without significant compression. Also, the facilities lack the resources and infrastructure to house an entire archive for long term storage. Complicating matters, a patient visiting one facility may have relevant priors that where completed at

other facilities.

This healthcare community utilizes a central PACS repository for all studies that is populated at the time the study is created.

This group could significantly increase their efficiency using pre-fetch. HL7 is currently fed to the PACS through a DICOM/HL7 protocol broker. The ORM messages could be copied to pre-fetch, processed, and relevant priors routed in real time to the point-of-care without manual intervention.

Not only would this increase efficiency in manpower, but has the potential to dramatically reduce the finite bandwidth currently being utilized during business hours by offloading this transfer to off-peak hours.

VI. CONCLUSION

Pre-fetch usage can be divided into 3 categories of use case. 'Near-line Archive to online archive' pre-fetching where cases residing on retired archives are pushed to online integrated PACS archives. 'Online to near-line workstation' describes pre-fetching where online data is sent to a dedicated workstation not fully integrated to the PACS client/server environment. Finally, an atypical application was assessed where pre-fetch could be used to automate fetching in a regionalized PACS environment where a high percentage of cases may be needed from other regional PACS.

Triggering pre-fetch is most common using HL7 and DICOM data feeds, although HL7 is preferred. With HL7, the pre-fetch is driven by data from a radiology information system, which is typically aware of events before DICOM data is generated.

Using pre-fetch, facilities could now efficiently migrate old PACS to new PACS thereby saving substantial time, effort, and money. In addition, routing relevant prior data using DICOM in a loosely coupled environment allows integration of near-line systems where manual processes are prone to human error and intervention.

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