Implementation of DICOM *Modality Worklist* at Patient Registration Systems in Radiology Unit

Daniel Kartawiguna and Vina Georgiana
Faculty Member, Information Systems Department, Bina Nusantara University, Indonesia

Abstract. Currently, the information and communication technology is developing very rapidly. A lot of hospitals have digital radiodiagnostic modality that supports the DICOM protocol. However, the implementation of integrated radiology information system with medical imaging equipment is still very limited until now, especially in developing countries like Indonesia. One of the obstacles is high prices for radiology information system. Whereas the radiology information systems can be widely used by radiologists to provide many benefit for patient, hospitals, and the doctors themselves. This study aims to develop a system that integrates the radiology administration information system with radiodiagnostic imaging modalities. Such a system would give some benefits that the information obtained is more accurate, timely, relevant, and accelerate the workflow of healthcare workers. This research used direct observation method to some hospital radiology unit. Data was collected through interviews, questionnaires, and surveys directly to some of the hospital's radiology department in Jakarta, and supported by the literature study. Based on the observations, the prototype of integrated patient registration systems in radiology unit is developed and interfaced to imaging equipment radiodiagnostic using standard DICOM communications. The prototype of radiology patient registration system is tested with the modality MRI and CT scan.

Keywords: Radiology Information Systems, DICOM, *Modality Worklist*.

1 Introduction

Application of information technology in healthcare issue is rather slow when compared with other fields such as banking, transportation, and trading. The healthcare system as being slow to understand information technology, to exploit it for its unique practical and strategic functionalities, and to incorporate it effectively into the work environment [1].

The condition above is due to different characteristics in healthcare that is different with common business applications. First, type of data and information in medical information systems mostly consists of alphanumeric data, graphic, image, and voice. Second, the healthcare workers as users are always mobile on doing their job. Third, beside physician or heathcare workers doing medical records, data sources may be obtained from high technology medical equipment producing analog/digital data. Fourth, mistake in processing may cause not only finance loss but also patient death. Fifth, the main function of medical information systems is not only for management purposes but also for maintenance of medical data useful for development in medical science.

Radiology unit is a hospital medical support unit which provides diagnostic services using both medical imaging equipment that uses ionizing radiation and non-ionizing radiation. Computer applications in radiology begin with the introduction of computed tomography (CT) that followed by other digital diagnostic imaging modalities in 1970. In line with the increasing use of computers in medical imaging applications, American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) developed DICOM (Digital Imaging and Communications in Medicine) Protocol, which is a standard method for transferring images and information between medical imaging devices and radiology information systems.

Aim of this research is to develop an interface that integrates radiology information systems and digital radiodiagnostic modality with DICOM protocol, especially for *Modality Worklist* (DICOM MWL) function. It can be used widely by doctors or radiographer in hospitals using digital radiodiagnostic modality that support DICOM protocol in order to speed up the patient administration process.

2 DICOM *Modality Worklist*

DICOM *Modality Worklist* is an excellent mechanism for transmitting patient and study information from the RIS to the image acquisition modality [2].

Although DICOM *Modality Worklist* has been a late entry into the implementation focus for paperless and filmless radiology, it is a key component that should be implemented to maintain as high a level of data integrity as possible and to speed up technical operations at the data collection points. Both radiologist and technologist productivity is improved with DICOM *Modality Worklist* in place. Interface design for DICOM *Modality Worklist*

is as crucial to successful implementation as successful networking and messaging between computer systems [3].

SOP (Service Object Pairs) *Modality Worklist* (MWL), shown in Table 1, is derived from the C-Find command, but provide completely different service functions. When the modality operator (radiographer or technologist) come to work, they will want to know the list of existing patients for examination, and even better if they have patient data that has been recorded on the modalities (such as CT or MR scanner). This is the actual function performed by the MWL SOP: sending and scheduling patient information into the examination modalities.

Table 1. *Modality Worklist* SOP.

SOP class name	SOP class UID
Modality Worklist	1.2.840.10008.5.1.4.31

This function puts MWL at the beginning of every DICOM workflow before the image is stored or scanned, as shown in Figure 1 [4]. To provide patient data and examination schedules to modalities, MWL SCP (Service Class Provider) need to get the data from somewhere. In most cases, this information comes from the Radiology Information System (RIS) in which patients were registered for radiological imaging examination. In case, RIS (or a similar system, used in certain clinical sites) are not based on DICOM - instead using the HL7 standard. So either the MWL server or DICOM broker need to convert the scheduling data from the RIS to DICOM additionally.

In this way, MWL SOP (server) takes demographic and scheduling patient information and store it in DICOM format. This is a time when MWL SOP communication begins, initiated by each modality. In the most common case, modalities that are configured to perform automatic request of MWL SCP server on a regular basis (with a minute period or more), take on a schedule that is available for each modality. Requests made by the command C-FIND-RQ, using MWL SOP UID 1.2.840.10008.5.1.4.31 in tag (0000,0002). To filter the schedule for each particular modality, type of modality (CT, MR, US, and so on) and AE (Application Entity) Title (for example CTSCANNERl) was used in addition to the command C-FIND-RQ-attached IOD (DICOM Information Objects).

In response, the MWL SCP (server) performs matching C-FIND-RSP (with the same UID MWL SOP) to restore data checks identified for each modality. This creates a worklist for each modality: the radiographer will know who should be served, when, and how. Then the whole cycle of making a list of patients recur for a minute or so, confirming that modalities have the latest scheduling information. In addition to the standard workflow, the modality operator can also use manual search interface, to have a more specific update schedule. When the patient is scanned, all MWL data transferred (such as patient name or date of birth) is embedded in the DICOM images, thus eliminating room for information error.

The main advantage is the DICOM MWL is:
• MWL eliminates manual data entry at the modality, reducing the main source of human errors and time wasted.
• Direct automatic fetching of MWL data from the RIS (Radiology Information System) makes the whole clinical support process quick, and reliable.
• MWL parameters such as pregnancy or allergy status, is usually supported by a modality, and important for different types of radiological examinations.

The main drawback of the MWL is the passive nature of these services, where modalities have to repeatedly pull MWL data from the MWL SCP server, and do not have the ability to cancel or delete the data that has been sent. Once the patient information/schedule is forwarded to the modalities, data will continue to be on the modalities, and can only be removed or edited by the modalities operator. In a busy clinic, patient information/schedule are subject to change at any time, and manually edit the patient data at the MWL modalities of after initial data pull, is incompatible with the real purpose of MWL.
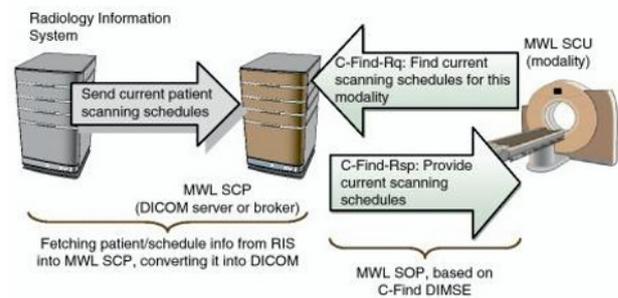

Fig. 1. Sample of DICOM *Modality Worklist*: transferring basic patient data to modality

This problem temporarily can only be solved by emptying MWL list for a day inspection plan or a time schedule scan next week. In the design of the system interface RIS, DICOM MWL mechanism must be "just-in-time". So the MWL data is only sent to the appropriate MWL server just before the data is required by the modalities operator. This approach minimizes the possibility of cancelling or edits information on modalities - and the benefits of automatic data flow free from typing errors can still be felt.

2.1 MWL IOD

IOD Modality Worklist contains information about a scheduled patient exam. In the form of a minimum, the information elements most commonly used in connection with information about the schedule of the examination patients are shown in Table 2.

Note that the elements (0040,0100) "Scheduled Procedure Step Sequence" SQ encoded with VR, so this element includes sub-order items (0040,0001), (0040,0002), and so on. This sequence encapsulates the schedule for scanning patients. When read from MWL

SCP, DICOM sequence matched pair on a modality and a specific time interval. Accession numbers in (0008,0050) was used to link the original inspection records in the Radiology Information System (which is usually generated Accession Number) with images obtained from DICOM modalities. After the Accession Number attribute stored in DICOM images (0008, 0050), then this information will link records checks in RIS and PACS uniquely.

Table 2. MWL IOD

(Group, Element)	Name
(0010,0010)	Patient Name
(0010,0020)	Patient ID
(0010,0030)	Patients Birth Date
(0010,0040)	Patient's Sex
(0010,21C0)	Pregnancy Status
(0008,0050)	Accession Number
(0032,1032)	Requesting Physician
(0008,0090)	Referring Physician's Name
(0040,0100)	Scheduled Procedure Step Sequence
>(0040,0001)	Scheduled Station AE Title (name of the modality)
>(0040,0002)	Scheduled Procedure Step Start Date
>(0040,0003)	Scheduled Procedure Step Start Time
>(0008,0060)	Modality
>(0040,0006)	Scheduled Performing Physician's Name

The list in Table 2 is a minimum list. In practice it is possible a particular modality will require more data to be reflected in the Declaration of Conformity DICOM modality in question. If some of the attributes that are not specifically given to the modalities, it would likely result in cancellation of MWL data transfer, so inevitably a complete list of attributes must be met. In other words, to develop MWL connectivity, it always has to start with understanding the modalities of the Declaration of Conformity. List the required attributes must be in accordance with the modalities provided by MWL SCP.

2.2 MWL DIMSE

DICOM Message Service Element or DIMSE is service commands in the DICOM protocol. MWL DIMSE is not different with C-FIND service command, which facilitates the implementation of MWL (Figure 2). So there is no table of MWL-RQ and MWL-RSP appear in this section because this command is identical to the C-FIND-RQ and C-FIND-RSP. The only real difference is

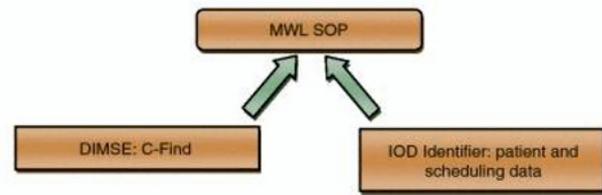the attribute value (0000,0002), which is worth l.2.840.l0008.5.1.4.31 for Modality Worklist SOP service.

Fig. 2. *Modality Worklist* SOP [4]

3 Radiology Information Systems

A Radiology Information System (RIS) is a computer system designed to support operational workflow and business analysis within a radiology department. A RIS is also a repository of patient data and reports, and contributes to the electronic patient record [5]. RIS is usually combined with Picture Archiving and Communication Systems (PACS) as a single product.
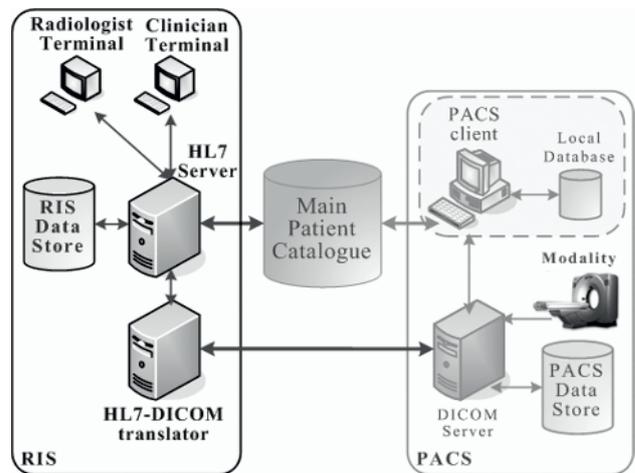
Fig. 3. RIS Architecture as part of a cooperative scheme with PACS

RIS architecture is composed by five structural entities, as shown in Figure 3: RIS Data Store, HL7 Server, HL7/DICOM Translator, Clinician Terminal and Radiologist Terminal [6].

Interfacing of RIS and PACS is an important part of implementing an electronic radiology department. Different levels of interfacing and integration between these systems are possible. It is essential that RIS and PACS communicate basic information such as patient demographics and patient examination information. Higher levels of integration provide important additional functionality to an electronic radiology department, such as when the RIS and PACS system interact for image prefetching and image routing. As PACS and RIS integration improves, electronic radiology departments will see increased benefits including improved workflow, improved data integration and improved patient care [7].

Medical systems can provide better services if they work cooperatively, sharing data with each other as needed. Patient identification information is a critical

piece of data that must be identical in all systems in order to link result data to the correct patient [8].

4 Research Framework

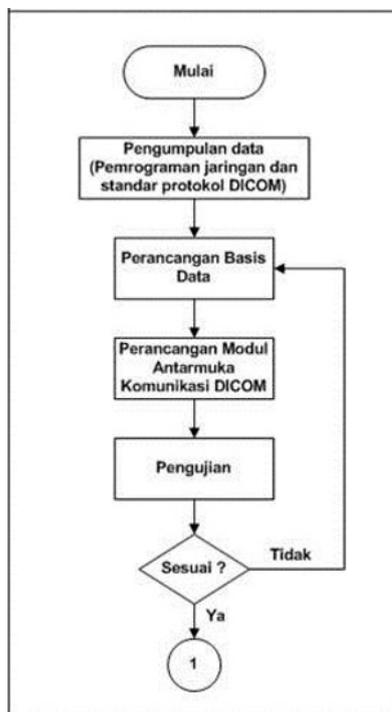Figure 4 below is a picture of the reference framework of study for the first phase of research:

Fig. 4. Research Framework for the 1st phase

Data was collected through observation, and literature study, as follows:
a. Gather information, journals, textbooks on radiology information systems, PACS, socket programming with JAVA, and DICOM protocol.
b. Learn radiodiagnostic equipment method of use and workflow of radiology departments in hospitals.
c. Studying the data transmitted over a LAN network with the TCP/IP socket programming with JAVA.
d. Studying the DICOM protocol in general and DICOM Basic Worklist functionality specifically.

Database design is done by studying DICOM Worklist communication using DICOM Worklist emulator and radiodiagnostic equipment (MRI). Communication exchange is analyzed using a network analyzer application. After learning data packets sent and received by the radiodiagnostic device, then the database systems design of radiology patient registration can be conducted.

After the database design, user interface design is carried out for radiology patient registration system. Interface module for radiology patient registration system is designed following the eight (8) the golden rule, namely: Consistency, allows user to use shortcuts, Provide informative feedback, designing dialogues for each sequence of activities that are organized in a group

with the beginning, middle, and end. Provide simple error handling, easy to return to previous action, Supports internal locus of control, and Reduce the burden of short-term memory by providing a simple look or a lot of page views that is put together, and given enough training time to code, mnemonic, and action sequences.

Devices required in this study consists of hardware, software, and computer network infrastructure (LAN). The hardware required is a computer for application development, the computer to be used as a DICOM emulator, Ethernet LAN network, and radiological imaging modality that supports the DICOM protocol to support the Modality Worklist. While the required software is Windows operating system, in this case the use of Microsoft Windows XP, Java Development Kit, Text Editor, Network Application Protocol Analyser, Database Applications, and Application DICOM emulator.

Notebook computers with the Microsoft Windows XP operating system functioned as a DICOM Worklist server is connected via a local computer network with Siemens MAGNETOM Avanto MRI machine that acts as a DICOM Worklist user (SCU). Communication occurs when the MRI request worklist data available on the DICOM Worklist server to be analyzed using the Network Application Protocol Analyzer Version 1.6.8 Wireshark running on a DICOM Worklist server and compared with the log available on the DICOM Worklist server.

Testing is done by simulation tests using the MRI and CT scan radiodiagnostic imaging equipment to observe the success of data communication exchange between radiodiagnostic imaging devices with patient registration information system in the radiology unit.

5 Results

Research outcomes generated in the first year of study, include: Survey Results, Interface Module (prototype interface) for Patient Registration System in Radiology unit, and Programming Java Class DICOM Modality worklist.

Based on the survey that was conducted to radiology units of several hospitals in Jakarta, associated with the research objectives have been formulated above, the data processing shows the following:
a. 70% of hospital radiology agency is not using a Radiology Information System.
b. Radiology Information System currently implemented in hospitals is not integrated with radiodiagnostic imaging equipments.
c. The need of the management and the medical staff to have easy access to information and reports.
d. The need for information compatibility between patient registration processes by tracking a patient's medical information in order to improve health care.
e. The importance of timely reporting of the results of a medical examination between the radiologist and the referring physician.

f. Completeness of the information generated by the radiology information system integrated with radiodiagnostic imaging equipment may accelerate the medical records process in radiology unit.

Interface Module Design (prototype interface) for Patient Registration System in Radiology unit shown in Figure 5.
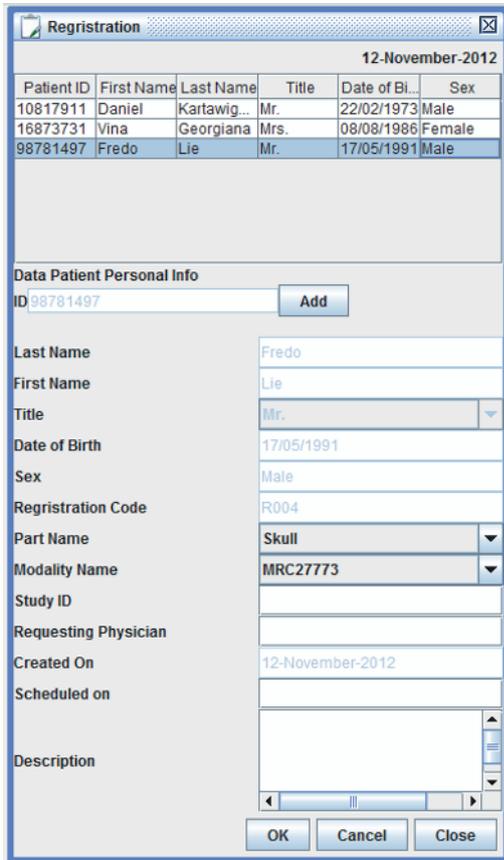

Fig. 5. Radiology Patient Registration System Interface

Java class for DICOM Modality worklist programming is created to transfer patient data from Patient Registration System to radiodiagnostic imaging modalities like CT Scan, MRI, and other digital radiology equipment using DICOM communication protocol.

To be able to communicate using DICOM protocol, the following information is absolutely necessary:
1. AE Title (AET) - alphanumeric characters up to 16 characters.
2. IP address of AE (application entity).
3. AE port number.

This information should be available for both SCP (Service Class Provider) and SCU (Service Class User) for the association before the data transfer can be done.

The circuit mechanism DICOM Modality Worklist communication process:
1. SCU sends a request message to the SCP association (A-ASSOCIATE-RQ).
2. SCP accepts requests the association and the association will be formed between the SCP and SCU (A-ASSOCIATE-AC).

3. SCU sends C-FIND command (C-FIND-RQ-DATA), to request delivery of data from the worklist SCP.
4. SCP responds to commands given by the SCU (C-FIND-RSP) and transmits data from the worklist SCP to the SCU (C-FIND-RSP-DATA).
5. SCP provides information when all commands have been implemented to the SCU (C-FIND-RSP).
6. SCU apply for termination of the association to the SCP (A-RELEASE-RQ).
7. SCP responded by terminating associates (A-RELEASE-RP as a response of the request for termination of the association).

In order to develop a prototype in this study, a class from the class library JDCM is used. The jdcm.jar package is imported into applications that are developed with the command: import jdcm. *;

Constants used in this StaticProperties class are:

```
AETitle (default: JDCM)        AET
Implementation Class           UID IMPLEMENTATION_CLASS
Implementation version         IMPLEMENTATION_VERSION
Verbose (default false)        VERBOSE
Max PDU Size (default 16384)   MAXIMUN_LENGTH
Organization root              UID ORG_ROOT
```

DICOM Modality Worklist Application acts as a receiver of association, so it will wait for incoming TCP/IP connections to the accept() method from java.net.ServerSocket on a specific port number (eg. 104) and devotes DCMServer thread for each incoming connection. Therefore, a class should be provided to process the new association. This class should be created by extending the class DCMServer.

```
public class AppSCP extends DCMServer {
public AppSCP(Socket socket){
super(socket);
…
}
public static void main(String[] args){
try {
AppSCP appSCP;
Socket socket;
ServerSocket serverSocket = new
ServerSocket(104);
while(true) {
socket = serverSocket.accept();
appSCP = new AppSCP(socket);
appSCP.start();
}
} catch(Exception e){...}
}
}
```

Before DICOM messages can be exchanged at all association then the association acceptor shall accept or reject the association request of the applicant association. If the application is agreed and the service request can be accepted, the application will call the method writeRPS() to establish the relationship between the two applications. If no agreement is reached for some reason, the reject() method is called.

```
public void A_Associate(A_Associate
associate) throws IOException {
associate.readRQ();
```

```
callingEntity =
associate.getCallingEntity();
calledEntity = associate.getCalledEntity();
...
if (<layanan dapat diterima>)
associate.writeRPS();
else
associate.reject(A_Associate.REJECTED_PERMA
NENT,1);
}
```

DIMSE services required for DICOM Modality Worklist Management communication is the C-Find. In order to perform the function of C-Find classes are created to override the DCMServer method.

```
public void C_Find(DimseService
dimseService)throws IOException
```

The general pattern for DIMSE service method is to extract information from the request, processes the information and then provide feedback. Request contains data passed between client and server. DimseService class defines methods for accessing the following information: transfer syntax used in property set of commands: MessageID, status, priority set of commands and data.

Delivery of messages is done using a sub-class of the class DimseService, such as: C_Echo, C_Find, C_Get, C_Move, C_Store, N_Action, N_Create, N_Delete, N_Event_Report, N_Get, N_Set to send messages and instances related to a specific association with a passing reference A_Associate as a parameter in the constructor class. Sub class DimseServices requires SOP Class UID information on composite messages objects to be delivered; therefore method setAffectedSOPClass() should be given UID parameter.

```
C_Find find = new C_Find(associate);
find.setAffectedSOPClass(
StaticProperties.InformationModelFINDPatien
tRootQueryRetrieve);
```

Method writeRQ() is used to send the request message.

Sub class DimseService DicomSet requires references to objects that encapsulate the message that will be sent as follows:

```
//Dicom set mengenkapsulasi pesan yang akan
dikirimkan
DicomSet dicomSet = new DicomSet();
dicomSet.setElement(new
DicomElement(0x0008,0x0052,"CS","PATIENT"))
;
dicomSet.setElement(new
DicomElement(0x0010,0x0010,"PN","*"));
dicomSet.setElement(new
DicomElement(0x0010,0x0020,"LO","*"));
dicomSet.setElement(new
DicomElement(0x0010,0x0040,"CS","*"));
find.writeRQ(dicomSet);
do{
dicomSet = find.readRPS();
//mengembalikan status pesan tanggapan
status = find.getStatus();
} while(status != 0);
```

Method getStatus() returns the status of the requested operation and must be a valid response code for the services involved. DICOM calendar code for specific commands is described in section 4 of the DICOM standard.

DICOM standard specifies that the association requester must decide associations when there is no further processing required. This is done by using A_Release class as follows:

```
A_Release release = new
A_Release(associate);
release.writeRQ();
release.readRPS();
```

Association termination or cancellation request status can be determined by using the class overriding methods DCMServer A_Release() and A_Abort ().

```
public void A_Release(A_Release release)
throws IOException
public void A_Abort(A_Abort abort) throws
IOException
```

At any time, each pair of the association may cancel the association in an abnormal situation with the command:

```
A_Abort abort = new A_Abort(associate);
abort.writeRQ();
```

After calling the release method or abort, then the socket and the associated closure is done with the command:

```
associate.close();
socket.close();
```

When the termination of the association has been made, then there is no other method associated with an object association that may be called.

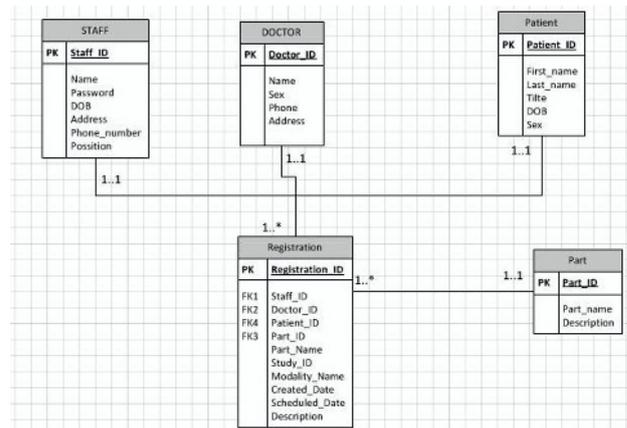Database design for the Radiology Patient Registration System unit is shown in Figure 6.

Fig. 6. Database Design of Radiology Patient Registration System

DICOM Worklist communication testing of radiological patient registration application has been developed, carried out with the radiology modalities of CT-scan and MRI. Notebook computers acting as DICOM Modality Worklist server is connected via a local area network with MRI machine acting as DICOM Worklist user (SCU). Communication occurs when MRI request worklist data available on the DICOM Worklist server to be analyzed using the Network Application Protocol Analyzer running DICOM Worklist server and compared with the log available on the DICOM Worklist server.

Figure 7 shows a prototype application for function test results with patient registration radiology imaging modalities with Magnetic Resonance Imaging or MRI. The data of patients who had been enrolled in a registration application has been transferred to the patient's MRI using the DICOM protocol over existing computer networks. Similar testing done by CT scan following the same procedure also functioned properly.

Fig. 7. Function test results with the MRI modality.

Communication success between radiodiagnostic imaging modalities with patient registration application at radiology unit using a DICOM Worklist improves the patient registration process, so that the input of patient data is only done once. Here is the proposed architecture of the system of patient registration radiology unit with radiodiagnostic imaging equipment, shown in Figure 8.

Fig. 8. Data exchange between radiodiagnostic modalities equipment with patient registration system.

6 Conclusions

DICOM protocol is a protocol developed in accordance with OSI standards. Each entity is declared as an object with its own attributes. This characteristic induces the use of object oriented programming in application development.

Based on the research in the first phase, the following conclusions can be obtained:

1. Ease of access to information and conformity information is needed to improve the effectiveness of patient care in radiology unit.
2. The success of communication between radiodiagnostic imaging modalities with the patient registration system in the radiology unit can increase the ease of access to information and the suitability of the information.
3. DICOM Protocol supporting Modality Worklist can be used to integrate the system of patient registration in the radiology unit with radiodiagnostic imaging modalities.

7 Recommendations

For further research, it is recommended to undertake the development from technical and information systems application point of view. From the technical side, it needs to develop its own DICOM library in Java to give more flexibility to the application and implementation of the DICOM protocol system. Additionally in terms of function it would be very useful to apply Modality Performed Procedure Step function (Retrieve and Notification) and a feature for transferring examination protocol from the patient registration system to modalities examination. From the information system application development point of view, patient registration in radiology unit should be integrated based on workflow of radiology unit with the hospital information system administration in order to improve the quality of health care services.

8 References

1. Shortliffe, Edward H., and James J. Cimino. Health Informatics: *Computer Applications in Health Care and Biomedicine*. 3rd ed. Springer Science+Business Media, LLC, New York. (2006).
2. Kuzmak PM, Dayhoff RE; *Minimizing Digital Imaging and Communications in Medicine (DICOM) Modality Worklist Patient/Study Selection Errors*. Journal of Digital Imaging, Vol **14**, No 2, pp 153-157, Suppl 1 (June), (2001).
3. Gale ME, Gale DR; *DICOM Modality Worklist : An Essential Component in a PACS Environment*. Journal of Digital Imaging, Vol **13**, No 3 (August), pp 101-108, (2000).
4. Pianykh, Oleg S. *Digital Imaging and Communications in Medicine (DICOM): A Practical Introduction and Survival Guide*. 2nd ed. Heidelberg: Springer-Verlag. (2012).
5. The Royal College of Radiologists. Radiology information systems. The Royal College of Radiologists, London. (2008).
6. L. Kolovou, M. Vatousi, D. Lymperopoulos, M. Koukias; *Advanced Radiology Information System*. Proceedings of the 2005 IEEE, Engineering in Medicine and Biology 27th Annual Conference, Shanghai, China, September 1-4, (2005).
7. Piraino D; *RIS and PACS Integration at the Cleveland Clinic Foundation*. Electromedica 67 no. 2, (1999).
8. Kuzmak PM, Dayhoff RE; *Experience with DICOM Interfaces at the Department of Veterans Affairs*. Journal of Digital Imaging, Vol **10**, No 3, pp 144-145, Suppl 1 (August), (1997).