Enabling Components of HYGEIAnet*

Dimitrios G. Katehakis[1], Manolis Tsiknakis[1], Stelios C. Orphanoudakis[1, 2]

[1] Center of Medical Informatics and Health Telematics Applications (CMI-HTA), Institute of Computer Science (ICS), Foundation for Research and Technology – Hellas (FORTH), E-mail: {katehaki, tsiknaki, orphanou}@ics.forth.gr.

[2] Department of Computer Science, University of Crete, P.O. Box 2208, GR 714 09, Heraklion, Crete, Greece.

Abstract

Throughout all integrated healthcare system environments, a wide diversity of autonomous, networked clinical information sources exist with different internal structures (database schemata) and different vocabularies to describe the notions used by them. Bearing in mind that legacy systems will continue to be present in the future, a fundamental pre-requisite for the establishment of a scaleable regional health telematics network is the development of an architecture and tools for the integration of specialized autonomous applications that are supported by a healthcare information infrastructure. Based on an effective horizontal integration of networked information services, the interoperability of applications and services within a healthcare institution, the interconnection of different institutions, and the intelligent management of health related information that exists within such an integrated network, can be supported.

In the context of HYGEIAnet, which is the regional health telematics network of Crete, a number of key components have been identified and utilized to provide end-users with seamless access to necessary clinical information. The effort has been based on an open architecture, which provides the framework for the reuse of standardized common components and public interfaces. Technologies linked to the corresponding execution architecture include CORBA, COM++, X.500, SQL/ ODBC, Java and XML. In particular, the underlying capabilities of XML technologies allow for dynamic navigation according to personalized end-user preferences and authorities, and prepare the ground for the integrated, and personalized delivery of healthcare.

Keywords: Healthcare Information Infrastructure, Integrated Regional Network Services, Federation of Clinical Information Systems, Integrated Electronic Health Record, XML Technologies.

1. Introduction

The development of HYGEIAnet is a conscious effort to provide an integrated environment for health monitoring, and healthcare delivery, as well as medical training and health education across the island of Crete, in Greece. The objective is to put in place, over the next five years, the people, the resources, the culture and the processes necessary to ensure that healthcare professionals and managers have the information needed to support the core purpose of the healthcare system, in caring for individuals and improving public health.

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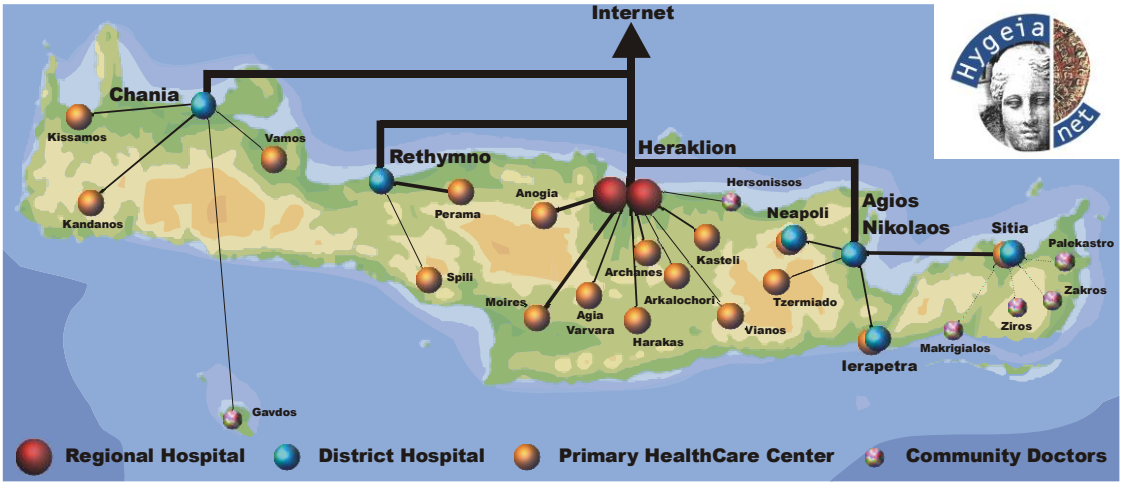

Figure 1. HYGEIAnet, the Regional Health Telematics Network of Crete.

Existing issues that have been identified in the context of HYGEIAnet include the following:

- Citizens lack consistent access to reliable information regarding where to go for the best treatment, how well health care programs and services serve patients, or on the overall performance of the health care system. This mainly because of continuous health reform and restructuring.
- Patients want more information on the treatment options available to them, and on strategies to protect their health. In addition, many citizens want to be more informed about whether their lifestyle or nutritional choices are truly healthy. However, while ever more health information is becoming available through the media and the Internet, it is hard to distinguish reliable and accurate information.
- During an emergency in the middle of the night or when traveling within the region, it is often impossible for patients to ensure that the health care professional or provider on the scene has access to their health history.
- Most of the first-time patients visiting doctors' offices, community clinics and hospital outpatient clinics or emergency wards bring with them little or no medical history, only their own subjective impressions. This situation adds potential risks to diagnostic and treatment decisions. Even if the patient brings a record from a physician or health care professional, it is incomplete and unhelpful in all too many cases.
- Because access to past medical information is difficult to be gained, health care professionals and providers often order potentially avoidable laboratory tests and imaging examinations, adding to health care costs and sometimes creating potential risks for patients.
- Health reform and restructuring have created a much more complex health care system in which it is increasingly difficult to prevent patients from slipping between the cracks. Coordination and keeping track of patients is a challenge for newly merged hospitals and medical facilities with campuses in several locations. Only the most basic data are often available on public health, home care services and community health.
- For people in remote or rural areas or requiring very specialized forms of treatment, costly travel to metropolitan areas where the necessary expertise exists is often the only option for securing a needed treatment or diagnosis.
- In the last decade, health managers have faced many difficult decisions on everything from how to cut budgets to how to restructure their institutions without compromising patient care. While mountains of information exist and everyone has a strong opinion, very little solid empirical information is available to help managers make the best decisions.
- Although our understanding of medicine and health is growing by leaps and bounds, it is often impossible to find information relevant to a particular environmental hazard or a patient with a specific background, life-

style and socio-economic status - to mention only a few of the variables relevant to an understanding of non-medical determinants of health.

- Each healthcare institution now takes a different approach to privacy, with the result that the level of protection varies greatly across the region. At the same time, the level of security in hospital record offices and in physicians' offices can leave much to be desired.

Current trends in the provision of healthcare services call for integrated user-oriented telematic services, which ensure prompt and secure access to information resources, provided proper authorization is available. To achieve this goal, complex problems and issues related to data heterogeneity, heterogeneity of platform and service requirements, complex protection and authorization policies, and interoperability protocols and standards for information exchange ought to be addressed. Strategically important therefore becomes the issue of developing an open, scalable and evolvable Healthcare Information Infrastructure (HII). The HII must primarily provide the framework for the effective integration of distributed and heterogeneous components, ensuring overall integrity in terms of functional and information inter-working, while advances in network technology should enhance and extend applications, rather than replace them or make them obsolete.

2. Enabling Components of the Healthcare Information Infrastructure

The strategic objective is to ensure that patients can be confident that the healthcare professionals caring for them have reliable and rapid access, 24 hours a day, to the relevant personal information necessary to support their care. Basic principles to be followed in providing effective solutions to integrated health telematics services networks include the promotion of interoperability (among multi-vendor applications and services), the use of open standards (made available to the customer), the provision of high quality services (useful not only to end users but to the society as well), the implementation of modular architectures (to be scaleable, secure, effective, and affordable – even for small hospitals). An important consideration has to do with the commitment to evolve from the currently available infrastructure, while adding new capabilities as soon as they become available and can become part of the local culture. Developed extensions should be integrated in the run-time environment without any modification in the already existing components of the system.

The telematic services, which are typically delivered within a regional healthcare network, may be classified into the following categories:

- **Resource services** that facilitate the interaction of end-users and services with information and middleware services related to resource availability and allocation. Examples include yellow pages, software entity activity repositories, etc.
- **Collaboration services** that bridge the gap created by physical distance separating the users. Examples include virtual communities, tele-consultation sessions, etc.
- **Educational services** that are especially important in rural regions where access to information sources is scarce and can help raise the public awareness and support continuity of care. Examples include digital libraries, distance learning environments, videoconference tools etc.
- **Added-value services** that provide specialized support to healthcare professionals. Examples include image processing tools, search engines, information filtering tools, pre-fetching mechanisms, etc.
- **Integrated Electronic Health Record (I-EHR) services** that provide uniform ways for accessing parts of he patient record data that are physically located in different clinical information systems.

These classes of telematic services are applicable to all four healthcare application areas of home, primary, hospital, and emergency care (Figure 2).

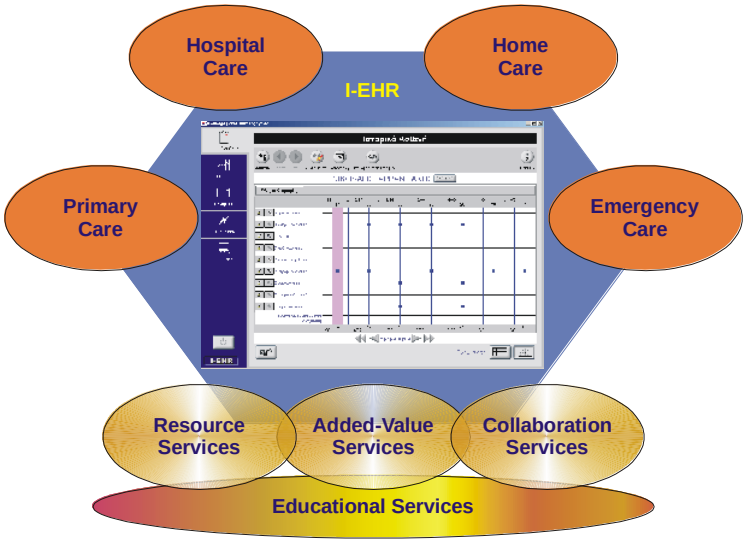

Figure 2: Healthcare Domain Application Areas, Clusters of Telematic Services and the I-EHR Continuum of Care.

The effective horizontal integration of networked information services can provide support for the interoperability of applications and services within a healthcare institution, and the intelligent management of health related information within such an integrated network. Reusable components of the middle layer may exist in a number of alternative types; e.g. they can have the form of a data base schema, a software module performing certain types of actions, an Extensible Markup Language (XML) Document Type Description (DTD), a standardized object-interface, and/ or a communications standard. Services making use of the above should be capable of providing secure, role-based access to services unique patient identification (together with semi-automated resolution of conflicts), and measurable usage results, together with the health status of the population to healthcare planners. In this context the services required for the proper delivery of integrated health telematics services should include:

- **Adoption of public interfaces** that guarantee functional integration like e.g. HL7, DICOM, for the efficient communication of information. These interfaces can support functional integration of healthcare processes in and across healthcare facilities, promoting cost-effective healthcare delivery and continuity of care.
- **Collaboration services** that provide the technological platform that allows general practitioners and medical experts share patient-related information in the context of a teleconsultation session. Every teleconsultation request should result in the creation of a teleconsultation folder and initial health data associated with the specific medical problem to be stored in it.
- **Patient Identification services** that allow for the unique association of distributed patient record segments to a master patient index. This is a very challenging task to perform and one of the major barriers in developing a reliable I-EHR environment. Apart from person identifiers, identifiers are also needed for providers, devices, etc.
- **Authentication services** that manage the roles and corresponding access rights of users, together with associations to personalized profiles. Their purpose is to certify the role and authority of both users and services (or applications) within the regional healthcare network, and requires the existence of a regional/ national certification authority. This way consent management may also be facilitated through electronic signatures.
- **Encryption services** that are responsible for the secure communication of sensitive personal information over the regional healthcare network, as well as over the Internet. The combination of digital signatures for authentication, public key cryptography for recipient authentication, and secure socket layer protocols for secure data-transfer, provide the necessary technological framework for secure communication of healthcare related information across the Internet.

- **Auditing services** that are accountable for recording all interactions between middleware services and/ or end-user applications. The logs produced can be useful for both tracing back transactions in time, and charging purposes. It may also serve as a profiler tool for individual server loads, and for the construction of end-user interest profiles by means of data mining techniques.
- **Resource location services** that are responsible for identifying available healthcare-related agents (like e.g. organizations, devices, software, etc.) and the means for accessing them. Examples of resources include pharmacies on-duty, hospitals and clinics, clinical information systems and services available at a regional level, methods and technologies available for accessing primary information, and protocols for the exchange of information.
- **I-EHR Indexing services** that are required for indexing information that is necessary for locating primary information found in different patient record segments. Indexed information can be related to existing encounters, allergies, personal information of relevance, etc. In this context, encounter is the term used for describing clinical information produced during the communication about the patient, between two or more individuals, at least one of who is a member of the responsible healthcare team.
- **Primary Health Information Access Services** that are required for obtaining crucial information directly from clinical information systems. This service requires the implementation of standardized gateways for each clinical information system for securely importing/ exporting/ propagating/ indexing patient record data. Certain filters ought be supported for the better location of information based on time and examination type criteria.
- **User Profile Services** that track the long-term interests of users and maintain personalized preferences. Initially they automatically assign end-users with user profiles according to existing stereotypes after gathering some initial user-specific information. Users can also actively contribute to the incremental building of their own profiles.
- **Terminology Services** that have a dual objective: to map and associate existing coding schemes, and to relate the internal semantics of the numerous clinical information systems. In the latter case, they enable the transformation of information from one form or representation to another. While the first objective can be accomplished by means of code mapping systems (like e.g. SNOMED, READ, or UMLS), the second requires a conscious effort by clinical information system developers and people responsible for maintaining I-EHR services up to date. Such services guarantee semantic interoperability.

3. Integrated Electronic Health Record

The main driving force for implementing EHRs is the need to share information. The feeder systems of a federation of clinical information systems are usually heterogeneous, autonomous, and geographically distributed. Each one maintains its own information model, uses a local database management system, and provides its individual user interface. The introduction of a feeder system inside any federation is a process that requires human mediation and involves the following steps:

- The definition/ adoption of a federated/ global schema that is capable of supporting effective solutions to the patient's immediate needs without imposing significant constraints in dealing with the issue of incorporating new systems in the federation.
- The required consent from all organizational units that want to become part of the federation and get access to the means for mapping and exporting all local schemata to the federated/ global schema. This involves concept mapping and the implementation of the corresponding data extraction gateways and the registration of the new feeder systems inside the federation's resource directory.
- The adoption and use of standardized/ public interfaces for getting access to primary information
- The regulations of the required mechanism for achieving the prompt update of all the relevant information that can guarantee in practice an acceptable quality of service. This may be implemented by means of scheduling periodic, pull or push, updates, or propagation of information on demand.

- The implementation and enforcement of an adequate security system that will be capable of handling consent management
- The provision of usable graphical interfaces for browsing the I-EHR. This is coupled with the resolution of all HCI related issues.

This approach provides the foundations for any environment that aims in providing scalable, integrated, round-the-clock access to clinical information. Primary information is kept at the place where it is produced and maintained by the most appropriate clinical information system in all cases. As seen in Figure 3, a set of the following elements is necessary in order to develop the service: (i) Information propagation from clinical information systems to the middle layer of the HII. (ii) A set of components residing at the middle level of the "architecture" managing the required minimum data sets, as well as indexing, and finally (iii) an HCI environment to make available the I-EHR to the end users of the service (citizens, physicians, and medical staff). End users expect the service to be able to offer role-based, secure access to reliable, patient information 24-hours a day, and since speed is considered as an important factor in the overall acceptance of the service no compromise should be made on the availability of the highly distributed information.

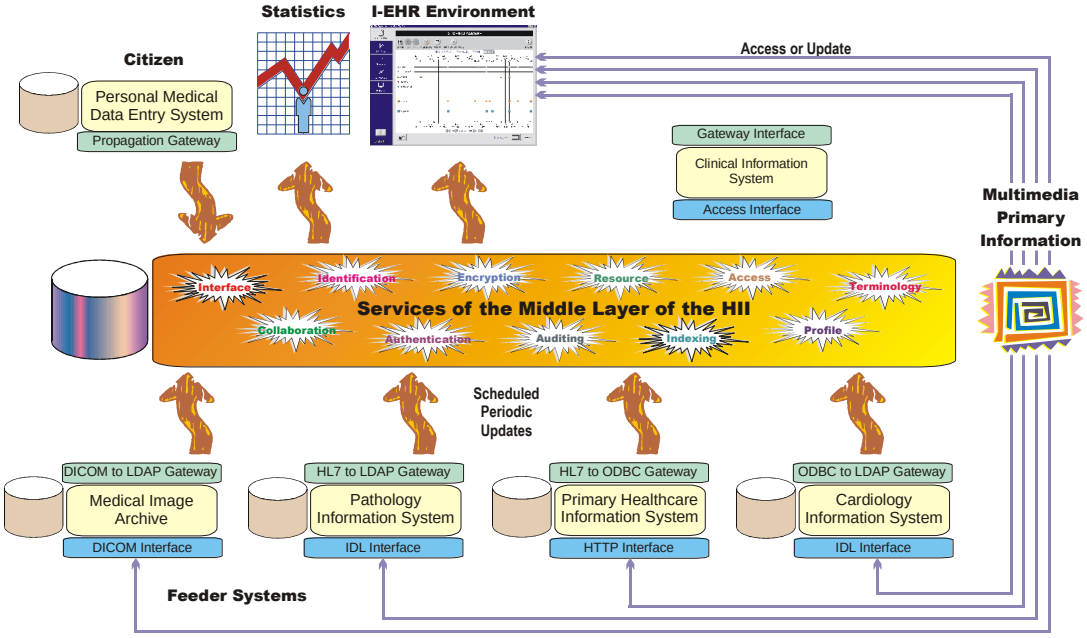

Figure 3: Clinical Information Systems Propagate Indexing Information to the Middle Layer of the HII, Through Which End Users Get Access to Primary Information, Subject to Proper Authorization.

New Information and Communication Technologies (ICT) provide a unique opportunity for more efficient delivery of quality care and improved access to healthcare resources and health information. Beyond relational databases that are used today extensively for storing enterprise, data technologies for the integration of EHR-related information also include the following:

- **Directories** for creating distributed, hierarchical structures of accessible resources. In essence, directories are distributed databases capable of storing, in a hierarchical data model, information about people and objects at various servers or network nodes. It is these servers, which provide the potentially global access to information, made possible by X.500.
- **Distributed object computing** for implementing advanced modular functionalities. Unlike client/ server architectures, where the client discovers and communicates directly with the server, when dealing with distributed object computing, communication middleware acts as an extra functional layer between clients and serv-

ers and enables application development without knowledge of the location or any given implementation offering all external functionalities.

- **The Internet** as a means of integrating systems and services.
- **Java** and its supporting technologies to glue pieces of scattered information across various platforms.
- **XML** for data interchange over the World Wide Web, and the synthesis of multiple information sources. Requirements best addressed by XML include customizing front-end applications, data mining searches, synthesis of multiple information sources, and electronic commerce-type applications. Extensible Style Language (XSL), which is a map language that allows transforming XML documents into other language documents, further enables the seamless presentation, and personalization of information. XML technologies act complementary to existing object technologies, and are expected to have significant impact in the future.
- **Portable devices** and **mobile communications** to enable access from anywhere at any time, and
- **Human Computer Interaction technologies** to support access for all.

Judicious use of ICT has the potential to improve the quality of care and the cost-effectiveness of its delivery. For example, it will make possible the timely electronic provision of essential health services and medical expertise in remote areas. It will encourage more efficient and effective management of patient services by hospitals, individual physicians and community doctors. It will make possible improved surveillance of emerging diseases by public health authorities at the municipal, regional, national and international levels. It will facilitate the creation of health information databases that, under appropriate safeguards for confidentiality, can be used by researchers, health practitioners and policy makers to improve all aspects of health care. Finally, it will provide patients and consumers of health services and people concerned about their health with ready access to health information ranging from nutritional data to information on disease prevention.

4. Discussion

In the framework of HYGEIAnet HII, medical information systems and services are treated as information sources to be integrated under the common reference architecture. The final goal is to provide integrated, user-oriented telematic services and uniform access to networked information sources. These services, in addition to achieving customizable functionality for the user, will also constitute common components of specific clinical information systems. To meet this challenge, an execution architecture is being implemented in order to support the seamless integration of information. Currently, within the context of HYGEIAnet, a number of sub-domains attract attention. Namely:

- **Home Care:** Aiming at providing health telematics services to the home of a patient or citizen. Various such services are in development, ranging from the provision of telemonitoring for patients undergoing kidney hemodialysis to asthma suffering children.
- **Primary Care.** A primary healthcare network is already in operation. The primary health care centers of the island are all fully equipped and support efficiently all patient related clinical processes.
- **Pre-hospital Health Emergency Care.** An integrated system has been developed and is currently operational providing telematic tools and services for the optimal planning, and response management of pre-hospital health emergencies.
- **Hospital Care:** Clinical information systems have been developed or purchased and installed in various clinical departments.
- **The Integrated Electronic Health Record:** The required infrastructure is in place and a large number of clinical information systems are currently supported, ranging from primary health care and nursing to departmental information systems for pathology, cardiology, radiology, laboratories, etc.
- **Education and Information to the Citizen:** The development and operation of any Integrated Health telematics network is not only a matter of applying new ICT technologies. Above all, it requires the continuous education and training of medical, nursing and administrative personnel from all involved healthcare organizations. Since this is a decisive factor in the acceptance of new technologies, more than 2000 staff be-

longing to all three levels of the national healthcare delivery system, as well as the national health emergency center branch of Crete, were given formal training courses during the past two years.

- **Health Monitoring and Surveillance:** The fundamental objective is to provide the technological infrastructure (networks, information systems, analysis tools, etc) for the routine collection of primary health data and their analysis for the extraction of the relevant health indicators. A health care monitoring information system will be specified and implemented and tools for the analysis and reporting of primary health data will be provided in the context of an operation center.

HYGEIAnet takes advantage of the increasing capacity of terrestrial networks, wireless and mobile communications and the development of advanced health telematic services, to provide continuity of care in the different phases of healthcare, from prevention to care itself, to rehabilitation. Expected benefits of HYGEIAnet includes the development and dissemination to citizens of evidence-based information on treatment options, healthy lifestyles and emerging health concerns in many different ways. This will give people new means of obtaining insight and support when making personal health care decisions. In addition it will provide access to critical personal information for citizens in their health records 24 hours a day, seven days a week, with fuller assurances of confidentiality than can be provided today with a paper-based system.

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6. References

HYGEIAnet web site: http://www.hygeianet.gr/

Katehakis DG, Lelis P, Karabela E, Tsiknakis M, Orphanoudakis SC: "**An Environment for the Creation of an Integrated Electronic Health Record in HYGEIAnet, the Regional Health Telematics Network of Crete**". TEPR 2000, Your Connection to Electronic Healthcare, San Francisco, CA, May 9-11, 2000, Vol. 1, pp. 89-98.

Katehakis DG, Sfakianakis S, Tsiknakis M, Orphanoudakis SC: "**An Infrastructure for Integrated Electronic Health Record Services: The Role of XML (Extensible Markup Language)**". Journal of Medical Internet Research 2001, Vol. 3, No. 1, e7, <URL: http://www.jmir.org/2001/1/e7/>.

Katehakis DG, Tsiknakis M, Orphanoudakis SC: "**Information Society Technologies in Healthcare**", in "SOFSEM 2000 - Theory and Practice of Informatics", Havlac V, Jeffery KG, and Wiedermann J (editors), LNCS, Vol. 1963, Springer-Verlang, 2000, pp. 152-172.

Tsiknakis M, Katehakis DG, Orphanoudakis SC: "**Intelligent Image Management in a Distributed PACS and Telemedicine Environment**", IEEE Communications Magazine, vol. 34(7), pp. 36-45, 1996