Collaborative Project in Healthcare Services

Project Title: Service Oriented Architecture for Healthcare (SOAH)

1. Abstract:

The aim of this project is to develop a model of a fully integrated healthcare system using SOA concepts, including processes from both planning and operational perspective with focus on medical imaging processes. The overall architecture should be able to support functionality of a system that is to be used in any healthcare institution, build from an enterprise point of view: a medical institution has partners, providers, suppliers, customers (patients), employees and it is a customer of other institutions. The model focuses on three main issues: reduce medical errors that can cost human lives, provide high quality healthcare services and management of resources in order to reduce costs.

Healthcare Information Systems help administrative personnel, nurses and physicians in their daily operations. Technical reports available in literature present most of the implementations in the area of healthcare information and communication systems as a network of systems designed for certain hospital areas like emergency information system, pharmacy system, radiology information system (RIS), picture archiving and communication system (PACS), laboratory information system (LIS) or pathology information system (PIS).

Healthcare environments consist of health service providers (physicians, specialists that work outside hospitals, clinics, home nursing, etc.), patients as the medical service consumers, payers (health insurance companies), pharmaceutical companies and IT services companies. Healthcare ICT deals with two main processes that involves described parties: drug management and healthcare provisioning, processes that require massive information flows and high computing resources. Drug management process is typically conducted by a pharmaceutical company that runs his own research, for drug discovery, drug development and delivery management process in an in-house IT infrastructure, increasing costs with acquiring, utilizing and maintaining computing resources for a pharmacy information system. Healthcare provisioning process includes hospital as the entry point that runs as in-house platform applications like EMR, HER, PACS, RIS and is directly linked to the patient, physician, etc. and pharmacies, IT providers and payers as third parties, each of them using their own application.

The healthcare industry imply huge costs for provisioning healthcare services to patients first of all due to the high number of involved applications that are required being one of the largest industries globally that estimate as total cost around 7 trillion USD public and private spending in 2013.

Actual turbulent business environment requires an appropriate enterprise resource planning (ERP) for more efficient and strategic management decisions. ERP systems for healthcare provide activities, processes and functions that are to be used in order to design, measure, analyze, improve and control hospital operations. Recent Healthcare ERPs are designed to integrate specific hospital business resource activities, decision processes and activities fully integrated with billing capabilities mapped to payments, related patient billing and billing accounts. This kind of system has extended integration functions with customer

relationship management (CRM), supplier relationship management (SRM) and clinical decision support system (CDSS).

The purpose of this model is to build a framework that is able to integrate already existent components within the medical imaging department (human resources, hardware, software etc.) due to the fact that implementation costs of customizing and interfacing an ERP with a non-ERP are lower than those of building up a designated system.

Using a specialized ERP tailored to the specific medical standards, processes and challenges of healthcare industry, the hospital organization will improve his operational efficiency, mitigate risk and control cost while enabling innovative business models and patient service. In the last years many researchers focus their activity on studies meant to integrate in a secure, optimal and cost affected system all healthcare information systems from clinical side to management and support systems from operational side, in unique end-to-end designated healthcare information system.

2. Technical Description

2.1. The Business Model

Fig. 1 describes a traditional sequence flow in an imagistic department that use PACS technology system: (1') patient from emergency is automatically admitted for examination and in case the physician request (2) image exam this is to be placed with high priority for scheduling in the system that plan the work lists (3); (1) patient is admitted for consultation and the physician require image exam (2) that will be forward to work list planning (3); (4) image exam is performed using given information that are attached to work list identifier; (5) images are registered and store in PACS; (6) Radiologist retrieves and analyzes patient's exam and writes the image outcome comments report. The report that is provided (7) by the radiologist is to be received by the physician (2) that required the image exam using the health information system in order to give a diagnostic to the patient.
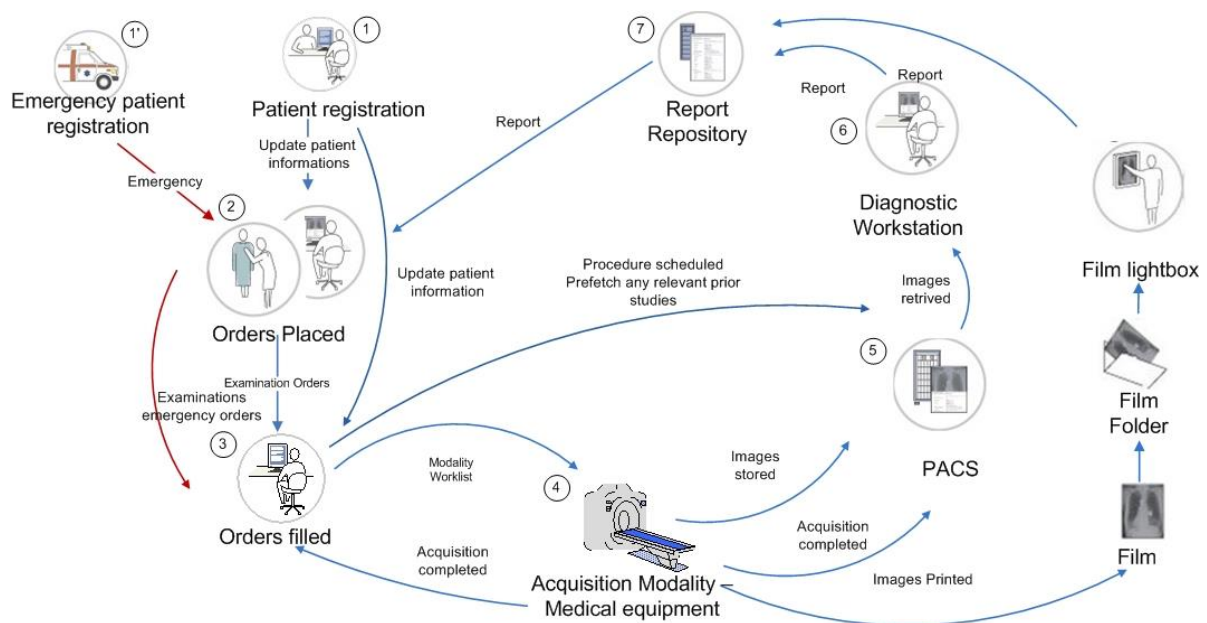

Fig. 1 Workflow in a radiology department

After medical images are captured by medical equipment, they are sent and stored on a central server PACS from where they are retrieved in a context of patient care.

This workflow represents a basic imagistic workflow that considers the use of an information system for activities performed at point (1) – (4) using additional information about patient such as name, age, sex, procedure details (imaged organ, imaging protocol, image resolution). The report that is provided at point (7) contains patient history, procedure performed, results and radiologist's conclusions.

Context diagram (Fig. 2) of the complete medical information process that is purposed in this project is described from the communication between the two systems perspective.
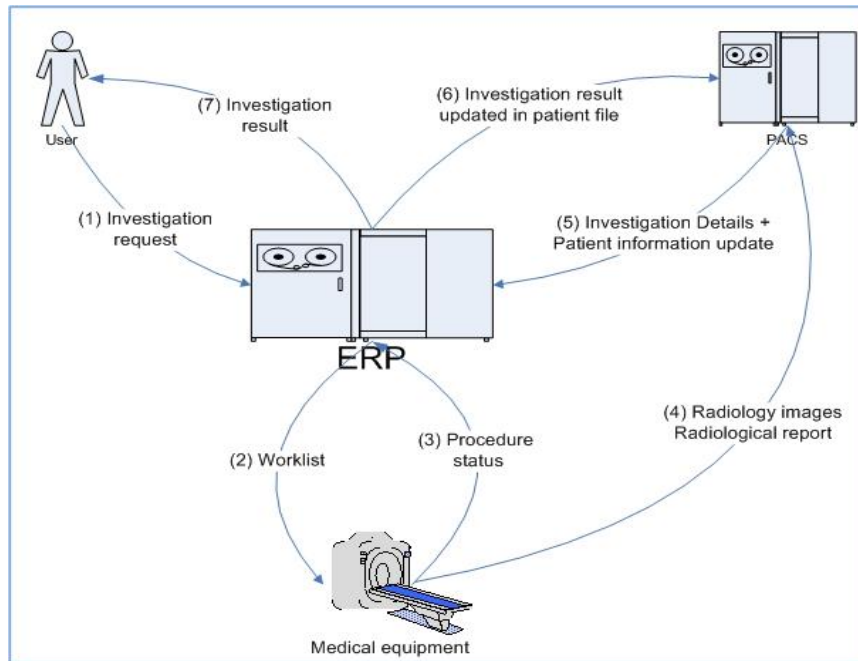

Fig. 2 Context diagram for ERP and PACS integration

A key architecture consideration with ERP and any other legacy system is the ability to integrate at any level from the database to the application throw user interface. In this case integration is done by the use of Web services and by using the middleware application from ERP side. Middleware applications allow flexibility in the decision to integrate the processes, procedures and tools between an ERP system and non-ERP system.

PACS updates information received from the medical equipment in the local database and offers required information to ERP (5).

Medical equipment integration with ERP and PACS is done at both levels: hardware and software. Procedure parameters for equipment are set by the technician from the work list that is provided by ERP (2) and updates procedure status in ERP (3).

2.2. The SOA Model

ERP provides accurate information about the patient, location in the hospital or clinic, orders for the patient, medical information and the complete radiology reports (Fig. 3).

ERP bidirectional integration (medical equipment and PACS) is essential in order to maintain updated procedure status in PACS. Clinician receives patient list from ERP (Report), examines the patient and if it's the case, places the medical imaging examination

request back to ERP (Order). Radiology orders are placed by ERP through Modality Worklist. After technologist performs procedure steps that are described in Modality Worklist medical imaging are available on medical workstations. Radiologist interprets the studies, adds comments and sends the report (picture + radiology comments − radiological diagnostic) to PACS. PACS stores the radiology file and send the radiology report to ERP from where the clinician accesses the radiologist comments and if it's the case the identified problem on the attached picture.
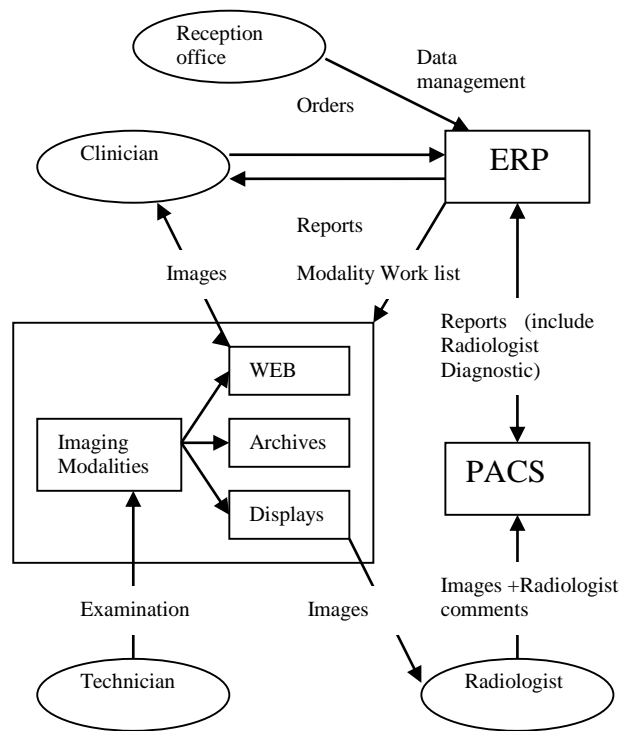

Fig. 3   ERP and PACS integration – elements

IHE transactions (Workflow) between applications are implemented through DICOM operations. Messages (Domain activities) are defined based on flow sequences (Workflow services) that correspond to a set of related actions performed by the actors that have been defined in Fig. 3 (reception office, technologist, radiologist etc). The model considers an inter-organizational workflow having a mixed environment build up on Intranet and Internet principles. Gateway, acquisition modality and PACS are connected directly through middleware layers; gateway and ERP are connected through Internet, using medical web services; ERP and PACS are connected through middleware provided by ERP system for data exchange with non-ERP.

IHE web service based workflow models for medical web services are implemented by gateway application (Fig. 4). This application attaches messages (patient information which results in a reduced number of examinations) to XML workflow messages; apply security and transaction support and supports standardization for medical industry.

DICOM standard covers Client/Server communications and it is used to exchange patient and examination information. The standard covers objects like patients, visits, medical procedures, images, films, printers, and examination modalities.
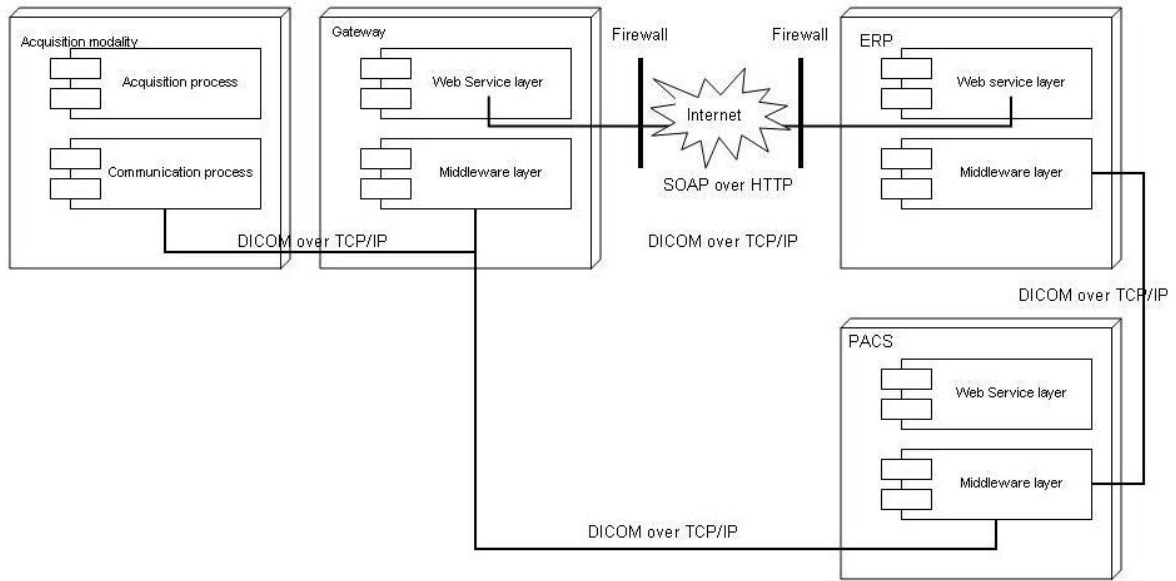
Fig. 4 ERP and PACS communication protocols

Medical images in DICOM format include binary image representation and attributes for the different modalities that describe imaging parameters and patient conditions (e.g., imaging-specific treatments and preparations - such as the injection of contrast agents - that the patient has gone through).
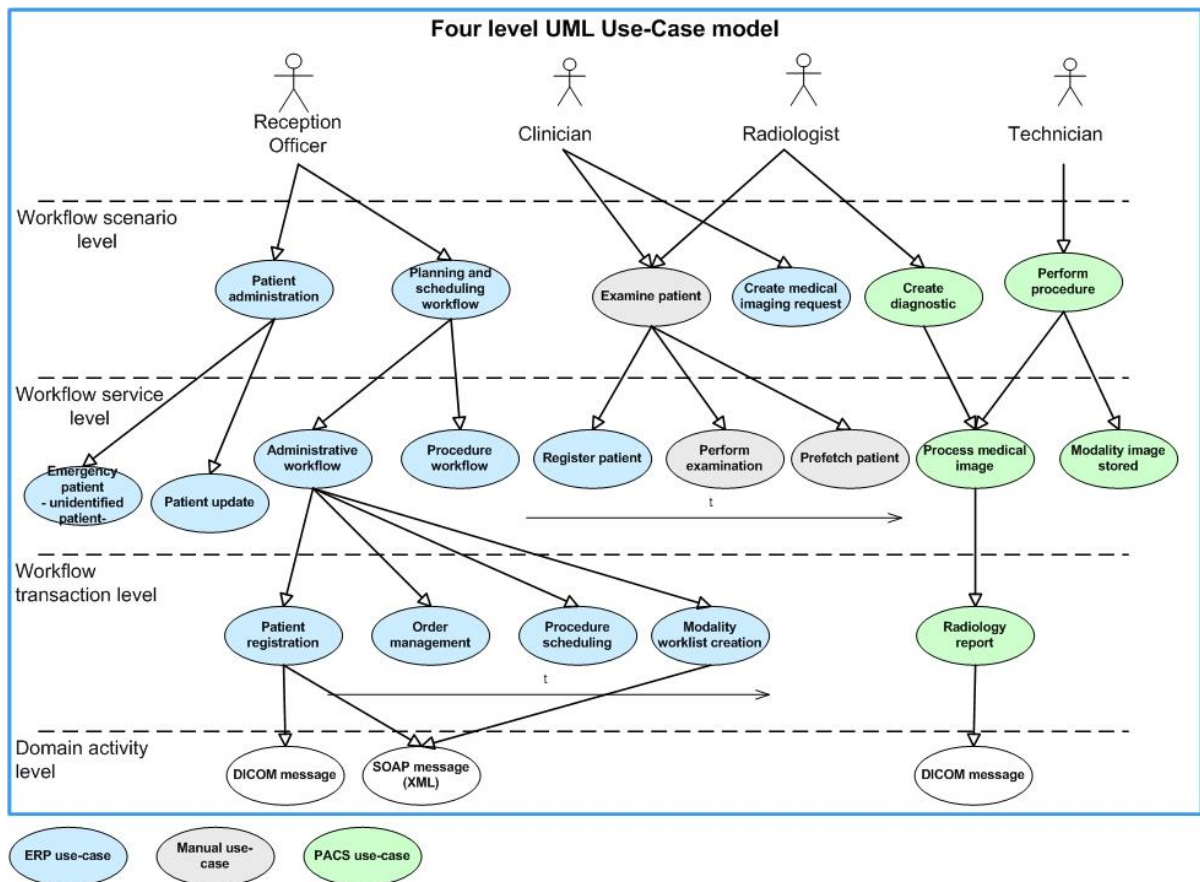

Fig. 5 Medical services use-cases split into ERP, PACS, and manual designated cases

A single DICOM file contains both a header, which stores information about the patient, type of scan, image dimensions as well as the image data which can contain information in three dimensions. DICOM image data is processed (accentuates a certain part, adds comments etc) and compressed (reduce the image size) in order to be transmitted to ERP through middleware layer.

IHE web service based workflow models for medical web services are implemented by gateway application. This application attaches messages (patient information which results in a reduced number of examinations) to XML workflow messages; apply security and transaction support and supports standardization for medical industry.

Medical web services modelling are out of the scope of this thesis therefore, this paper will resume presenting the four levels UML Use-Case model [59], [60] in order to accentuate what use cases belongs to ERP and PACS (Fig. 5). UML Use-Case model presents the four levels UML use case diagram of medical services infrastructure, workflow and domain layers, where workflows are split into scenarios, services and transaction.

2.3. Case Study: SAP - SOA

This section presents a case study done based on the medical institution requirements (with focus on IHE specifications) and the functionalities that are provided by SAP Enterprise Resource Planning (SAP ERP), SAP IS-H (SAP Industry Solution for Healthcare) and Picture Archiving and Communication System (PACS) technology at hardware and software level. The case study is done based on interviews with SAP consultants and developers, provided documents and information's from SAP website [13] mainly from the integration perspective with focus on communication between SAP, PACS and protocols.
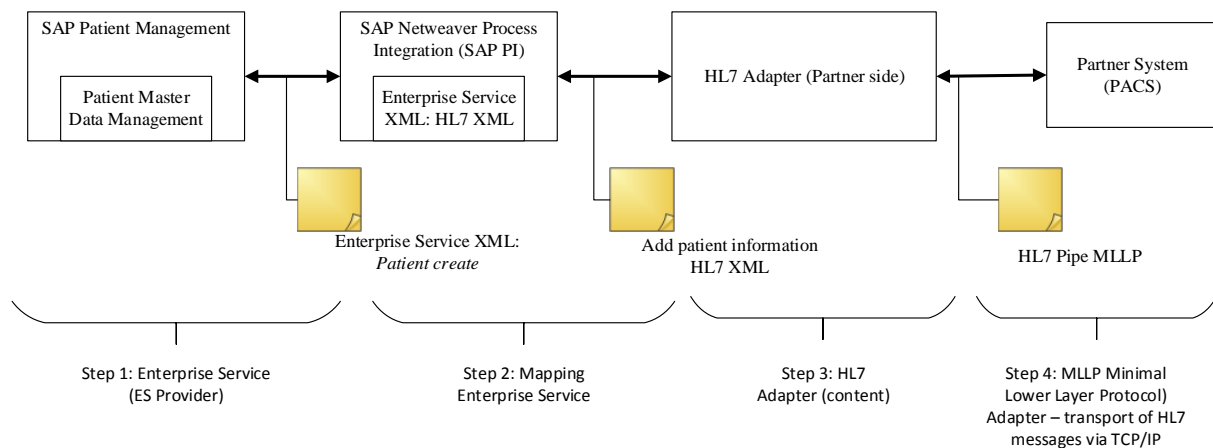

Fig. 6   SAP Solution using SOA

The scope of this case study is to exemplify an end-to-end process for planning and scheduling resources, storing, sharing, examination and reporting of radiological images.

The clinician receives the patient list from SAP (Report), examines the patient and if it is the case, places the medical imaging examination request back to SAP (Order). Radiology orders are placed in SAP throws Modality Worklist document. After the technologist performs procedure steps that are described in Modality Worklist, the medical imaging are available on medical workstations. The radiologist interprets the studies, add comments and

sends the report (picture + radiology comments – radiological diagnostic) to PACS. PACS store the radiology file and send the radiology report to SAP. The clinician accesses the radiologist comments and eventually the identified problem on the attach picture. After medical images are captured by medical equipment, they are sent and stored on a central server PACS from where they are retrieved in a context of patient care[11].

The SAP Business Process Platform for Healthcare is used as web services based platform for customer and partner systems based on healthcare standards and not on SAP proprietary standards. Integrating SAP with partner systems through Enterprise Service requires an IAH (Integration Adapter for Healthcare) HL7 Adapter (HL7 and IHE compliance).

The imaging department management central point is represented by the operations that are carrying out in the imaging department by each work centre, considering the orders that are placed by the clinicians and stock management (purchase of needed materials stock transfer).

The overall scenario requires as a basis the following modules of SAP ERP: material management (SAP MM) for materials definition, sales and distribution (SAP SD) for purchase orders, stock management, financial (SAP FI) and accounting (SAP CO) and designated healthcare modules (included in SAP IS-H).

SAP Business solution for integrating radiology workflow into the overall process includes two designated modules: Radiology information System (RIS) – supports the work and communication processes in the department providing required data and Image Connector (IC) responsible for data transfer between RIS and PACS using predefined communication events and interfaces.
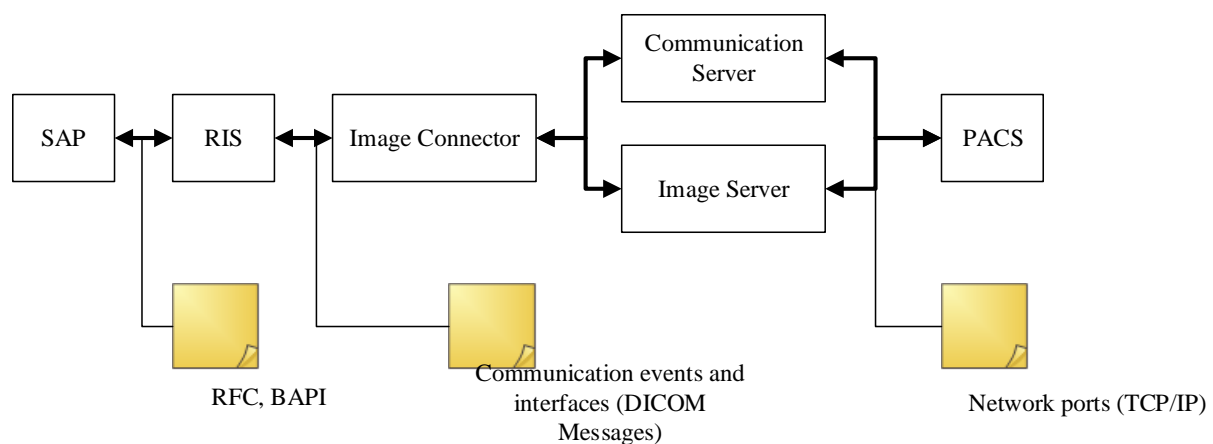

Fig. 7   SAP Healthcare for Radiology solution non-SOA based

PACS is technically connected to SAP system in two levels: first by IC interfaces used to control the viewer and to prepare information and at the second level, RIS system for study, result, patient and work list management. The complete process is able to support the clinical and operational activities and processes excluding the manual input from the user interface. The RIS system is integrated in SAP IS-H module, customizing and developing a web based user interface on SAP Netweaver platform.

The RIS system can be integrated in SAP IS-H module, customizing and developing a web based user interface (SAP Netweaver). PACS Communication in SAP Business Solution SAP applications use three protocols and standards for communication and data transfer between different systems(SAP12):

- Transmission Control Protocol/Internet Protocol (TCP/IP) standards: an IP address is assigned to the host system;
- Network Ports: port numbers are defined using standard naming conventions and rules in ABAP applications for incoming network connections;
- Remote Function Call (RFC) interface: Client-server model provided by SAP solutions as function modules that pass on the data, and get a reply (value) back from the RFC server.

The Image Connector uses communication events and interfaces in order to convert messages into DICOM standard. The data transfer maps the communication processes in the following DICOM Service Classes: Work List Management, Patient Management, Study Management, Result Management and Query / Retrieve Service Class.

A model to integrate SAP ERP with PACS as legacy system in order to keep all advantages provided by SAP ERP and PACS is presented further.

Functional requirements that are raised by a Healthcare Information System built up on SAP ERP and PACS from Imagistic department approach are overlapped with functionalities that are provided by HIS-RIS-PACS assemble from clinical process perspective (investigation scheduling, work lists or reports) including also all functionalities of SAP ERP in financial, accounting, planning, operations, human resources, material management, etc. The following modules are required by SAP for this scenario:

Patient Management

The Patient Management module is built as a specialized healthcare module obtained from a mixture between logistic and human resource modules. Patient, physician, insurance provider etc. are to be defined here as business partner.

The organizational structure is to be defined at this level considering the following elements: hospital, clinic, department and ward. Radiology equipment (computer radiography, computer tomography, digital subtraction angiography, magnetic resonance tomography etc.) is defined in the system as work centers and assigned to a certain ward entity.

Processes for outpatient (appointment, treatment, dispensing to billing) and for inpatient (registration, payment, bed assignment, treatment) are defined with references to each kind of ward.

Material Management

Material Management (MM) module is part of logistics area, is included in SAP ERP system and includes processes from the field of supply chain and inventory management. Requirements and procurement requirements are created based on analyses of data from database and requirements that are introduced by other modules. Transactions defined here are followed by additional supply operations: starting with price list, contracts, orders and

ending with invoice verification. Inventories of materials are monitored based on quantity and price.

An **Activity master** is to be designed as storage off all activities that can be performed with the existent equipment with the following pattern:

Activity name / Setup time / Execution time / Consumable materials / Personnel specialization

The Bill of materials is to be implemented as a hierarchical structure of activities that need to be performed in order to complete a procedure (medical examination). Based on the activity structure, standard fees for personnel and equipment utilization, consumables and other indicators the procedure cost is passed to the financial module.

Routing is to be defined for each procedure as a path taken through various work centers in the imaging department in order to perform the required procedure.

Medical Equipment Management

The Medical Equipment Management module is to be customized in order to manage regular/breakdown maintenance and overhaul.

The Imaging department management central point is represented by the operations that are carrying out in the imaging department by each work centre, considering the orders that are placed by the clinicians and stock management (purchase of needed materials stock transfer).

The patient, medical personnel and vendor data as well as price lists, discounts, tax, assurance cover and pricing procedures definition are supported at SD (Sales and Distribution) and MM (Material Management) level.

Sales and Distribution

The Sales and distribution (SD) module requires customizing for orders (example: purchase order), pricing procedures, taxes, assurance policies, etc.

The examination order is placed in the system by the clinician requiring a certain procedure. Based on the data that is defined in the activity master, procedure execution is defined as a series of activities, bill of materials and the corresponding routing.

The Order planning job runs periodically and schedule the order for the required date and procedure creating the planned order. Based on planned order stock management and activity requirement planning jobs are triggered. Stock management performs an availability check for the materials that are required (contrast substance, logistic materials etc.) and if it's necessary a purchase request is created; stock status will get updated to respond the current situation. After the purchase request is done it has to be turned into a purchase order. Purchase order is created in SD module. All the necessary information for buying the materials e.g. vendor, materials and quantities are set here and stock status is to be changed. Modality Worklist is to be created daily based on the planned orders, and the schedule for medical equipment from the imagistic department.

After the procedure is executed, the stock management will be triggered again in order to update stock and a financial report is sent to the financial department in order to create the invoice to the patient. Invoice order is created based on pricing procedures, taxes, assurance policies that have been defined in SD module.

The Imaging department management central point is represented by the operations that are carrying out in the imaging department by each work center, considering the orders that are placed by the clinicians and stock management (purchase of needed materials stock transfer) (Fig. 8).
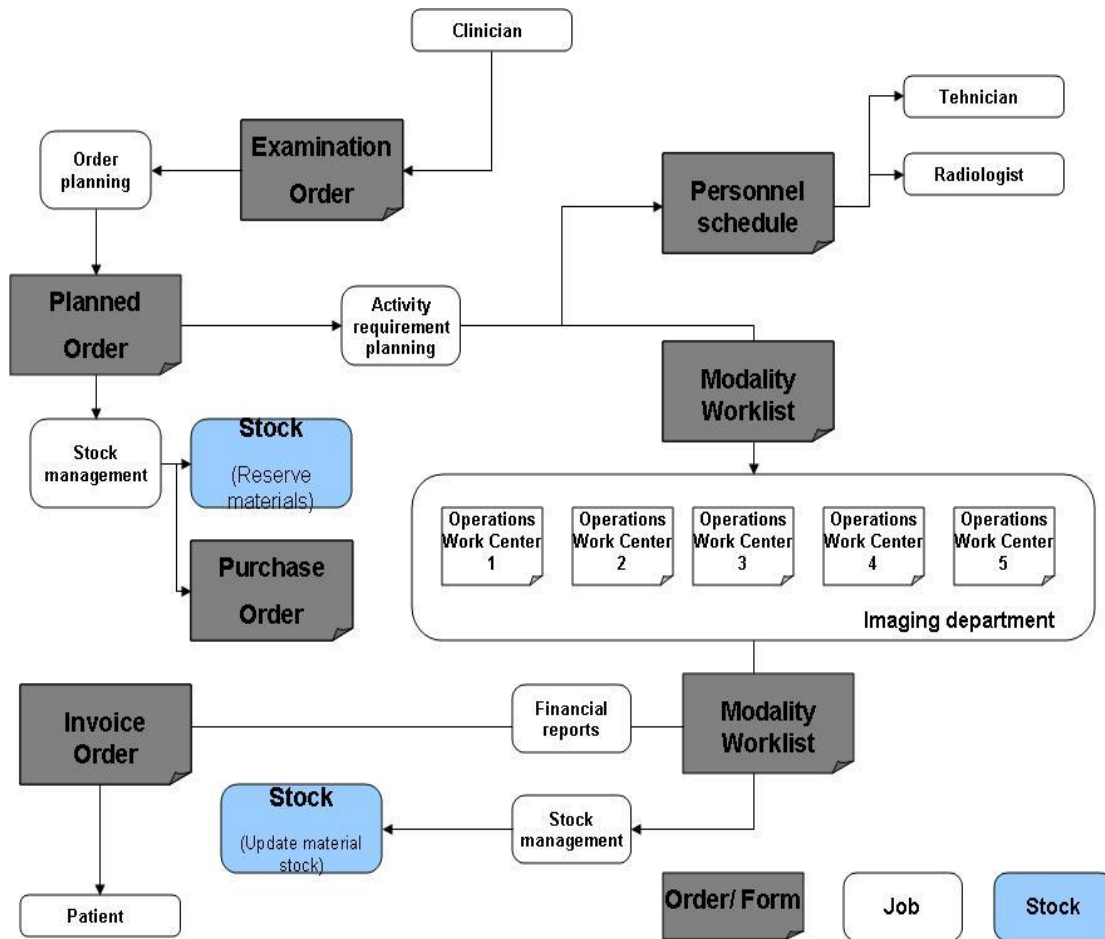

Fig. 8   SAP ERP – SAP IS-H – PACS integration scenario (Order perspective)

Further, main requests for implementing the above scenario will be discussed and assigned to a system that needs to be customized in order to provide a complex, fully integrated with focus on the planning and operations.

Authentication

The system needs to support users authentication based on password for predefined users group (administrator, radiologist, physician, reception officer, etc.). Daily task list are available for each employee from the radiology department based on authentication. Patient data confidentiality is assured by restriction of access based on group access, provided by the ERP.

Storage of data local

There is a need to control the access number of patient data and their updates and maintain locally alerts like infection risk and allergies. Local storage is supported by PACS database

that is to be updated by the SAP ERP system using the middleware provided for legacy system integration. It is recommended a standard format of database containing minimum four fields: name, DOB, address and patient unique identifier number.

Electronic requests

Communication with other non-radiology based information system needs to be supported. Partner institution that does not have a radiology department should be able to place a request for medical imaging examination and to follow his flow (examination status).

Electronic requests functionality is supported by SAP ERP with minimum level of customizing.

Patient scheduling

The Radiology department for patients must be integrated in the hospital scheduling including all departments in order to provide a continue flow for a patient that needs a series of investigation in multiple departments. Special workflows need to be provided in order to support special flows that are included in an imagistic department: multiple step investigation (nuclear medicine investigation requires a series of investigations during a number of days), procedures with dead times (contrast material investigation), etc. Radiology patient scheduling is available in the modality work list and covers all the investigation types that are to be performed within the department.

Patient scheduling functionality is fully integrated in any industry solution for healthcare ERP that includes a planning module. SAP IS-H provides complex workflows for patient scheduling integrated in patient administration and billing functionality that covers all related administration, scheduling and accounting processes.

Investigation details

Based on investigation details, required resources, technical details, contrast material, equipment and image acquisition techniques the system needs to provide financial information.

Sap IS-H is fully integrated with SAP ERP components needed for billing (financials and controlling), materials management and resource planning. Investigation details functionality is fully provided by standard SAP ERP workflows without major customizing.

Images acquisition

Digital images are transferred from the medical equipment to PACS being processed by the radiology technician (format adjustment); clinical comments are added by the radiologist and attached to the image together with procedure parameters and additional information if needed (for example allergies). Medical images are formatted using DICOM standard and transferred between PACS and ERP for administrative scope.

Image management and processing functionality is fully provided by standard PACS systems.

Supplies control

Requirements and procurement requirements should be created based on analyses of data from database and requirements that are introduced by logistic department. Supplies stock

need to be planned based on existing forecasting, seasonal influences or individual values of past demand periods. Inventories of materials need to be monitored based on quantity and price and implied in contracts, order execution and ending with invoice verification.

Supplies control functionality is fully provided by standard material management module inside SAP ERP system with minimum effort of customizing.

Invoices

Radiology investigations have standard prices for groups. Invoices need to be generated in real time based on local rules of billing for radiology procedures.

The Invoice procedure is provided by the standard financial module of SAP ERP system with minimum level of customizing due to SAP IS-H integration.

Report management

User friendly interfaces are required for report management. Such interface should provide the possibility for customer database query and predefined reports that include radiology investigation results; activities flow based on personnel number, procedure and work list; radiology activity report (radiology procedure can have one or more reports depending on the case).

The Report management functionality is provided by analytics component integrated in standard SAP ERP.

3. Implementing perspective

This project described a case study for implementing an integrated healthcare solution able to support end-to-end medical processes, including clinical and operational flows that appear inside a medical institution focusing on radiology department. The case study is done mapping SAP Solution for Healthcare and PACS solution from the SOA (Service Oriented Architecture) perspective, following IHE (Integrating the Healthcare Enterprise) profiles based on HL7 and DICOM standards.

The SOA architecture concept is used in a SAP solution for Healthcare solution in order to model the methodology and technical system architecture using concepts like: service – consumer - provider, business object, process component, communication patterns and quality of service.

An integrated information system for a healthcare institution that includes medical imaging department (internal or external) can be implemented based on SAP ERP system and PACS for medical imaging domain. The system is able to cover both integration of administrative and clinical workflows that are designed for hospital entity and the specific tasks that are required by the radiology specific entities.

- The first task, from the SAP ERP side, is to examine scheduling and registration of patients integrated with financial and statistical functionality for overall hospital. Requests for radiological examination are retrieved by the SAP ERP and transformed to planned orders, contained in the modality worklist. SAP ERP implementation convers the following functional areas: finance, procurement, logistics, asset management and human resources management.

- The second task, performed by PACS, is to support image management. Medical procedure are prepared by transferring patient management of the ERP worklists to the examination facilities and processes like sending, querying, retrieving and archiving images.

The SAP solution for Healthcare integrated with designated medical information systems like PACS over SOA guided by IHE requirements currently used in the real world implementations is based on TCP/IP, DICOM, RFC and BAPI protocols and requires specialized servers (Image Server and Communications Server) connected with Siemens connectors (Image Connector) in order to be able to exchange data. When individual patient data is needed from one entity to another – both having different health information systems, for example from ERP system to PACS system - it will be transmitted in real time to the proper location using an HL7 CDA message solution.

IHE/HL7 acts as base business requirements and semantics for SAP Healthcare – PACS integration taken into consideration following: use cases, business processes, roles, responsibilities (actors), communication content, transport protocols, authorization and authentication processes.

SOA Healthcare Information System integrates a large number of heterogeneous systems in a scalable solution (hardware and software) based on HL7 standards and web services delivering "reasonable response time under the different outpatient, inpatient and emergency system usage conditions".

Available information at the right moment is the central requirement for healthcare therefore a better management of the resources and control of data is demanded for an IT infrastructure.