ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

SWF: Scheduled Workflow Integration Profile for the Connectivity Problems in Radiology Workflow.

Vinay Kumar E* and Prabadevi B.

School of Information technology and Engineering, VIT University, Vellore, TN, India

ABSTRACT

In this connected world most of the devices are able to interact and share information with each other. Modern hospitals are equipped with various medical systems like CT, MRI, and Ultrasound etc. which are often from different equipment manufactures. The kind and amount of data generated by these devices results in an increased complexity for analyzing the information and to diagnose the patient. Exchange of the clinical data among these medical systems requires connectivity and a defined structure for the data. As these medical systems operate in multi-vendor environment there is the need for a standardized format for the information to be exchanged so that each device can actually receive, process, analyze, store encode and transmit the data in the specified format. Health Level-7 refers to the set of international standards for transfer of clinical and administrative data between the various software applications run by healthcare vendors. Digital Imaging and Communication in Medicine (DICOM) is a communication protocol in healthcare which defines the data structure to be exchanged between the medical systems. This paper aims to discuss the brief overview of these standards and their roles in resolving the radiology workflow integration problems.

Keywords: DICOM, Health Level-7, Radiology, CT, MRI, Ultrasound.

Corresponding author

INTRODUCTION

In recent years the Healthcare enterprise entered in to a new technological era with the application of communication and information technologies in medicine. There is a shift in information systems from past isolated Hospital Information System (HIS) and Radiology Information System (RIS) in to a new healthcare connected system which integrates the healthcare information management, patient information and medical imaging [7]. Earlier administrative systems for managing the patient data, Laboratory systems and financial systems for billing were completely isolated there was no interface or interaction between these systems. Patient data was either entered manually or captured from printer output or through screen scraping. Films were used for printing the Scanned images in laboratories. HL7 and DICOM are most commonly used standards in healthcare for sharing and communicating the information. HL7 mainly used for communicating the administrative data. DICOM is mainly used for collecting, processing and storing of medical images and patient related information [1]. Integrating Healthcare Enterprise (IHE) is an initiative taken by the professionals of healthcare to resolve the various integration problems involved in radiology workflow by making use of existing standards (HL7, DICOM, ISO etc.). Scheduled Workflow (SWF) Integration Profile it is one of the IHE profile designed to resolve various integration problems involved in patient care workflow. This paper discuss the Scheduled Workflow (SWF) Integration Profile of IHE which addresses the problems in integration of registering of patients, scheduling the procedures, imaging acquisition, storage of images and viewing activities associated with radiology workflow.

BACKGROUND

Earlier in Hospitals before the development of HL7 and DICOM healthcare standards conventional methods was used for the communication of information within the hospitals. Medical records related to Patients like Patient Identification, out-Patient Registration were completely paper based processes.

In early 1960's mainframe based medical support systems developed with their own databases were dominant. In 1970's there was an evolution of Mini computers acting as a clinical support subsystems. These systems played a major role in providing the clinical services for Radiology, pharmacy and in clinical areas. These clinical support systems served better than the mainframe based support systems. There was an increasing interest for using the minicomputer based systems at various clinical platforms, which results in increase of headache since most of the hospital vendors were using clinical support systems which are based on mutilframe technology for financial and registration needs and to support some extent even for order entry, Which results in ever increasing need for the system integration for clinical data interchange.

Clem McDonald and Donald W.Simborg are the two key persons who laid the path towards the development of HL7 protocol. Clem McDonald is the person behind the publications of ASTM (American society for Testing and materials) E1238 and E1294 standards for clinical data interchange. Don Simborg the key person who laid the foundation of HL7 was Chief Information Officer (CIO) at University of California at San Francisco (UCSF) Medical Centre. He developed a "back-end" network (figure 1) which enabled the computers handling exchange of messages without any user interaction, resulting in a first application-level clinical data interchange protocol in health care domain.

It was a challenging approach during the implementation stage of HL7 to deviate from the 'single-vendor' mainframe-computer-based model which was used in many hospitals on those days.

In mid 1980s there was a transformation from manual transmission of diagnostic images through films to transmission of diagnostic images digitally using a medical imaging technology called Picture Archiving and Communication System (PACS) [6]. PACS mainly performs real time gathering, storing, analysing and transmission of medical images and associated information [7]. PACS was developed with the intention to eliminate the manual retrieval and transmission of film jackets. Due to the usage of different format for storage and transmission of diagnostic images among the medical devices manufactured by different vendors leads to an issue in exchange and storage of information among the medical devices. In order to overcome these issues American College of Radiology (ACR) and National Electronics Manufacture Association (NEMA) framed a committee and drafted a standard called Digital Imaging and Communication in Medicine (DICOM).

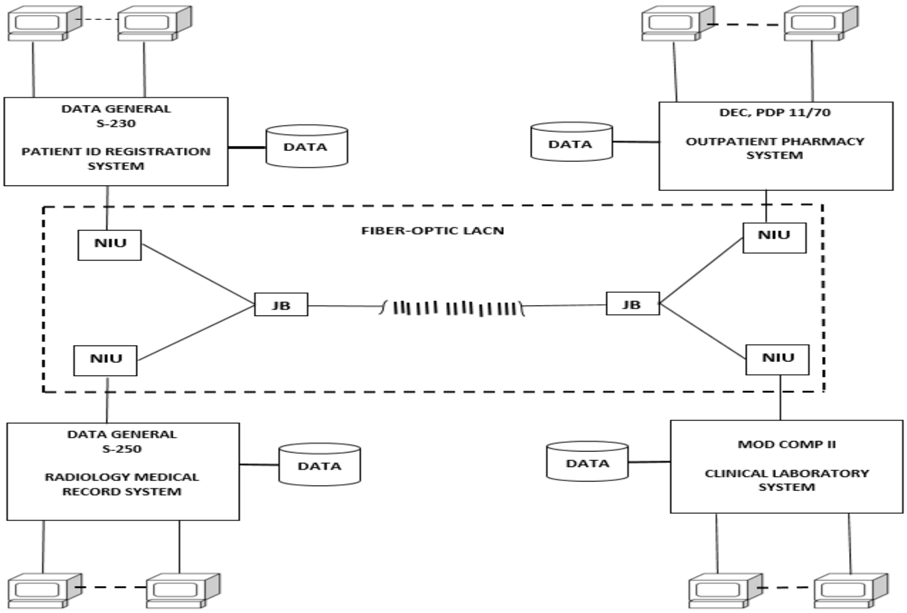


Figure 1: UCSF System Diagram

OVERVIEW OF TWO STANDARDS

HL7 STANDARD

HL7 version 1 protocol got published in October 1987.The "Level-7" refers to the application level, the seventh level of Open System Interconnection model (OSI) developed by International Organization for Standardization (ISO).The HL7 defines a set of standards, definitions and formats for exchanging and development of Electronic Health Records (EHRs) to communicate clinical and administrative data irrespective of specific communication technology or healthcare domain. The goal of the HL7's is to standardize format for management and clinical information by developing the hospital data transmission standards and protocols. And also to reduce the efforts and cost needed in custom interface programming by simplifying the implementation of interfaces between various healthcare software applications and to enhance the data sharing capability between the hospital information systems.

Electronic medical record (EMR) refers to the systematized collection of patient electronically-stored health information in a digital format [2]. EMR are created with an aim to improve the clinical performance, eliminate the medical errors and also to provide patient access to their own health information [2]. EMR includes range of patient information like medical history, allergies, radiology images, laboratory results and personal information like individual patient sex, age, weight and other financial data like billing information etc. The EMR is shared among the various information systems.

The major application areas of HL7 is Hospital Information System (HIS) and Radiology Information System (RIS) [7]. It regulates HIS, RIS and their interaction between devices, related to patient registration system, Laboratory system, radiology system and other aspects of administration like billing system. The standards of HL7 describes mainly the structure and formats related to management and administrative data [7]. The transaction set of HL7 describes the structured clinical data related to patient which is more in the form of text and numbers communicated between the systems. The transaction messages of HL7 doesn't carry the image, this leads to the path for development of standard which supports transmission of images.

ISSN: 0975-8585

TAG	Attribute Name	Value Representation
(0010,0010)	Patient Name	PN
(0010,0020)	Patient ID	LO
(0010,0030)	Patient's Birth Date	DA
(0010,0032)	Patient's Birth Time	TM

Table 1: Attributes of Patient Root Query/Retrieve Information Model –FIND SOP class of DICOM

DICOM STANDARD

ACR-NEMA framed a joint committee in the 1983 to meet the needs of equipment manufacturers and to provide interface for medical imaging equipment's to the displays or with other connecting devices like PACS, Work Station etc. The committee surveyed many existing standards and adopted an idea of using data elements of variable lengths identified using Key or tag from the standard of Storing medical images in magnetic tapes developed by American Association of Physicists in Medicine (AAPM).The first version of the standard is released in 1985 on the name ACR/NEMA 300 version 1.0 was distributed during the annual meeting of Radiological Society of North America (RSNA) [6]. The version 1.0 undergone subsequent improvements by fixing the errors and in 1988 second version of the standard ACR-NEMA 300 version 2.0 was published. This version retains the hardware specifications and resolved various errors of version 1.0 and also includes few new data elements. The version 2.0 was originally designed for point-to-point interface though it supports high data transfer but lacked in the parts for the direct interface to the network. After lot of reworking on feedbacks and suggestions from industry and universities, committee in 1993 released version 3.0 of the standard on the name DICOM 3.0. This version addresses the gaps in version 2.0 by specifying the items necessary for implementing the interface to the network which supports Transmission Control Protocol/Internet Protocol or ISO Open Systems Interconnect standards. DICOM follows the client/server network model. In every DICOM service one DICOM node acts as a service class user (SCU) and another node acts as a service class provider (SCP). The same DICOM node can act both as a SCU and SCP based on the context. The SCU raises the request for a service by initiating the Association and SCP grants the service after accepting the association and it is SCU closes the connection after the completion of the requested service. The SCU raises the Association request by proposing single Abstract syntax and one or more transfer syntax, similarly the SCP accepts the any of the supported transfer syntax and sends the Association Accept response. The figure 2 describes the protocol model of the DICOM.

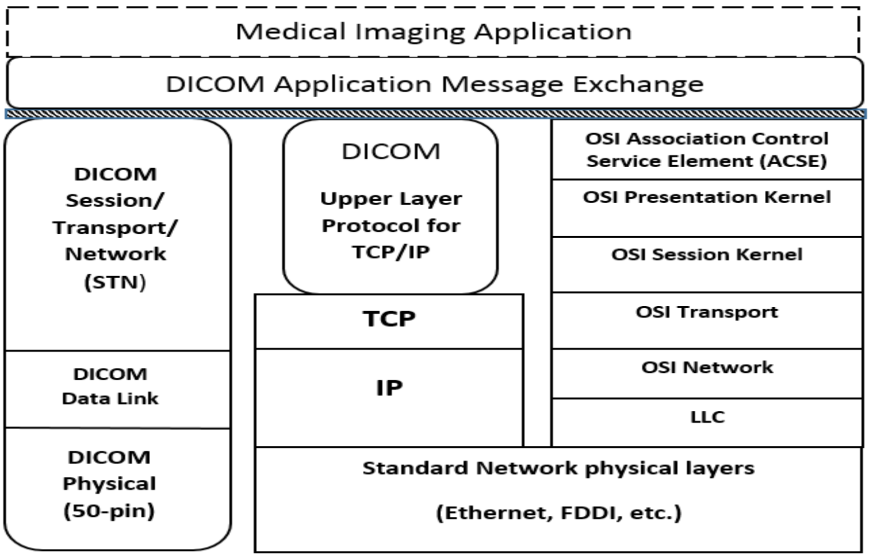


Figure 2: DICOM Protocol Model

DICOM is a much larger standard and also supports more other features than version 1.0 and 2.0.Data elements in version 1.0 and 2.0 modelled based on the experience of the designer were as data elements in

DICOM modelled based on Entity-Relationship model which defines “how the data elements are related to each other”. DICOM standard follows Object Oriented Design Methodology and make use of widely accepted standards as far as possible. DICOM standard mainly emphasis on two things: Data Structures for storage and Communication. Data structure describes about the structure and format of images and associated data exchanged among the PACS, Medical imaging equipment’s and other Information systems [7]. Communication aspect describes the definition of the protocol to be followed among the PACS and other nodes [5].DICOM messages contains two Parts, Command set and Data set refer figure 3.

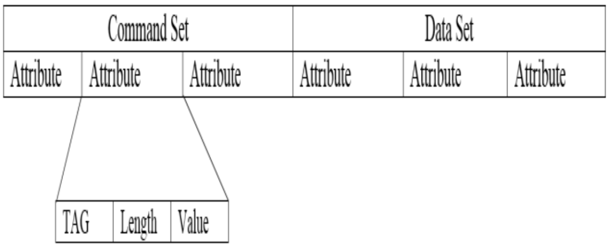


Figure 3: DICOM message divided in to command set and data set

Command set describes about the data in the data set. Data set contains a list of attributes, every attribute is identified by a tag [5]. Set of related attributes forms an Information Object Module (IOM) and further a set of related IOM forms an Information Entity (IE). A collection of one or more IE forms an Information Object Definition (IOD) and collection of IOD’s forms a service object pair class (SOP). The Table 2 describes the IOD of Computed Tomography Image.

IE	Module
Patient	Patient
	Clinical Trial Subject
Study	General study
	Patient Study
	Clinical Trail Study
Series	General Series
	Clinical Trial Series
Equipment	General Equipment
Frame of Reference	Frame of Reference
Images	General Image
	General Reference
	Image Plane
	Image Pixel
	Contrast/Bolus
	Device
	Specimen
	CT Image
	Overlay Plane
	VOILUT
	SOP Common
	Common Instance Reference

Table 2: Computed Tomography Image IOD

INTEGRATING THE HEALTHCARE ENTERPRISE (IHE)

Integrating the Healthcare Enterprise (IHE) is an initiative taken by the Hospital Information and Managements Systems society (HIMSS), Radiological society of North America (RSNA) and American College of Radiology in 1998 [3]. The purpose of this initiative is to achieve interoperability and communication among various medical systems for effective and convenient access to the patient data and clinical information. The integration of PACS with other medical equipment like digital imaging devices and information systems makes diagnosis process much more convenient by an effective transmission of both administrative and imaging data. Achieving connectivity among these equipment’s is one of the major challenge for IHE due to the usage of varied technologies, proprietary protocols and communication standards.

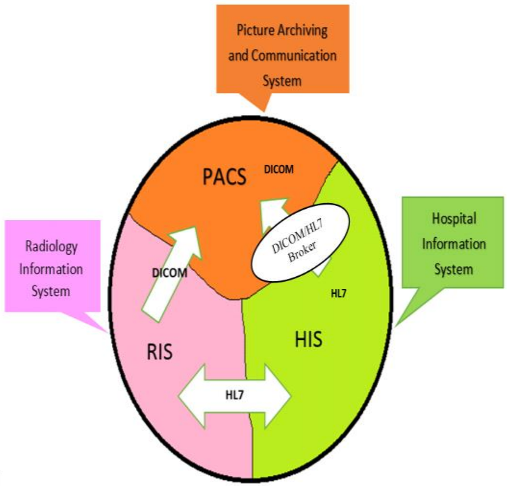


Figure 4: Integration of two standards and its range of Applications

IHE organization does not develop new standards, but describes how to make use of the existing standards (HL7, DICOM, ISO etc.) to address the various integration problems in healthcare [3]. IHE Integration profiles provides a common language which can be used by healthcare professionals and vendors for communicating the requirements for the integration of products. IHE profiles describes specific set of capabilities of integrated systems or real world scenarios and documents the solutions, by making use of the existing standards for various integration problems. An Integration Profile applies to a specified set of actors and for each actor specifies the transactions necessary to support those capabilities. Every IHE profile refers to the set of actors and specifies the set of transactions required in implementing those capabilities. The figure 5 describes the various integration profiles framed by IHE.

SCHEDULED WORKFLOW INTEGRATION PROFILE (SWF)

Scheduled Workflow is one of IHE Integration profile designed to establish the continuity and integrity of basic departmental imaging data .SWF integration profile specifies set of transactions required to maintain the consistency in ordering, patient information, scheduling of activities and image acquisition procedure steps. The figure 6 provides overview of activities between actors in workflow.

This profile makes sure the images and other objects associated with a particular performed procedure step have been archived and they are available for the subsequent activities in the workflow, like reporting. SWF Integration profile describes the semantic mappings between the messages which bridges the gap between HL7 based systems like RIS and DICOM based systems like modalities and PACS. In overall SWF integration profile provides the central coordination for completion of reporting and processing steps in radiology workflow. The figure 7 describes the various actors involved and the transactions between them.

The following are various scenarios under “normal” circumstances addressed by the SWF integration profile for the process and information flow during the patient care:

ADMINISTRATIVE AND PROCEDURE PERFORMANCE PROCESS FLOW

The above case covers for both outpatient and inpatient procedures. The figure 8 describes the sequence of steps involved in a typical radiology workflow flow when there is a request for performing the imaging procedure of a patient.

After ADT registration system registers the patient by sending a Patient Registration [RAD-1] message to the Order Placer and Department System Scheduler/Order filler. Patient Registration [RAD-1] compliance with HL7 standard. Order placer places the new order or cancel the order through Placer Order Management [RAD-2] which is compliance with HL7 standard. Oder Filler schedules the procedure by sending Procedure Scheduled [RAD-4] message to the Image Manager. Acquisition Modality through Query Modality Worklist [RAD-5] which is compliance with HL7 standard queries for the scheduled procedures in order filler.

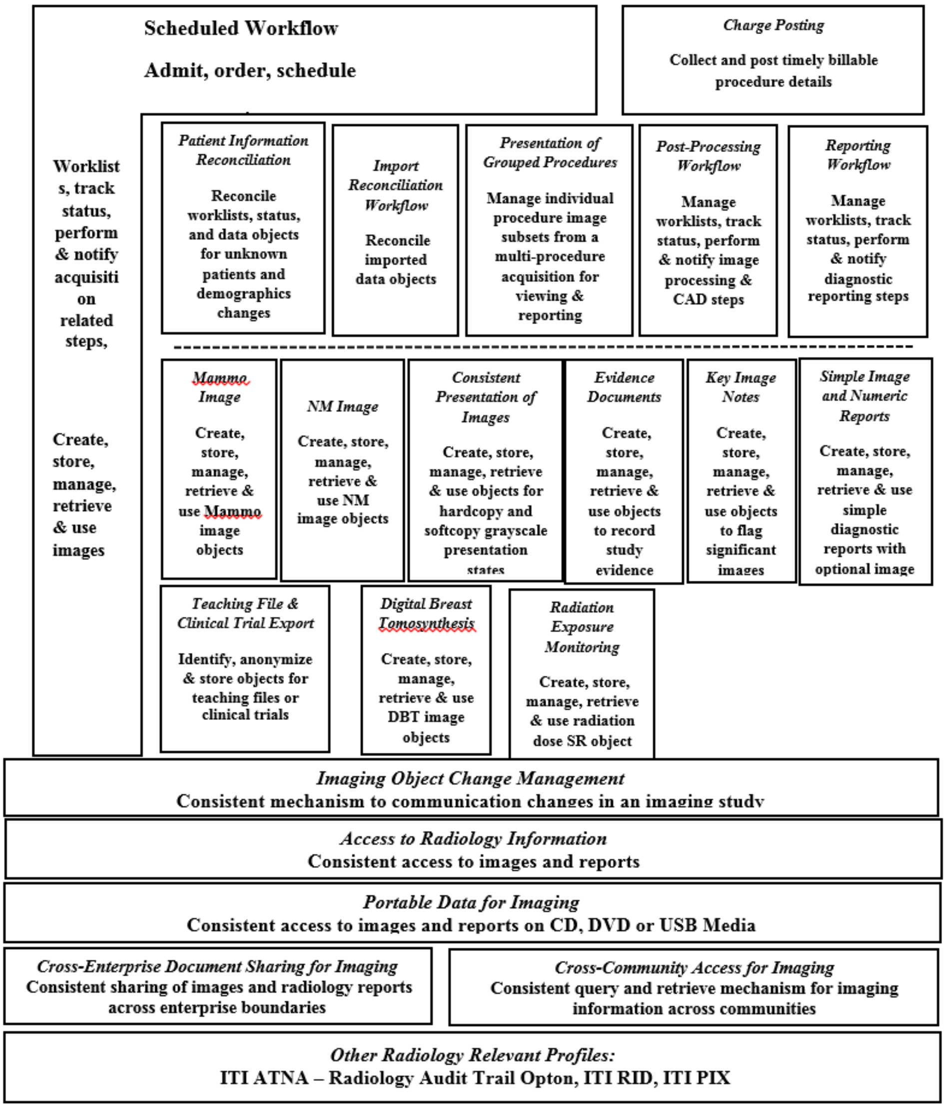


Figure 5: IHE Integration Profiles

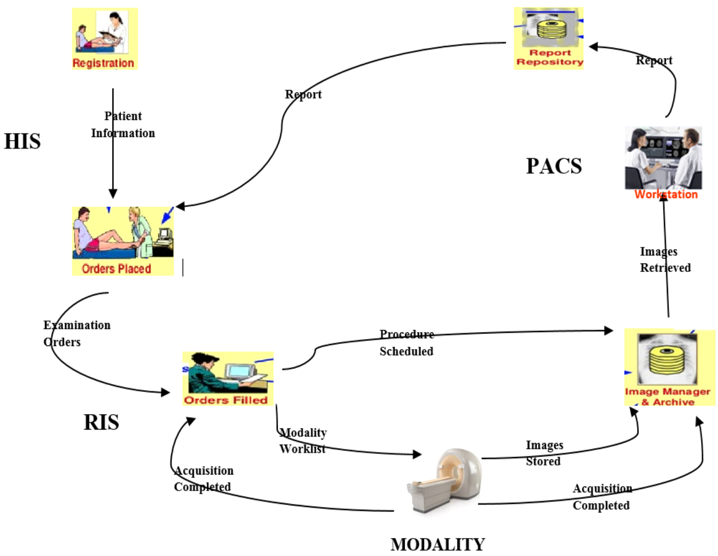


Figure 6: SWF Integration Profile

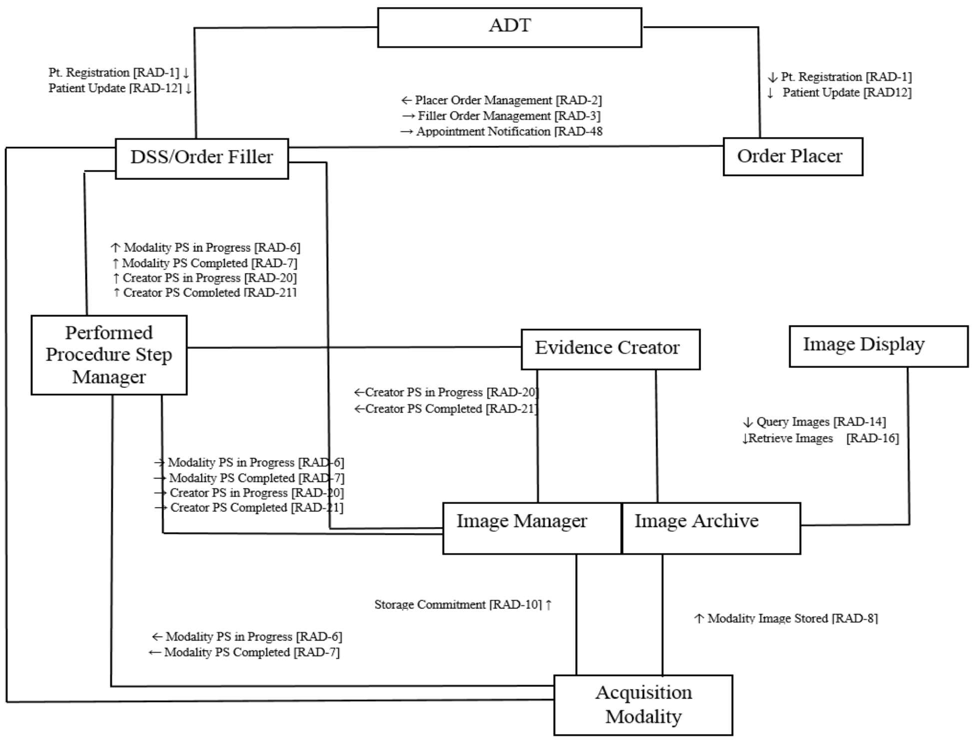


Figure 7: Actors and Transactions between them in Schedule Workflow Integration Profile.

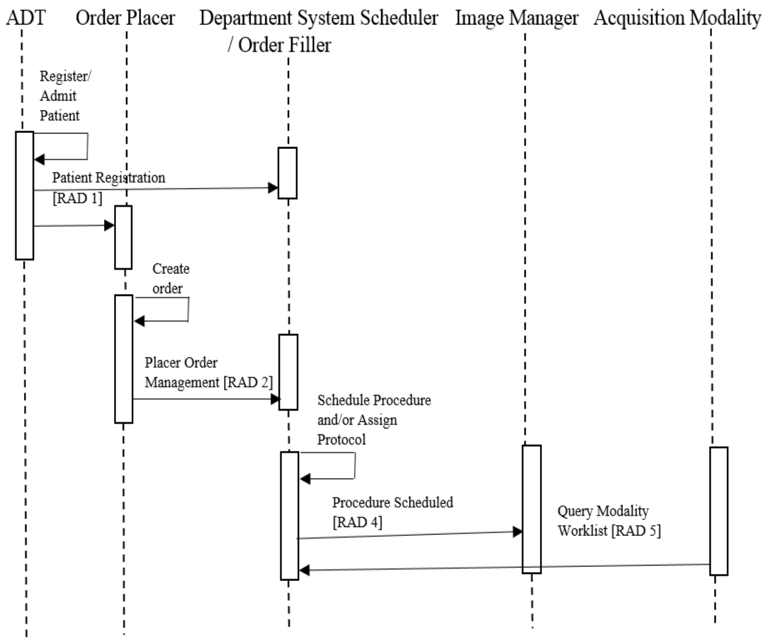


Figure 8: Administrative Process Flow

Acquisition Modality indicates the particular performed procedure step is started by sending the Modality Procedure Step in Progress [RAD-6] which is compliance with HL7 standard to the Performed Procedure step manager which in turns send the message to the DSS/order Filler. Similarly up on completion of the scheduled Procedure acquisition modality sends completion message via Modality Procedure Step Completed [RAD-6] message which is compliance with HL7 standard. Modality transfers the acquired images to the image achieve in one or more DICOM associations through Modality Images Stored [RAD-8] message which is compliance with DICOM standard.

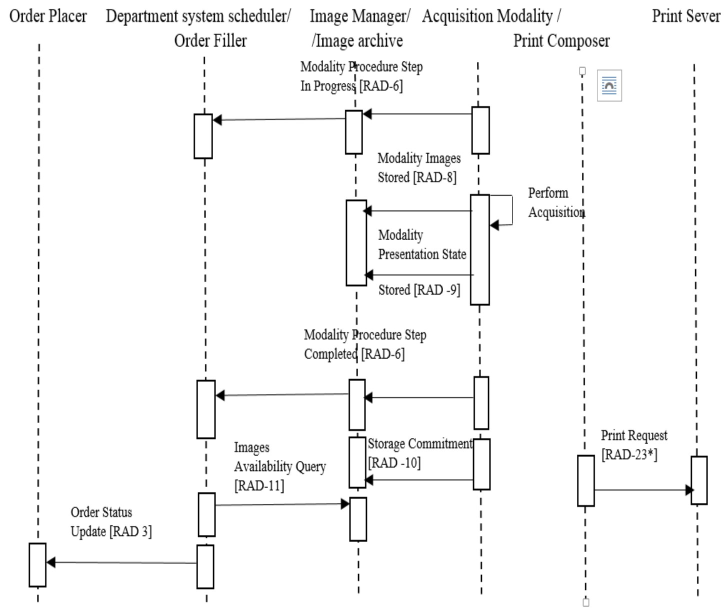


Figure 9: Procedure Performance Process Flow

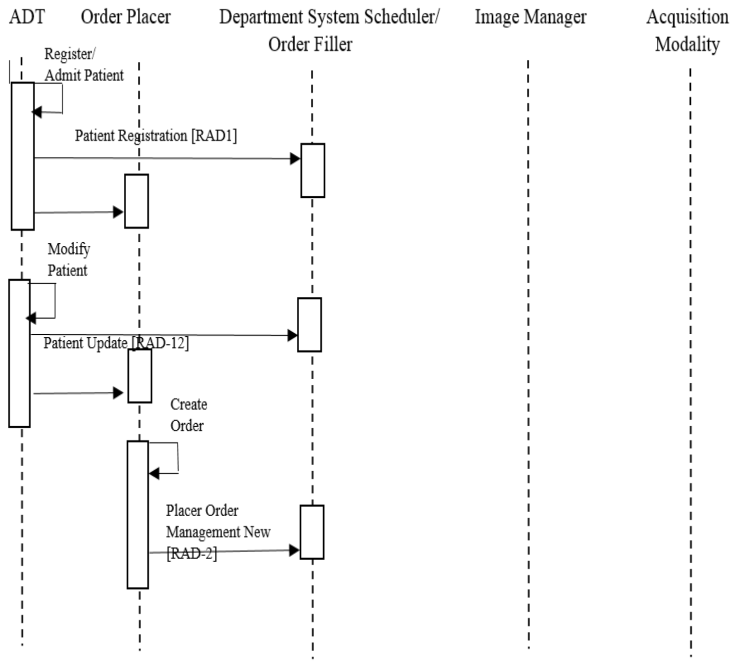


Figure 10: Patient Updated before Order Entry

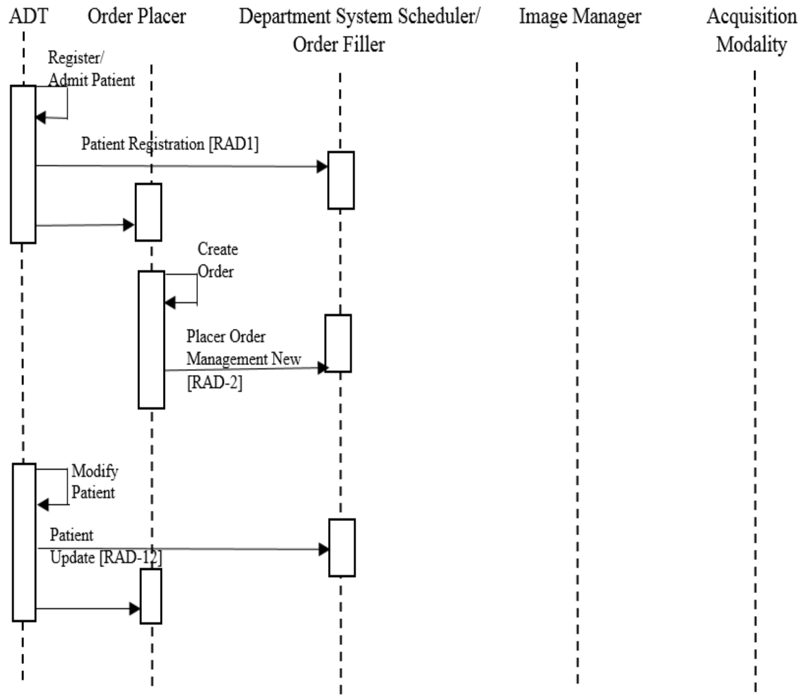


Figure 11: Patient Update after Order Entry

PATIENT UPDATE FLOW

The Patient update flow case covers the update of patient information occurs in the system at the various levels of the information flow to ensure the synchronization of information among the related actors. The following figure describes the process steps involved in update of the patient information before the corresponding procedure is scheduled by the DSS/Order Filler. Change of information after the registration of patient is handled using Patient Update [RAD-12] message which is compliance with HL7 standard initiated by the ADT registration system to the order filler and order placer. The figure 10 describes the sequence of transactions involved between the actors in radiology workflow during patient update.

The figure 11 describes the process steps involved after the corresponding procedure is scheduled by the DSS/Order Filler for update of the patient information.

DEPARTMENTAL APPOINTMENT BOOKING

The above case addresses the New order bookings, Rescheduling of orders or cancelling the orders by making use of Departmental Appointment Notification. In IHE SWF Integration Profile it is order filler responsible for the scheduling, rescheduling and the cancellation of orders. An Appointment Notification (New Bookings) compliance with HL7 standard is sent to the order placer when a new order is scheduled by order placer or order filler. Similarly up on rescheduling or cancelling the order an Appointment Notification (Reschedule Bookings) and Appointment Notification (Cancel Bookings) which are compliance with HL7 standard are sent to the order placer. The figure 12 describes the sequence of transactions involved between the actors in radiology workflow for departmental appointment booking.

CHANGE ORDER FLOW

The above case addresses the situation when the department system scheduler /order filler or order placer has to change the order information for the system that follows HL7 v2.5.1. IHE framework allows the order initiator to change the order information with a new information whenever the change is necessary. The figure 13 describes the steps involved in the radiology workflow when the change of order information is initiated by the Order filler.

Order filler/Department System scheduler can change the order received from the order placer. The figure 14 describes the transactions between the actors during the change of order flow in the radiology workflow.

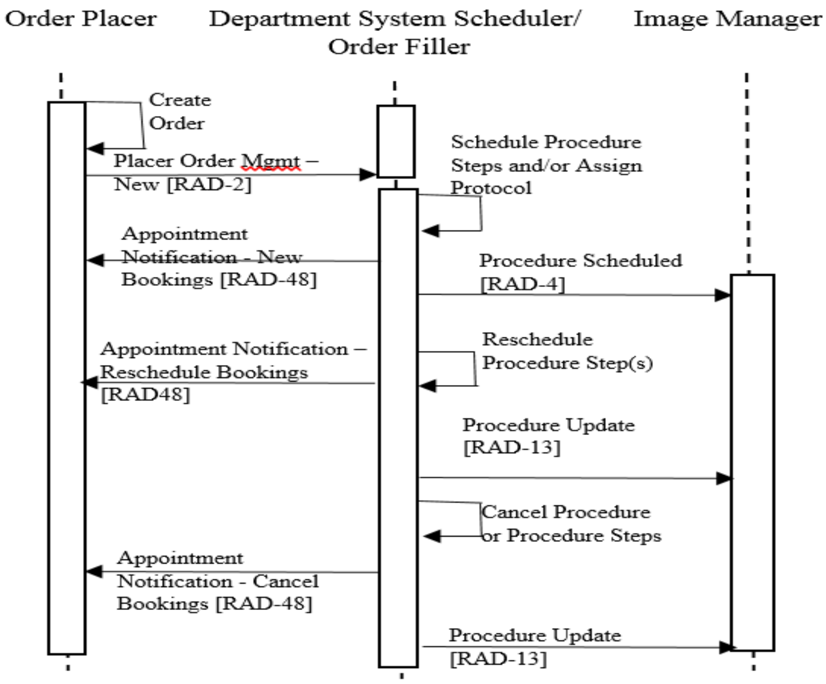


Figure 12: Departmental Appointment Bookings process Flow

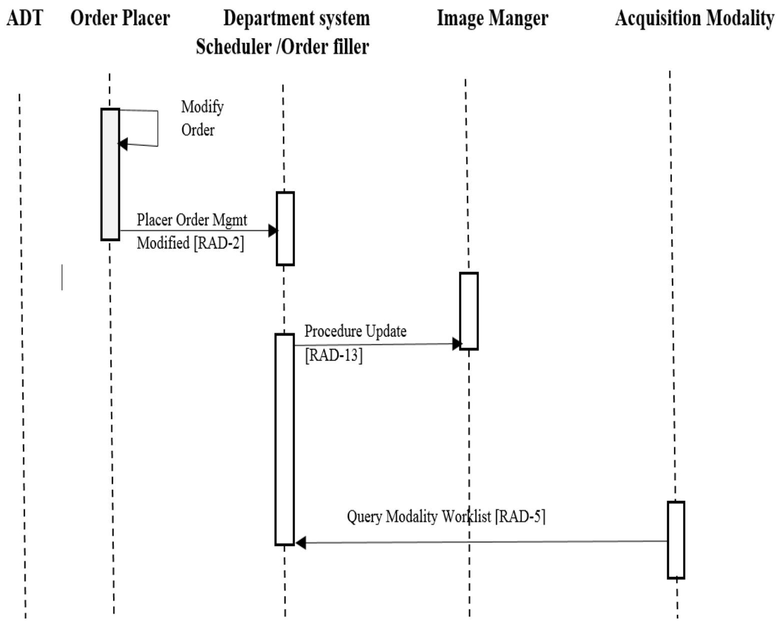


Figure 13: Oder modified by Order Placer

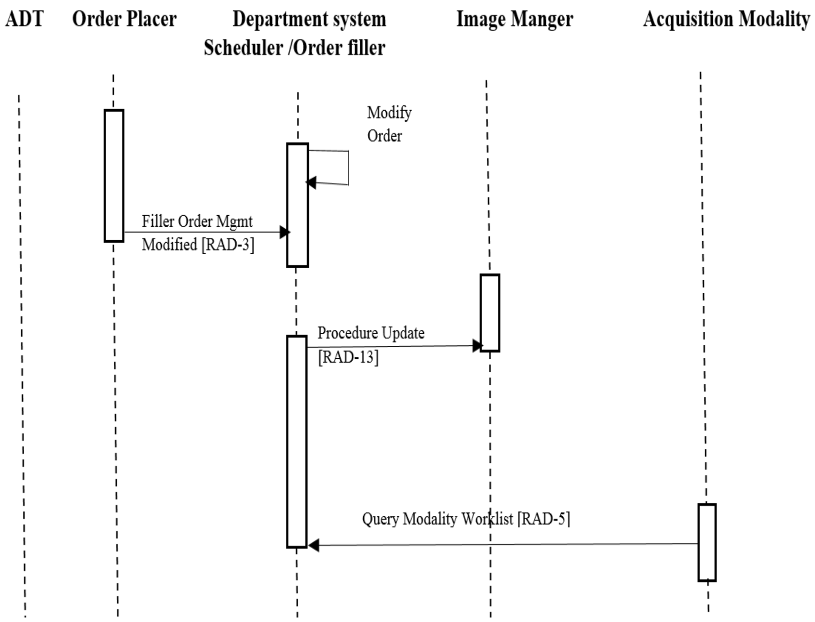


Figure 14: Order modified by the department system scheduler/Order filler.

RESULTS AND CONCLUSIONS

The table describes modality acting as a DICOM node trying to store the series acquired of a patient to the DICOM Validation Tool (DVTk) playing the role of PACS through C-STORE service defined in DICOM. Modality acting as SCU and DVTk acting as a SCP. First the modality sends an A-ASSOCIATE-RQ to the DVTk tool, after receiving ASSOCIATION confirmation message from the DVTk tool modality sends the C-STORE-RQ by sending the acquired images to the DVTk. DVTk sends C-STORE-RSP message indicating the images has been received.

The images stored in the PACS is retrieved to perform the post processing of the scanned images by the radiologist. Work station makes use of the Query/Retrieve service defined by the DICOM to retrieve and view the images. The following figure 15 describes the image obtained from modality launched in the Sante viewer after retrieving from the PACS.

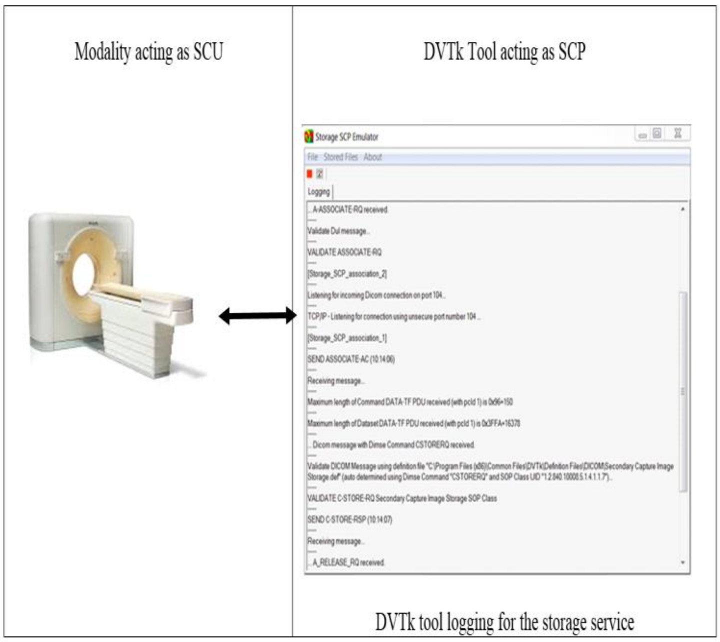


Figure 15: Screenshot of the C-STORE service between MRI Modality and DVTk Tool

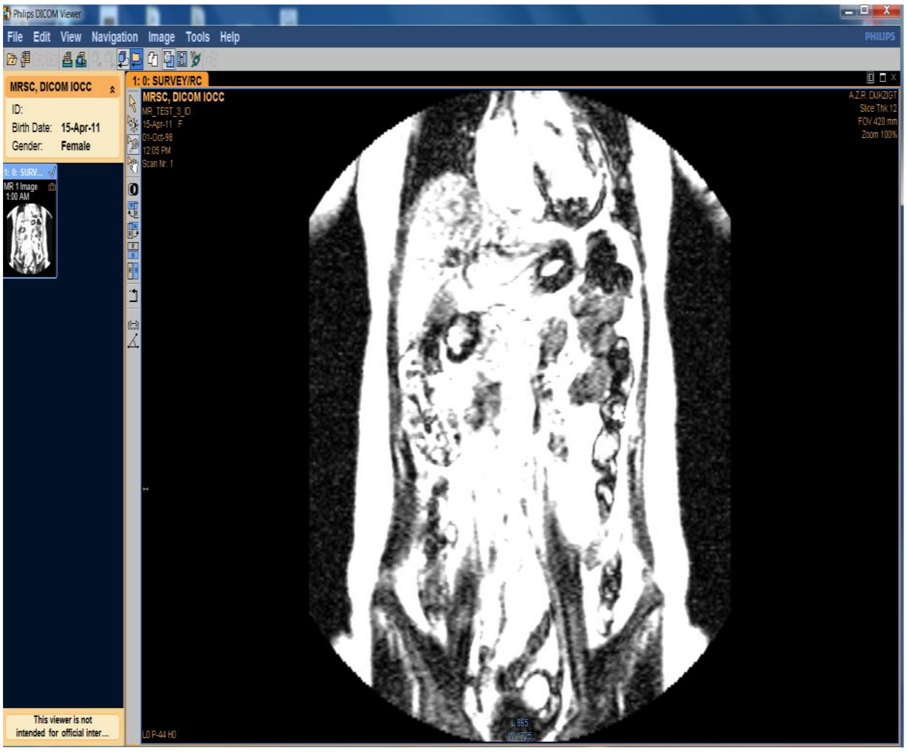
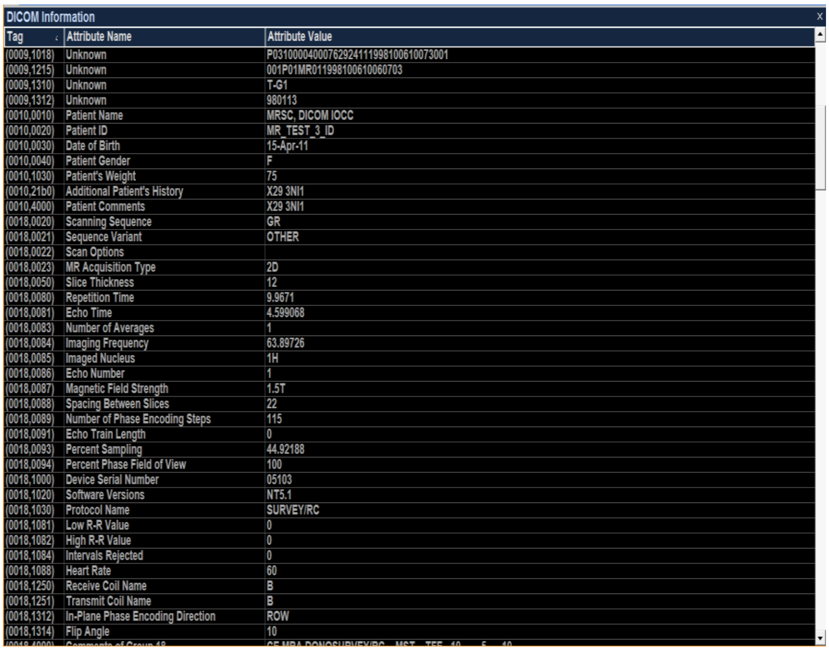


Figure 16: Philips DICOM viewer screen shot of image obtained from MRI Modality



DICOM Information

Tag	Attribute Name	Attribute Value
(0009,1018)	Unknown	P031000040007629241119981006100730001
(0009,1215)	Unknown	001P01MR011998100610060703
(0009,1310)	Unknown	T-G1
(0009,1312)	Unknown	980113
(0010,0010)	Patient Name	MRSC, DICOM IOCC
(0010,0020)	Patient ID	MR_TEST_3_ID
(0010,0030)	Date of Birth	15-Apr-11
(0010,0040)	Patient Gender	F
(0010,1030)	Patient's Weight	75
(0010,21b0)	Additional Patient's History	X29 3NI1
(0010,4000)	Patient Comments	X29 3NI1
(0018,0020)	Scanning Sequence	GR
(0018,0021)	Sequence Variant	OTHER
(0018,0022)	Scan Options	
(0018,0023)	MR Acquisition Type	2D
(0018,0050)	Slice Thickness	12
(0018,0080)	Repetition Time	9.9671
(0018,0081)	Echo Time	4.599068
(0018,0083)	Number of Averages	1
(0018,0084)	Imaging Frequency	63.89726
(0018,0085)	Imaged Nucleus	1H
(0018,0086)	Echo Number	1
(0018,0087)	Magnetic Field Strength	1.5T
(0018,0088)	Spacing Between Slices	22
(0018,0089)	Number of Phase Encoding Steps	115
(0018,0091)	Echo Train Length	0
(0018,0093)	Percent Sampling	44.92188
(0018,0094)	Percent Phase Field of View	100
(0018,1000)	Device Serial Number	05103
(0018,1020)	Software Versions	NT5.1
(0018,1030)	Protocol Name	SURVEY/RC
(0018,1081)	Low R-R Value	0
(0018,1082)	High R-R Value	0
(0018,1084)	Intervals Rejected	0
(0018,1088)	Heart Rate	60
(0018,1250)	Receive Coil Name	B
(0018,1251)	Transmit Coil Name	B
(0018,1312)	In-Plane Phase Encoding Direction	ROW
(0018,1314)	Flip Angle	10

Figure 17: Screenshot of Philips DICOM viewer listing the DICOM attributes associated with image.

The figure 17 screenshot describes list of DICOM attributes i.e. Patient data that is associated with the image archived in PACS.

BENEFITS OF SCHEDULED WORKFLOW INTEGRATION PROFILE (SWF)

- Prevents the errors caused due to manual entry, by entering the patient registration details only once and reusing across all systems.

- Prevents the time consumption in patient treatment, by making information available on time.

Improve Throughput

- Saves the manual data entry time by registering the details only once and sharing across all the systems involved in radiology workflow.
- Tracking the study identification and status accurately throughout the department reduces the loss of studies.
- Saves the time spent in detecting and correcting the errors among the systems involved in radiology activities.

Reduce Deployment Cost/Time

- IHE technical framework provides the detailed specification for interface implementation, which eliminates custom interface specification cost and time.
- Reduces maintenance time due to the maintenance of single interface (IHE) instead of multiple custom interfaces.
- Combinations of systems are tested together during IHE Connect at hon which reduces intersystem testing time and expense.

REFERENCES

[1] Am Suk Oh, Oh Hyun Kwon and GwanHyung Kim. (2014) “Design and Implementation of Standard DICOM Interface Module”, Vol.6 No.2, pp.141-146. International Journal of Bio-Science and Bio-Technology.

[2] Jim Atherton, MD. (2011) “Development of Electronic Health Record”, Vol 13, pp 186-189. American Medical Association.

[3] IK Indrajit and BS Varma. (2007) “DICOM, HL7 and IHE: A basic primer on Healthcare Standards for Radiologists”, Vol 17, pp 66-68, International Journal of Radiology and Imaging.

[4] Alin CORDOS1, Bogdan Orza, AurelVlaicu, Serban Meza, Carmen Avram and Bogdan Petrovan. (2010) “Hospital Information System using HL7 and DICOM standards”, Vol 7, WSEAS Transactions on Information Science and Applications.

[5] BojanBlazona and Miroslav Koncar. (2007) “HL7 and DICOM based integration of radiology departments with healthcare enterprise information systems”, Vol.76, pp.425-432. International journal of medical informatics.

[6] ShanmugamVeeramani, Muhammad Nasir Masood and Amandeep S. Sidhu. (2014) “A PACS alternative for transmitting DICOM Images in a High Latency Environment”. Paper presented at IEEE conference on Biomedical Engineering and Medicine.8 - 10 December 2014, Miri, Sarawak, Malaysia.

[7] Lidong Yang and Yu Gu. (2011) “Design and Realization of DICOM/HL7 Gateway in PACS”. Paper presented at International Conference on Electronic & Mechanical Engineering and Information Technology. 12-14 August 2011.

[8] Harpreet Kaur, Rupinder Kaur and Navdeep Kumar. (2015) “Lossless Compression of DICOM Images using Genetic Algorithm”. Paper presented at International Conference on Next Generation Computing Technologies. 4-5 September 2015, Dehradun, India

[9] Brenda Courtney. (2011) An investigation into the use of HL7 Clinical Document Architecture as a standard for Discharge Summaries in Ireland, University of Dublin, Dublin, Ireland.