# A Framework for the Evaluation of Integration Technology Approaches in Healthcare

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***Abstract*— A fundamental requirement for achieving continuity of care and supporting clinical and administrative work in healthcare organizations is commonly accepted to be the integration and interoperability of both valuable legacy systems and new technologies. However, there is much marketplace confusion today in the healthcare domain, due to the variety of overlapping or complementary integration technology approaches, standards, and activities, which have evolved over the years addressing different interoperability levels.**

**This paper aims to present the challenges and alternative approaches for integrating heterogeneous healthcare information systems, and propose an evaluation framework, in order to provide healthcare decision-makers and system integrators with a clear perspective regarding the assessment of available technology integration approaches in healthcare organizations.**

## I. Introduction

THE ever increasing demand in the healthcare sector for cost containments, provision of high-quality and shared delivery of patient care, has turned, over the past decade, the interest of many healthcare organizations, in many countries, towards the creation of a Health Information Infrastructure (HII) to support a wide range of intra- and inter-organizational processes, through the integration of different information systems [1,2]. However, after years of development experiences, the majority of healthcare organizations across the world are far behind from their desired goal of supporting shared healthcare through the establishment of advanced health information architectures that can facilitate system integration at different levels in an open and generic way [1,3].

One of the major impediments is that healthcare organizations consist of a large number of disparate and heterogeneous information systems, which have been deployed to support specific departmental needs [4]. Most of these information systems today are proprietary and have been designed autonomously by different vendors, in order to optimize specific processes within various departmental units. Therefore, each system, required to participate in the co-operative healthcare process, differs in technological and architectural aspects, preserving the problem of system integration prevalent and of significant complexity [5]. This has resulted in healthcare organizations being left with islands of heterogeneous systems and technologies that are difficult to integrate [6]. Moreover, the continuous evolution of technological innovation has led in the development of many complementary and also overlapping healthcare integration technology approaches, as well as standards, which in turn have raised much marketplace confusion regarding the adoption of the most appropriate solution for each organization. This evolution has appointed the selection of the best integration approach, and standard, a very complex task for healthcare decision makers and system integrators, as quite often, different integration aspects and types of organizational requirements can not be satisfied by one integration approach only [7,8] . Therefore, both healthcare decision-makers and system integrators need an efficient method to comprehend and evaluate the capabilities of each integration approach at different interoperability levels.

This paper aims to present the challenges and alternative approaches for integrating heterogeneous healthcare information systems, and propose an evaluation framework, in order to provide a clear perspective regarding the assessment of available technology integration approaches in healthcare organizations.

## II. Integration Issues

Although, successful departmental solutions are very helpful in optimizing processes within various hospital departments, consistently combining data from heterogeneous information systems takes a great deal of effort. This is mainly due to the fact that each participating subsystem, within a healthcare organization, usually, differs in many aspects, such as user interface, functionality, presentation, terminology, data representation and semantics, imposing therefore a number of great challenges in terms of systems integration. These technological challenges, according to [5], can mainly be separated in the two categories of data and functional integration.

### A. *Data Integration Challenge*

In order to capture differing concepts and multiple healthcare data from various sources in a structured and computer understandable way, usually, during the

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development stage of an information system, software engineers try to create a formal Reference Model and encode, within the application product, the domain-specific concepts (semantics) and data structures, which the system has to process [9,5]. Consequently, each system typically possesses its own database, which in turn encodes these concepts into a database schema [10]. A common drawback arising between proprietary systems is the general meaning disagreement and different interpretation of same or related data within the context of the healthcare domain, which leads to substantially different implementations. Semantic interoperability requires the ability of the systems that share health related information and need to communicate to be understood at the level of formally defined concepts by sharing a single common information model. This can be achieved by conforming to a single health information standard that can work as a basis for semantically consistent - message-based - information exchange between heterogeneous systems. Industry standards such as Health Level 7 (HL7) [11], and Digital Imaging and Communication in Medicine (DICOM) [12] have made an important step in this direction and have met wide acceptance in the healthcare industry.

### B. Functional Integration Challenge

In addition to the data integration challenges, problems towards the integration of heterogeneous systems also result from the insufficient functional harmonization of different subsystems. Multiple distributed systems, which may have been developed in different languages (e.g. C, C++, Java, COBOL, etc) with possibly differing function calls, classes, and concepts, usually require, from an engineering perspective, additional mechanisms to functionally communicate [14]. The typical message-based communication, as mentioned before, provides only a loose coupling of systems by utilizing interfaces and interface engines, and does not include in particular any function calls to other systems [5,13,14,15]. In other words, only the results of data modifications are transmitted between systems, via dedicated messages, offering interoperability only at the data and not at the functional level. Nevertheless, if heterogeneous applications that have been developed independently by different vendors should work together in a seamless way to support processes within the healthcare environment, a functional integration of the various system components is required.

## III. Interoperability Model and Requirements to Address Integration Issues

Any effort to integrate distributed and heterogeneous systems must address appropriately the following important questions during the early phases of an integration project.

*What*: What is the scope, the objective, and the desirable extensibility of the integration project? What are the systems, processes and policies that have to be integrated? What are the meanings, values, and semantic structures of the systems and what functional reference models do they implement?

*How:* What are the available and most appropriate integration technologies and standards? Do they support an architectural framework and in what way? What are the interaction modes and interaction protocols that each integration technology utilizes, and how do they support communication technically?

*Where:* Where are the integration points located? Where are the responsibilities of each participating system located?

To meet these challenges of open distributed and interoperable health information systems, the Object Management Group for Open Distributed Processing (RM-ODP), in the context of the Healthcare Domain Task force [16], identifies several viewpoints, which can be applied to address the integration issues mentioned above. These viewpoints are:

- The *Enterprise viewpoint*, which focuses on the purpose, scope, and policies governing the integrated applications and services.
- The *Information viewpoint*, which focuses on the analytical presentations of how semantic homogeneity of information is achieved, and what concepts and vocabularies are necessary for the implementation.
- The *Computational viewpoint*, which focuses on the description of the subsystems the overall infrastructure consists of, their functional decomposition into objects, and the precise definition of each subsystem‘s interfaces.
- The *Engineering viewpoint*, which focuses on the mechanisms to support distributed interaction between the systems.
- The *Technological viewpoint*, which focuses on the description of the physical implementation technology of the system.

### A. Interoperability Model

Drawing partially on the aforementioned viewpoints, as well as on a seven layer model, whose layers have been defined in [17,18], the authors have constitute an interoperability model of four layers, which serves as an input to the Evaluation Framework that is presented in Section V. These layers are the following:

1. *Functional Reference Model (L1):* Defines the underlying software models, as well as the database schemata that affect system interoperability.
2. *Semantics (L2):* Specifies the data elements, data values and the meanings of each element with regard to a specific process or operation. In healthcare the semantics represent the knowledge of the domain, which the system addresses.
3. *Functional Interfaces (L3)*: Focus on the description of the precise interfaces of the systems. These interfaces, on one hand, can support, either asynchronous, or synchronous message-based communication via an interface engine (middleware) by transmitting the data

results or modifications through syntactically predefined messages. On the other hand they might support functional calls through Remote Method Invocation (RMI) capabilities that have been available in component-based middleware.

4. *Technical Interfaces (L4)*: Describe which technologies are used to achieve interoperability. Technical interfaces include application programming interfaces (APIs) for differing program language bindings, common architectural infrastructure – requiring an architectural agreement, or message-based interfaces, which require the participating systems to conform to the same protocol or standard.

These interoperability layers must be appropriately addressed by system engineers so that heterogeneous systems can interoperate. Usually, this happens either in an ad-hoc way or by the adoption of a specific healthcare related standard.

### B. Interoperability Requirements

In addition to the interoperability model, in order to support efficiently the comparison between different integration approaches, the authors have identified a number of basic requirements, based on a literature review in the area of Enterprise Application Integration. It is argued that the proposed engineering requirements are needed and focus on non-functional requirements, as these influence the better selection and use of specific technology approaches.

1. *Reliability:* Refers to the protocols and techniques that are practiced in integration technologies to guarantee that every packet of data that a sender transmits is actually received by the receiver system and that the order is which they are sent is preserved. The reliabilities that have been suggested in the distributed system literature are (i) best effort (ii) at-most-once (iii) at least once and exactly-once [19].
2. *Scalability*: Denotes the ability of integration technologies to accommodate a growing future load as well as the ability of an information system to provide high performance as greater demands are placed upon [20,21,22].
3. *Heterogeneity:* Applications are usually written in different programming languages. In order for legacy and newer components to interoperate integration technologies have to resolve this problem through the availability of appropriate programming language bindings [19].
4. *Flexibility:* Refers to the capacity of the integration technology toward adjustments (e.g. software engineering modifications) with a minimal effort as well as operational capabilities between different computing environments [20].
5. *Reusability:* Reusability refers to the ability of information system components to be used again for the development of new applications within a specific domain. Reusability holds a very important role in the evaluation of integration technologies as it significantly reduces time and cost resulting in flexible and maintainable systems [20,21,22].
6. *Complexity:* Describes whether an integration technology is difficult to be implemented from a technical and organizational perspective. Usually, complex integration solutions may not be preferred due to increased development and maintenance costs [22].
7. *Maturity:* Describes whether an integration technology or available standards are well tested, established, and mature, in order to be fully implemented. The more mature a technology is, the better it is since software engineers and analysts can draw on available successful implementations [22].

## IV. Integration Approaches: Legislative - Industry Standards, and European Projects

In this section a summary of the most dominant health informatics industry and legislative standards, as well as European R&D projects is presented. A difference between legislative and industry standards is that the former can take many years to produce and ratify, and risk being too generic to be of real value [8]. However, industry standards and de facto standards, whilst often more rapidly developed, risk favouring the originating company or organization, in other words the "owner".

### A. Industry Standards

**HL7 v.3**

Health Level Seven [11] is an American National Standards Institute (ANSI) accredited Standards Developing Organizations (SDOs) operating in the healthcare area. HL7 provides a collection of communication standard formats specifying syntactically and semantically standardized messages as well as interfaces for the electronic interchange, management, and integration of data between computer applications from different vendors within the healthcare environment. Although, the HL7 standard does not focus on the requirements of a particular department within a healthcare organization, it supports various healthcare systems by specifying the precise messaging syntax to be used, including definitions of segments and internal code strings. In general, it can be viewed as a message oriented middleware designed to support communication among distributed and heterogeneous systems by utilizing a trigger event model that causes the sending system to transmit a standard pre-defined message to the receiving unit with a subsequent response by the receiving unit. Being aware of the growing demand for sharing multiple categories of health related information across medical disciplines and organizations, the HL7 has "re-engineered" its structure by currently working out a "modern" object-oriented version the HL7 V.3. Its Reference Information Model (RIM) [23] is the cornerstone of this version and acts as a large pictorial representation of health related data identifying the life cycle of events and message groups from which all domains create their messages. HL7 offers only a loose coupling of systems, since it only provides system integration at the data and not the functional level, requiring a high degree of interfaces during software engineering and conformance of standardized messages, which in many cases in general is not scalable [9,14,15].

**CORBA/CORBAmed**

CORBA (Common Object Request Broker Architecture) is a middleware technology defined by the OMG (Object Management Group) [24], an industry consortium with the aim to provide a common framework architecture model (standardized object software) utilizing object oriented technology, which allows the development of scalable and re-usable software components to evolve independently from operating systems and hardware platforms. In addition, for the healthcare domain, a special taskforce team CORBAmed (the Healthcare Domain Taskforce or HDTF) was formed, in order to define standardized object oriented interfaces between healthcare specific middleware services and components to provide a high degree of interoperability between a variety of platforms, languages and applications. Some of the most important CORBAmed activities for healthcare include:

- *PIDS* - Patient Identification Service
- *CIAS* - Clinical Image Access Service
- *COAS*- Clinical Observation Access Service

**DICOM**

The Digital Imaging and Communication in Medicine standard [12], building on two previous specifications, was first published in 1993 jointly by the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA). The goals of the DICOM is to address the issue of vendor-independent data formats and data transfers for digital medical images, in order to achieve compatibility and to improve workflow efficiency between imaging systems and other clinical information systems within the healthcare environment. The application domain of the standard is mainly radiology. Bidgood [25] has led the development of a standard information model for the representation of medical image structured reports, which acts as a controlled vocabulary for reporting imaging studies to permit their semantic analysis. This has been published as the SNOMED DICOM Microglossary. The DICOM-SR specifications provide a simple and generic structure for electronic report documents. The DICOM standard has met wide acceptance by being adopted virtually by many suppliers of imaging products [8].

### B. Legislative Standards

**CEN/TC251**

Much of the work and experience gained through European R&D projects has sincerely informed progress on standards through the CEN Technical Committee 251. CEN/TC 251 [26] is supported by the European Commission DGIII (industry), healthcare organizations, suppliers of ICT solutions, and users to develop standards that enable compatibility and interoperability between independent systems in healthcare. TC 251 comprises four working groups, which cover: information models, systems of concepts and terminology, security measures, and technologies for interoperable communication. One of the important outputs of these groups has been the development of a “Standard Architecture for Healthcare Information Systems”, commonly known as “HISA”. This standard seeks to enable the development of modular open systems to support healthcare [27]. HISA builds on the extensive work of RICHE, NUCLEUS, EDITH, and HANSA. Its architecture specifies the structure of the data maintained and retrieved by a set of services, without prescribing internal structures. Both applications, responsible for supporting a variety of user activities and its middleware, which consist of healthcare-related common services and generic common services, rely on a set of technological facilities (bitways layer) to enable the physical connection and interaction of various modules. A number of middleware models based on the standard have emerged over the years.

### C. European R&D Projects

**SynEx**

Synergy Extranet [28], a European Fourth Framework program, running between 1998 and 2000, defined a middleware architecture for the delivery and collaboration of health information components. SynEx aimed at providing an integration platform for integrating both new and legacy applications [29]. However, the time-scale of the project was insufficient to permit both the engineering of individual components and joint evaluation within demonstrator sites. Therefore, interoperability demonstration has been limited. Nevertheless, a good example (considered within this paper’s evaluation process) is that of a middleware component - the UCL Federated Health Record Service - which draws on the results of the Synapses project and has been implemented in many healthcare sites in Europe [30].

**HANSA/DHE**

The HANSA project was launched under the EU Health Telematics Fourth Framework programme. The DHE middleware [31], developed by GESI in Rome, still represents one of the most complete implementations of this kind, which has also been a conformant reference implementation of the aforementioned CEN “HISA” standard [27]. The DHE middleware allows information to be entered, stored, modified, and retrieved through a set of common services, which are accessible to the applications by means of stable and public Application Programming Interfaces (APIs). Such APIs, independent of technological environment, are provided through libraries, accessible by the applications [31]. Through the collaboration established in Hansa, the DHE middleware has being used in the live environment of more than 20 hospitals for 15 European countries.

## V. Evaluation Framework and Assessment of Integration Approaches

It has commonly been accepted that the evaluation of available integration approaches in the healthcare domain

TABLE I
EVALUATION FRAMEWORK OF TECHNOLOGY INTEGRATION APPROACHES

| | | INDUSTRY & LEGISLATIVE STANDARDS | | | | EUROPEAN PROJECTS | |
|---|---|---|---|---|---|---|---|
| | **EVALUATION CRITERIA** | **HL7 v.3** | **CORBAmed** | **DICOM** | **CEN/TC215** | **SYNEX/SYNAPSES** | **HANSA/DHE** |
| **Integration Layers** | **(L1) Functional RM** | HL7 RIM, D-MIM, R-MIM, Interaction models | Conceptual UML models (PIDS, COAS, CIAS) | DICOM-Structure Reports (SR) | Textual and diagrammatic description of conceptual model (set of common data, and procedures) | Syn Object Model (SynOM) | Integrated-Conceptual Model of middleware managed data |
| | **(L2) Semantics** | HL7 message types, vocabulary domains | OMG Specifications, HL7 2.3 trait names | Information Object Definitions and modules (IOP, IOM), DICOM-SOP, DICOM-VR | Concept and domain vocabularies | Syn Object Dictionary (SynOD) | Concept and domain vocabularies |
| | **(L3) Functional Interfaces** | Hierarchical message definitions, HL7 CMETs, message types | OMG Component Interfaces | DICOM message exchange definitions, DIMSE | Distibution and specification rules, (IDLs) for Corba, HL7 (*partially developed), standard APIs | Synapes Interfaces (COBRA server wrappers, CGI server wrappers, ORB) | Stable &public APIs |
| | **(L4) Techical Interfaces** | XML, SOAP, Implem. Technology Specifications (ITS) | CORBA Interface Definition Language (IDL) | Binary DICOM stream | EDIFACT, XML DTDs | XML (DOM, SAX), ODBC, CORBA (IDLs) | HL7, DICOM, CORBA & DCOM (IDLs), |
| **Integration Requirements** | **Reliability** | ● | ● | ● | ● | ● | ● |
| | **Scalability** | ○ | ⊖ | ○ | ● | ● | ● |
| | **Heterogeneity** | N/A | ● | N/A | ⊖ | ● | ● |
| | **Flexibility** | ○ | ⊖ | ○ | ● | ● | ● |
| | **Reusability** | ⊖ | ● | ⊖ | ● | ● | ● |
| | **Complexity** | ● | ● | ⊖ | ○ | ○ | ⊖ |
| | **Maturity** | ⊖ | ○ | ● | ⊖ | ⊖ | ⊖ |

requires a more holistic approach, which takes into consideration a wide range of technologies, criteria, and requirements at different levels. In light of this situation, over the past year, the authors have developed a novel framework for the formalization and harmonization of systems representation towards the facilitation of a comprehensive comparison between different healthcare integration technology approaches. In order to effectively facilitate this task, the underlined formalization is based on evidences derived from an extensive literature review as well as the authors' experience in the domain of healthcare informatics. The proposed framework and the assessment of the integration approaches presented in Table 1, is based on the interoperability layers, as well as the integration requirements, discussed in Section III. It follows a low (○), medium (ɵ), high (●) ranking scale, while the (X) symbol is used for when an integration requirement is not supported.

## VI. Conclusions

It is generally accepted that some of these approaches mentioned above built their foundation on different frameworks and architectures [15]. Based on the literature review, as well as the authors' experience, there is no single technology that supports the system challenges of both data and functional integration. Moreover, a combination of integration technologies may be required to achieve inter and intra-organizational integration, depending on the organization's specific needs and objectives. However, as one interoperability approach may involve several technologies such as XML, Message or Object Request Brokers, etc., much technological confusion is raised as well as difficulty towards the comparison and evaluation of different integration architectures.

The proposed framework attempted to clarify this confusion by presenting a consistent evaluation method which provides healthcare service providers and system integrators with a clear perspective, regarding the characteristics, advantages, and disadvantages of each integration approach.

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