Evaluating Alternative Approaches for Integrating Clinical Information Systems: "Messaging" vs. "Federating"*

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Abstract

A fundamental requirement for achieving continuity of care is the seamless sharing of multi-clinical information. Several different technological approaches can be followed to enable the sharing of health record segments. In all cases interoperability between systems is a prerequisite and this requires presently a major technological challenge. Interoperability can be achieved either through messages or through a more advanced approach based on a federation of autonomous systems. Message based integration is centered mainly on the exchange of HL7 and DICOM messages for achieving the functional integration of clinical information systems (CIS) at institutional or regional level. The federated approach is principally used for facilitating the virtual view of the Integrated Electronic Health Record (I-EHR), without having to replicate unnecessary information.

Within the context of HYGEIAnet, which is the regional health telematics network of Crete, both approaches have been utilized for providing end users with seamless access to clinical information. Both are based on an open architecture, which provides the framework for the reuse of standardized common components and public interfaces.

This work presents the experiences related to the implementation of "messaging" and "federating" in HYGEIAnet, which are used complementary to each other. The architectural framework of HYGEIAnet that enables for the provision of integrated services that can be extended beyond the hospital boundaries is also presented. A comparison of the two parallel approaches, together with their strengths and weaknesses is described, and evaluation is given from the technological as well as the end users' perspective.

Keywords: Integrated Electronic Health Record, Message-based Integration, Federation of Clinical Information Systems, Healthcare Information Infrastructure, Component-Based Architecture.

1. Introduction

Continuity of care requires the cooperation of healthcare facilities that offer complementary set of services. When this is translated into the exchange of clinical information in electronic form, then the course for achieving the sharing of patient records can take several alternative forms. Furthermore, when this is applied to legacy information systems, managing individual segments of the patient record that are self-consistent and main-

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tained independently, achieving interoperability is a challenge. This can either lead to the delivery of the personal I-EHR, or just instances of it that are related to the case under investigation.

In the case of a healthcare organization, a number of clinical departments, offering complementary services, cooperate to provide integrated care. Each department has its own needs for keeping health records and for communicating with cooperating departments (both inpatient and outpatient). Figure 1 shows a typical patient information flow scenario within a hospital where a medical or paramedical professional in a requesting department (like e.g. pathology) may need to request for certain types of examinations (like e.g. biochemical, imaging, etc.) for a number of patients who are being taken cared of in the clinic. The different CIS in which these examinations are stored must then communicate and possibly exchange information in order to respond to such a request.

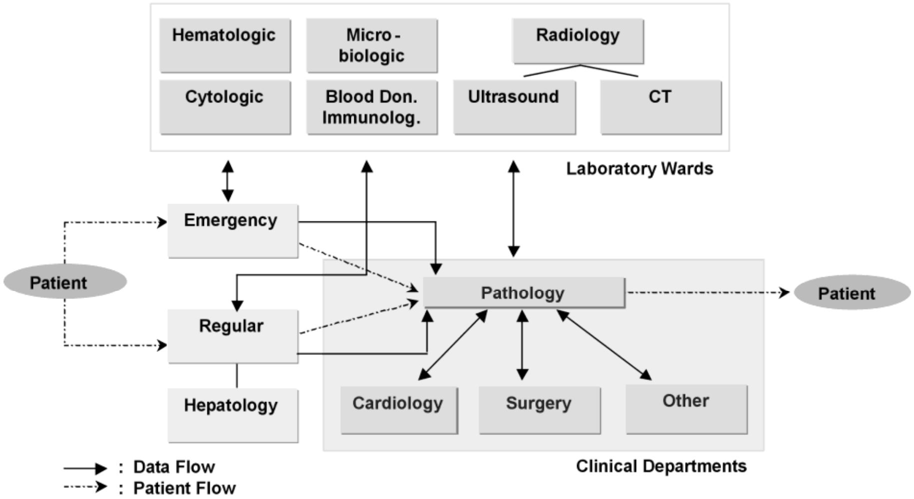

Figure 1.Typical patient information flow scenario within a hospital.

The communication and sharing of information among autonomous systems with different requirements may involve system extensions. The implementation of such extensions may require the agreement of respective vendors, and certainly increases the cost of development. Therefore, interoperability of systems and services based on relevant standards is a critical issue in any attempt at achieving integration of healthcare networks at a hospital level [1]. Interoperability ensures the prompt propagation of information and the efficient use (and re-use) of software to order medical examinations, access examination results, and manage workflow.

2. Message Based Integration

Message-based communication and HL7/ DICOM[†] based communication in particular, is considered as a mechanism that facilitates the functional integration of clinical and administrative information systems at institutional or regional level, thus resulting in the automation of medical processes, such as patient admission, transfer and discharge, ordering of laboratory and radiological examinations, and automatic or on demand (solicited or unsolicited) receipt of results. The first step in achieving message-based communication is modeling of the workflow(s), the associated exchanged messages, and their content. In this context, UML, XML, and related standards come to play an increasingly important role. This way, clinical and/ or administrative information is shared among departments or organizations assimilating closely their traditional paper-based communication.

[†] Other, important messaging standards, that are in use today, include X12N, NCPDP, ASTME31, ADA, as well as JTC1 for imaging.

This approach relies on the definition of standardized messages that enable CIS to exchange messages carrying data [2]. Although the pure message-based approach can be suitable when the number of possible inter-system communications is kept low, when this rises an underlying infrastructure is required to support it. At this level, issues dealing with identification (of physicians, patients, equipment, CIS, etc.), semantic mapping of coding schemes (e.g. for diseases, diagnoses, etc.) and security ought to be dealt with.

From a technical viewpoint, message-based communication is a problem of heterogeneous autonomous decentralized information systems that need to interoperate through messages. One way to achieve this so-called "message-based" integration is the use of common components and services. In specific, message-based integration, can be realized by (a) middleware services such as terminology, and naming, (b) a set of task agents to enable active behavior, and (c) a set of common software components that facilitate communication mechanisms in general (e.g. TCP/IP communication) as well as communication in the healthcare domain (HL7, DICOM). That way, compliance with the integrated architecture for the provision of Health Telematic Services is achieved [3]. This form of interoperation can be applied both at the level of a single organization (e.g. hospital or a primary healthcare center) as well as within the context of a regional network.

Clinical and administrative information systems make use of the middleware services to identify possible destinations for the clinical messages (Directory Services), to define common accepted terms the content of the messages (Terminology Services), and to provide for authenticated, secure, and non-reputable communication (Security Services). Furthermore, heterogeneous data sources ought to be extended with COM messaging components for the encapsulation of the message content in a standard manner (DICOM and HL7 protocols), and the dispatching of clinical messages to their destinations [4]. Task agents receive, parse, and handle messages, which may involve interaction with the databases of the various CIS (see Figure 2).

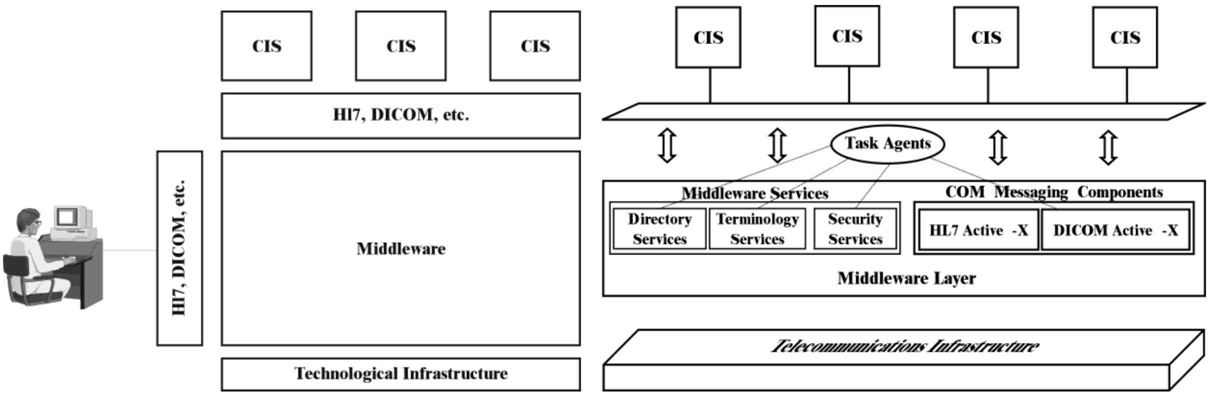

Figure 2: Architecture for the realization of a scalable message based integration.

The message based approach is tailored to the needs of professionals who explicitly need to select the type of information to be communicated and shared, as well as the destination. This way messaging is mainly used for sharing only parts of the I-EHR, and uses multiple places to store information. Despite the produced information redundancy (which in many cases may lead to inconsistencies), since it focuses on episodes of care and referrals, it eases data entry and is fast enough to cover quite a big number of end-user needs.

3. The Federated Approach

When dealing with sharing clinical information, personal health records have the most important role and are the central entities and point of reference in the whole healthcare delivery process. Seamless access to clinical information is translated into seamless access to the I-EHR in cases where critical information needs to be available by both patients and physicians, preferably in electronic form. Any federated approach towards an I-EHR environment should be capable of providing uniform ways for accessing authentic, physician-generated, patient record information that is physically located in different CIS. Furthermore it must be able to provide fast and authorized on-line access to longitudinal views of each individual personal health record, in order to allow for the timely delivery of health care. Such an environment is expected to allow patients to become more actively involved in the monitoring and assessment of their own wellness.

At this point, the main reason driving the need for integrated access to clinical information is information sharing. Issues that need be resolved, on the way towards providing integrated solutions, are mainly focused around patient identification, interoperability among co-operating software components and the involved CIS, and all the security related medico-legal issues. Hence a key challenge facing researchers and system developers is to provide a new organizational framework that can integrate this heterogeneous collection of resources into what appears to be a uniform conglomeration of data and knowledge to increase the availability of previously inaccessible information and to address the demanding information processing requirements of modern medical applications [5].

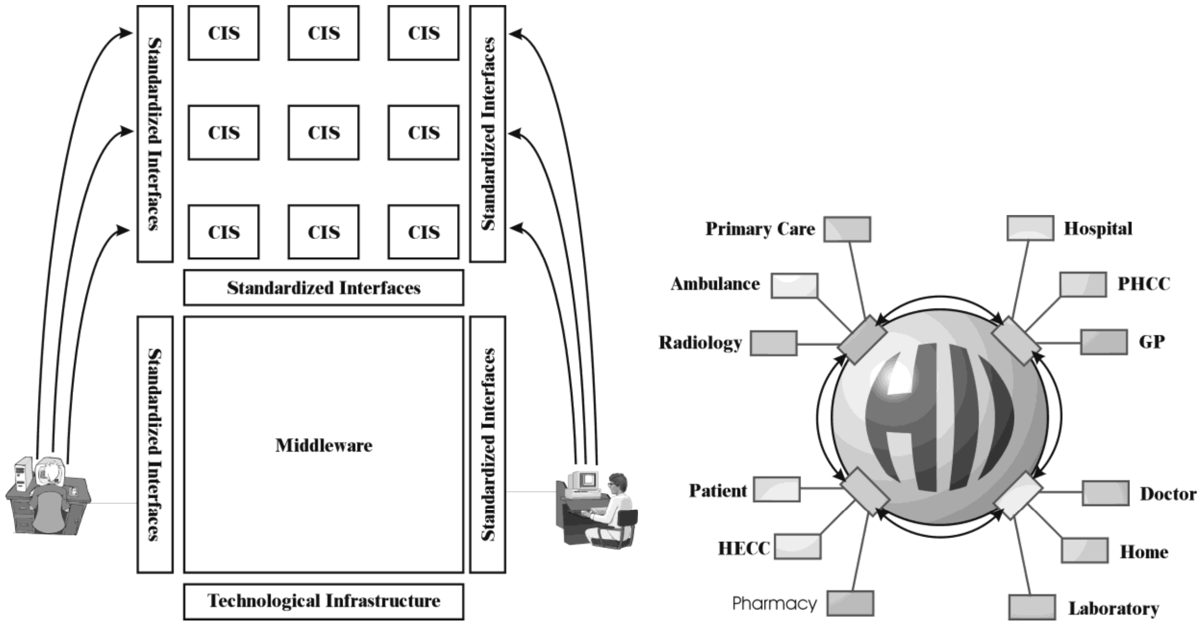

Figure 3. The federated approach towards the I-EHR. Systems and services share information with other systems through the existence of a Healthcare Information Infrastructure (HII). The HII is enabled by a set of both generic and health domain specific middleware services that facilitate direct access to heterogeneous sources of information. The underlying technological infrastructure of X.500 and CORBA provide support, for global access to information.

In essence, there is a trade-off between the diversity of clinical objects stored and managed by the middleware enabling services of the infrastructure [6] and the generality and expressiveness of the common model. The more information modeled, the richer the query model supported. This, however, limits the range of CIS that may be incorporated in the federation in a non-trivial way.

4. Both Approaches in Practice

The development of the regional health telematics network of Crete (HYGEIAnet) is a conscious effort to provide an integrated environment for healthcare delivery and medical training across the island of Crete in Greece. HYGEIAnet takes advantage of the increasing capacity of terrestrial and mobile communication networks and the development of advanced telemedicine services to provide every citizen of the island with effective healthcare and to support remote consultation with health care professionals in specialized centers, district and regional hospitals, and other points of care.

Since the hospital is by far the most complex organization in the health care hierarchy, a primary objective in developing any regional health telematics network is to design and develop an Integrated Hospital Information System (IHIS) capable of effectively and efficiently supporting all patient related clinical processes within a hospital. Within this context, the IHIS development is based on the definition and implementation of an open architecture where the individual modules: (a) are autonomous and self-consistent, supporting specific functional units, (b) inter-work through stable, public interfaces, and (c) are configurable, able to operate in a distributed environment, and can adapt to the specific requirements and characteristics of an individual organization.

In the case of a small hospital having six different CIS covering the needs of pathology, pediatrics, primary care, cardiology, radiology, and hematology most of today's communication between the corresponding departments is paper-based, compounding errors, delays and data re-entry. Pathology and pediatrics use CIS as a health record management system to keep all related information as a means for record keeping inpatients (named PATHIS and PEDIS respectively). In addition, the existing primary healthcare center information system includes electrocardiograms in the SCP format and the same format is also used by the cardiology information system (CARDIS). In radiology, the X-ray Film Digitization Console (XRFDC), a DICOM image archive, and components used by CIS provide the functionality of a minimal radiology information system and a PACS, where radiologists carry out X-ray examinations, digitize them using a medical scanner, and store them in the DICOM image archive. At the same time the hematology lab has been equipped with a third-party Laboratory Information System (LIS) that interfaces the medical analyzers.

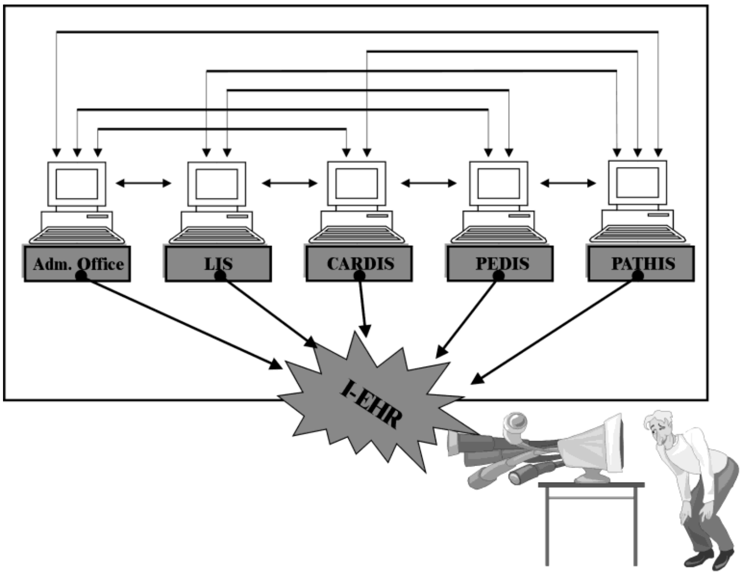

Figure 4. CIS integration in practice. Although CIS are autonomous and dedicated to the needs of each individual clinic, still they need of being capable to interoperate in a distributed environment, and provide a unified view of the I-EHR by means of adaptive and adaptable user interfaces.

Laboratories as well as radiology produce a substantial amount of information used by the practitioner to make clinical decisions. Therefore all systems ought to be capable of ordering laboratory examinations directly. The goal is to deliver information continuity across multiple clinical settings. Examination ordering is thus facilitated by allowing electronic propagation of related information. Important result acquisition information can then become instantly available upon completion and the subsequent request. Important problems with the exchange of clinical messages have to deal with lack of explicit security mechanisms, data replication, and the complexity of the task that arises when the number of possible interactions increases.

As far as federating is concerned, at present, the objective of the installed I-EHR environment is to deliver an encounter-centered view of the patient's EHR. It utilizes the existing CORBA interfaces to provide a consistent way to locate, access and transmit secure information about a patient's EHR segments. For this reason the technological approach followed in the currently installed pilot implementation includes CORBA interfaces (for data acquisition, patient identification, and semantic mapping), and X.500/ LDAP (for security services, naming services, user profiles, patient clinical information, and healthcare resources). Dedicated gateways (e.g. SQL/ ODBC-LDAP) have been implemented for scheduled directory updates, and XML is used for maintaining collected clinical information in a consistent way [6]. Security allows different levels of authority across and within departmental CIS [7].

5. Discussion

The messaging approach provides a solution as far as interoperability is concerned, but does not achieve real integration, since it produces major data redundancy, and it does not provide solution to the problem of the shared record, but rather to inter-system communication. Although it is quite effective and works well within a small hospital, when the number of possible interactions between systems increases, it suffers from scalability limitations. Integrating medical examination results, gathered from assisting laboratories, is not the appropriate way in achieving integration and standardized interfaces like HL7 and DICOM, when used, do not necessarily guarantee interoperability. Nevertheless, they are a quite useful solution in providing effective exchange of data.

The federated approach is based on an underlying infrastructure, based upon a minimum common/ federated data model, of both generic and health-related services to support the provision of integrated shared record services. Since mappings between the federated common schema and CIS local schemata is a prerequisite, a serious schema translation effort is required. The most important efforts towards standardization in this domain is mainly carried out by ASTM E31, ISO TC215, CEN TC 251, and CORBAmed.

	Message Based Integration	Federated Integration
End-User:	Medical staff (doctors, paramedical staff)	Healthcare Professionals or Citizens
Needs Covered:	Electronic ordering for observations, and request for or receipt of observation results	The provision of a uniform way to access patient record data that are physically located in different CIS
Requirements:	Fast, secure and authorized delivery of requests for various examinations and automatic or on demand receipt of results	Fast, secure and authorized access to distributed patient record segments
Not to be confused with:	Client-server access to common centralized data repositories	Store and Forward Communication of EHR Data, Centralized Clinical Data Repositories, or Monolithic Information Systems
Features:	Provides the environment to easily incorporate into CIS the ability to order automatically various kinds of examinations. Also, the ability to request for results or receive automatically the results for previous requests is provided.	Provides the environment for integrated access to clinical information, which is kept at the place that it is produced. This primary information is maintained by the most appropriate CIS in any case.
Prerequisites:	Standardized messages, and the existence of the corresponding interface engines by each CIS that wants data exchange.	Mappings between local and federated schemas, and the existence of the corresponding data extraction gateways by each CIS that wants to be part of the federation.

Table 1. Similarities and Differences between Message Based and Federated Integration. A step-by-step comparison, of the two approaches.

Both approaches require the definition of minimum data sets, so that information can be shared. Both approaches require significant administration and management effort so that they truly become part of the business, and it is a generic requirement that no compromises should be made as far as security is concerned. The role of the need of an underlying infrastructure is quite evident in both cases, and seem to converge towards one that benefits from new technologies that will allow personalized delivery of information, while maintaining the individual systems' autonomy.

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