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# Distributed PACS using Distributed File System with Hierarchical Meta Data Servers

Tomoyuki Hiroyasu[1], Yoshiyuki Minamitani[2], Mitsunori Miki[3], Hisatake Yokouchi[4] and Masato Yoshimi[5]

***Abstract*— In this research, we propose a new distributed PACS (Picture Archiving and Communication Systems) which is available to integrate several PACSs that exist in each medical institution. The conventional PACS controls DICOM file into one data-base. On the other hand, in the proposed system, DICOM file is separated into meta data and image data and those are stored individually. Using this mechanism, since file is not always accessed the entire data, some operations such as finding files, changing titles, and so on can be performed in high-speed. At the same time, as distributed file system is utilized, accessing image files can also achieve high-speed access and high fault tolerant. The introduced system has a more significant point. That is the simplicity to integrate several PACSs. In the proposed system, only the meta data servers are integrated and integrated system can be constructed. This system also has the scalability of file access with along to the number of file numbers and file sizes. On the other hand, because meta-data server is integrated, the meta data server is the weakness of this system. To solve this defect, hieratical meta data servers are introduced. Because of this mechanism, not only fault-tolerant ability is increased but scalability of file access is also increased. To discuss the proposed system, the prototype system using Gfarm was implemented. For evaluating the implemented system, file search operating time of Gfarm and NFS were compared.**

## I. INTRODUCTION

In recent years, storing and sharing medical information is becoming increasingly important. Among medical information, DICOM is the standard and network protocol for medical images. In DICOM standard, metadata such as patient information and examination information is stored with image data[1]. Medical institutions have systems which control DICOM file and this system is called Picture archiving and communication systems (PACS)[2][3].

PACS is now designed to use medical images stored at each hospital or facility[4] [5]. However, in the near future, several PACSs which exist in different hospitals or institutions will be worked together. There several ways to make collaboration among several PACSs. For example, using cloud platform is one of the solutions and there is an example of constructing the system using Microsoft Windows Azure[6]. When several PACS are trying to be worked together, most of the cases, all the files are stored into one site[7][8]. However, this strategy does not have scalability to the number of files and hospitals. Not only size of a medical image is large, but also huge number of images is added to the system every day. The amount of medical image information is increasing tremendously with the future development of medical equipment and systems. Based on current trends, it is estimated that over one billion diagnostic imaging procedures will be performed in the USA in 2014, which will generate about 100 petabytes of data[9].

To overcome these defects, Hiroyasu et al. proposed the distributed PACS using a distributed file system[10]. In the proposed system, there is a meta data server, which manages the information of the files, and DICOM files are stored in locally. This mechanism is very suitable for DICOM files, because DICOM itself consists of metadata and images itself. Using this mechanism, PACS whose medical images are managed in several hospitals and whose information can be shared from outside of hospitals can be constructed. At the same time, when users try to find the certain image, user access to the information which is restored in the metadata. Like this way, the retrieving files can be performed quickly. Moreover, since the proposed system is using distributed file system, the system has the scalability of accessing file speed and the capacities.

However, when the file information is managing on a single server, system has the low fault tolerance. To make it higher, metadata servers should be constructed hierarchically. Thus, in this paper, we propose a system that each medical institution builds a distributed file system individually and coordinates them using hierarchal metadata servers. To implement the proposed system, Gfarm is utilized as a network shared file system. Gfarm have mechanism to coordinate multiple distributed file system and store the metadata of the file as XML data[11]. Gfarm can retrieve the file by using XML in the multiple distributed file system. Therefore, the proposed system can be constructed easily with Gfarm. Using the implemented system, the proposed system is described and the evaluation experiments are performed.

## II. PROPOSED DISTRIBUTED PACS

### A. *Outline of proposed system*

In this paper, it is assumed the situation where several PACSs are utilized at multiple points and these scattered PACSs are integrated. In this section, PACS cooperated with the hieratical distributed file system is proposed. In this system, each medical institution builds a distributed file system and manages medical images. Here, we propose a

[1]Tomoyuki Hiroyasu is with Department of Life and Medical Sciences, Doshisha University, Japan tomo@mis.doshisha.ac.jp

[2]Yoshiyuki Minamitani is with Department of Engineering, Doshisha University, Japan yminamitani@mis.doshisha.ac.jp

[3]Mitsunori Miki is with Department of Science and Engineering , Doshisha University, Japan mmiki@mail.doshisha.ac.jp

[4]Hisatake Yokouchi is with Department of Life and Medical Sciences, Doshisha University, Japan hyokouchi@mail.doshisha.ac.jp

[5]Masato Yoshimi is with Department of Science and Engineering , Doshisha University, Japan myoshimi@mail.doshisha.ac.jp

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novel distributed PACS in which only the DICOM metadata are stored on file information server. Actual images are saved on the distributed site. For example, to find a specific image, the user accesses the information stored in the metadata. Thus, it is inefficient to access the entire medical image when user retrieves only the DICOM metadata.

Regularly, when files are uses for retrieving, the entire data is necessary. However, in the most of the cases, just a part of information is important. For example, when users are looking for the data which were created in the certain data, the image itself is not necessary but the meta data is important. In the proposed system, DICOM file is not stored into one database but metadata and image are separated. Each hospital constructs two layers of servers one of which stores metadata and the other stores actual image data. Furthermore, metadata servers are arranged hierarchically. In other words, an additional server for meta data is prepared at outside of medical institutions and this server helps cooperation among several PACSs. This server is called "Cooperation Server". When users try to retrieve a certain DICOM file, meta data server in own hospital is accessed first. If the target file is existed in this sever, the file is derived from local server. On the other hand, when the target file is not existed in the local meta data server, the cooperation server is accessed and the DICOM file is sent directly from the server which stores the target file.

To achieve this goal, it is necessary to prepare the distributed file system which can treat metadata information and can make cooperate multi distributed file system. In this paper, to construct proto type system of the proposed system, Gfarm which is one of network shared file systems is used.

## B. Gfarm

Gfarm (Grid file system) is a global distributed file system used to share data and to support distributed data-intensive computing[11]. Gfarm consists of two types of server: metadata servers, which manage the preservation of location information of each file; I/O servers where the main body of data is stored. The metadata servers manage file system data of a virtual directory tree and the locations of the actual files, etc., as metadata. Fig. 1 shows the Gfarm architecture.

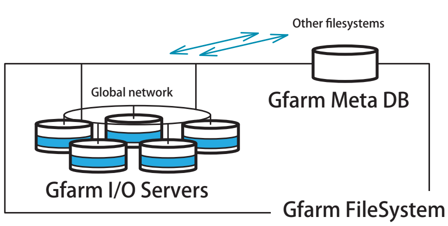


Fig. 1. Gfarm architecture[12]

The Gfarm metadata server not only manages preservation of the location information of files but also treats metadata as XML data. This mechanism, called XML extended attributes, specifies the related XML file of each saved file, and enables retrieval of the file by XPath. Furthermore, Gfarm has a function to make the cooperation of multiple servers.

## C. Distributed PACS using Gfarm

Fig. 2 shows the outline of proposal system by using Gfarm.

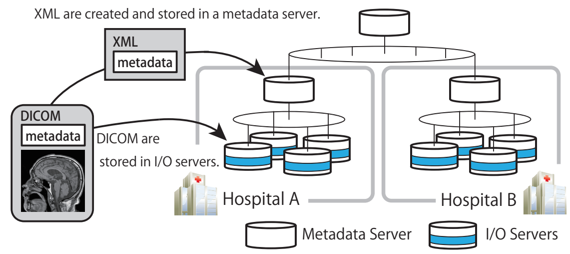


Fig. 2. Outline of proposal system

As shown in Fig. 2, DICOM images are stored at Gfarm I/O servers in each medical institution. On the other hand, XML are created from DICOM metadata and registered at Gfarm metadata server in each medical institution. Because the system have these two layer servers, the XML metadata itself can be operated without accessing the large DICOM file image information. Therefore, high-speed retrieval can be achieved.

In the proposed system, DICOM files which are managed at each medical institution can be accessed even from outside of medical institution. When DICOM file which is managed by the outside of local institution is retrieving, the cooperation server is accessed first. This cooperation server itself is not retrieving files but the metadata server of each medical institution performs retrieving. Like this way, the metadata of Gfarm can be operated in separately. The collaboration server itself (shown in Fig. 2) is also Gfarm metadata server. By mounting this cooperated server, clients can be recognized linked Gfarm of medical institutions as a single file system.

## D. File operation in institution

In the same institution, the following three DICOM file operations are performed:

- Saving of DICOM files
  When users store DICOM file through the client system, the client of the proposed system extraxts XML from DICOM metadata. XML files are registered XML extended attributes and stored in metadata server of each medical institution. On the other hand, DICOM files are stored in I/O servers in each medical institution. Location of the I/O servers are automatically determined from the load information of each server by Gfarm.
- Retrieval of DICOM metadata
  The retrieval is performed with the metadata server for the DICOM metadata stored in file system. In the implementation, retrieved items are specified by XPath and these items can be defined more than one.
- Reading of DICOM files
  When a user needs to access the DICOM file, metadata server is accessed first and destination information of objective files is derived. Then, clients download files by communicating directly with the I / O server.

TABLE I

SPECIFICATIONS OF A SERVER

| | |
|---|---|
| CPU | Quad-Core AMD Opteron 2.3GHz × 2 |
| Memory | DDR2 667 MHz 8GB |
| OS | Debian 6.0.3 |
| gfarm | 2.5.3 |
| gfarm2fs | 1.2.6 |

### E. File operation in an external medical institution

It is not necessary to write DICOM files, but to retrieve and read them in an external medical institution. When DICOM file is retrieved, the cooperated server shown in Fig. 2 accesses to the metadata server of each medical institution. Then the operation of retrieving which institution holds the target DICOM file is performed. Retrieval is performed whether the objective DICOM files exist where medical institutions store. In addition, when the target site is limited, operation of retrieving files can be performed much more quickly.

## III. SYSTEM IMPLEMENTATION AND EXPERIMENTAL ASSESSMENT

### A. Implementation of the proposed system

This section describes the implemented system. We assumed two institutions and two Gfarm file servers are prepared. There are two I/O servers and one meta data server on the same LAN. Table I shows Specifications of a server.

*1) Implemented function:* The required functions for the proto type system are the following three functions; uploading, retrieving and downloading DICOM files. These three functions are illustrated as follows.

- Uploading DICOM file
  We prepared a command to upload DICOM files to the experimental system. When the client uploads DICOM files to the experimental system using the command, the experimental system produces XML from the meta data of the specified DICOM files. After that, the experimental system stores DICOM files on the I/O server. The experimental system adds the XML extended attributes for DICOM files stored on the I/O server. The XML extended attributes are managed on the meta data server.
- Retrieving DICOM files
  When DICOM files are retrieving, "gffindxmlattr" command of Gfarm using XPath is performed. When the file which is existed outside of local hospital is retrieving, meta data servers of each medical institution are accessed.
- Downloading DICOM files
  When DICOM files are downloaded, DICOM files are specified from the destination information which server has.

### B. Experimental assessment

As described in this section, Gfarm was confirmed to show sufficient performance as a file system for medical images and to be useful for retrieval of meta data in the implemented system. Gfarm was constructed on the actual machines in experimental assessment. Gfarm was compared with NFS (Network File System)[13], which is a well-known small-scale file sharing system. We prepared some DICOM files whose sizes are 2048 × 2048 pixels (about 4.2 million pixels) which is the standard size of the latest MRI. Table II shows the sizes of DICOM and XML files used in the experiment.

TABLE II

DICOM AND XML FILE SIZES

| File | Size | Number | Sum size |
|---|---|---|---|
| DICOM | 12.6MB | 100 | 1.26GB |
| XML | 7KB | 100 | 0.7MB |

TABLE III

RESULTS FOR SAVING DICOM AND XML FILES

| Process | Gfarm (s) | NFS (s) |
|---|---|---|
| real | 21.7 | 27.6 |
| user | 0.26 | 0.33 |
| system | 3.59 | 2.92 |

We measured and evaluated the time required to write to the system for hundreds of DICOM files and XML files. We measured the time required for processing five times using the "time" command.

*1) Storaging DICOM and XML file:* Here, we compared the processing speeds of storing both DICOM and XML files between Gfarm and NFS. For NFS, DICOM files are stored in one of two servers and XML files are stored in the other server. For Gfarm, DICOM files are stored in two I/O servers with the XML extended attributes stored on one meta data server. Table III shows the measurement results for saving 100 DICOM files and 1000 XML files. In this table, "real" means the total time, "user" means the user CPU time, and "system" is the system CPU time.

*2) Storaging DICOM file:* The processing speeds of storing only DICOM files between Gfarm and NFS were compared. Table IV shows the measurement results for saving DICOM files.

*3) Storaging XML file:* The processing speeds of storing only XML files are compared between Gfarm and NFS. NFS stored XML files on one server. Gfarm added the meta data to the DICOM file already stored on the I/O server. Table V shows the measurement results for saving XML files.

*4) creating XML from DICOM:* The processing speed with creating XML from DICOM files was measured. Table VI shows the measurement results of creating XML from 100 DICOM files.

*5) Retrieving by XML extended attributes:* The processing speeds of retrieval DICOM files by using XML extended attributes were measured. In particular, DICOM 10,000 file (1.26 GB) was saved on Gfarm, and the picture ID number was retrieved using the XML extension attribute. The picture ID numbers differ in all the files. For measuring the retrieval process, we measured the processing speeds. In this operation, file is retrived from outside of server which stores this

TABLE IV

RESULTS FOR SAVING DICOM FILES

| Process | Gfarm (s) | NFS (s) |
|---|---|---|
| real | 20.9 | 26.9 |
| user | 0.046 | 0.028 |
| system | 3.28 | 2.65 |

TABLE V

RESULTS FOR SAVING XML FILES

| Process | Gfarm (s) | NFS (s) |
|---|---|---|
| real | 0.67 | 0.54 |
| user | 0.22 | 0.29 |
| system | 0.24 | 0.16 |

TABLE VI

RESULTS WHEN CREATING XML FROM DICOM FILES

| Process | Time (s) |
|---|---|
| real | 5.8 |
| user | 4.3 |
| system | 0.003 |

TABLE VII

RESULTS FOR RETRIEVAL BY USING XML EXTENDED ATTRIBUTES

| Process | inside (s) | outside (s) |
|---|---|---|
| real | 6.07 | 6.08 |
| user | 0.004 | 0.001 |
| system | 0.001 | 0.003 |

file. Table VII shows the measurement results for retrieval by using XML extended attributes.

## IV. DISCUSSION

In this experiment, the access time for writing of Gfarm is shorter than that of NFS as shown in Table III. As shown in Table IV, the most time was occupiued by the processing speeds of saving DICOM files (1.26 GB) occupied the most time. In this result, Gfarm is faster than NFS in processing time. This result suggested that Gfarm has smaller writting overhead than NFS. It has also been reported that Gfarm has the same access time as HDFS (Hadoop Distributed File System)[14]. Therefore, the implemented system has high file access capability because Gfarm is used.

As shown in Table V, the Gfarm processing time was longer than that of NFS with regard to writing the XML files on each server. For Gfarm, there is a process for adding XML extended attributes. This process may take some time. However, processing time is 0.67 second and it is very small time.

As shown in Table VI, the time for 5.8 seconds was required in order to create 100 files XML from DICOM. Even if it unites with the result of Table III, processing time is 27.5 seconds. It is appropriate as processing time of 1.26 GB of data.

In the retrieval of 10,000 subjects (126 GB) by using XML extension attribute, the result of 6.07 seconds was obtained as shown in Table VII. On the other hand, the retrieval speeds for external Gfarm is 6.08 seconds. This time is almost the same time in the case of an internal retrieval. Since this evaluation was performed in the same LAN, it is necessary to perform the experimental assessment between remote places about outside retrieval in the future works.

## V. CONCLUSIONS AND FUTURE WORK

In this paper, the concept of a new distributed PACS using distributed file system was proposed. In the proposed system, a distributed file system which has mechanism to store data into meta data and real data separately is utilized. Each medical institution builds a distributed file system separately and distributed PACSs are integrated as one system. Since only meta data is integrated among several institutions and real images are stored at each institute, it is easy to integrate as one system. At the same time, because users can access meta data, the system has the high scalability to operating file speed, such as finding a file operation. On the other hand, the meta data is stored into one meta data server. It may be the weak point of this system. Thus, in this paper, hierarchical meta data server mechanism is prepared and described. Through the experimental assessment, it was confirmed that the proposed system has high scalability of access speed.

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