A Healthcare Information Infrastructure to Support Integrated Services over Regional Health Telematics Networks*

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Abstract

Information and Communication Technologies (ICT) provide today a unique opportunity for a more efficient delivery of quality care and improved access to healthcare resources and information. ICT can undoubtedly improve the use of information by healthcare professionals in day-to-day patient care. However, there must be an equally strong focus on the practical use and communication of information to provide direct benefits to patients in their use of healthcare services at the point of need. In order to achieve the provision of integrated, user-oriented, health telematics services, which will eventually ensure prompt and secure access to information resources, several complex issues ought to be resolved. They are related to fragmented domain data, to platform and service heterogeneity requirements, to complicated protection and authorization policies, and to the multiplicity of existing standards for interoperability and information exchange. Therefore, the issue of developing an open, scalable and evolvable Healthcare Information Infrastructure (HII), based on a reference architecture, which is capable of supporting the seamless integration of existing information sources as well as new applications and services, is of strategic importance.

Introduction

Healthcare is usually delivered within certain organizational boundaries and information produced at each site is managed by isolated autonomous clinical information systems. In some cases point-to-point communication is enabled by telemedicine sessions that facilitate communication of information. In contrast, integrated regional health telematics networks enable accessibility to information and services without visible organizational boundaries, to provide decentralized healthcare through integrated services for seamless and personalized information delivery [1]. This has the advantage of enabling informed citizens to have an impact on the healthcare system and to be more concerned and care for their own health. The current vision comprises affordable access to healthcare resources and services for all citizens, thus making medical expertise a shared resource wherever and whenever needed. Important areas in which information society technologies are likely to have a significant impact include those of pre-hospital health emergencies, remote monitoring of patients with chronic conditions, and medical collaboration through sharing of health-related information resources.

Current trends in the provision of healthcare services call for integrated user-oriented telematics services, which ensure prompt and secure access to information resources, provided proper authorization is available. This requires the cooperation of healthcare facilities that offer complementary set of services and involves dealing with complex issues mainly related to patient data confidentiality, semantic heterogeneity, and the diversity of systems and services requirements. This further urges for the creation and/ or adoption of certain interopera-

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bility protocols and standards that will enable information exchange, and consequently raises the issue of developing an open, scalable and evolvable HII. The creation of an HII is also driven, among other factors, by the need for automating routine tasks to place the focus on patient needs rather than paperwork. It is also driven by the need to ensure continuity of care by providing flexible remote access to relevant information and resources, and to support research in order to enable all involved stakeholders to make effective choices.

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.

Technological Challenges

It is commonly accepted that care capacity, available at local level, is greatly enhanced when local practitioners have access to a patient's healthcare record and, as the need arises, when specialists can assist them, wherever they may reside. ICT can support access to an Integrated Electronic Health Record (I-EHR) that is distributed, as well as the sharing of medical knowledge and expertise for the benefit of society as a whole. Important objectives in any effort toward establishing global networks of integrated telemedicine services are the following:

- Adoption of a common reference architecture for the development of clinically significant health telematics services.
- Interconnection of cooperating regional healthcare networks for the purpose of creating trans-regional healthcare networks.
- Definition of medical and operational procedures for sharing resources and expertise over such trans-regional healthcare networks, so that patient mobility and improved care practices can be supported effectively.
- Development of environments for information exchange among regional healthcare networks based on agreed information exchange protocols for the medical domain.
- Promotion of the coordinated and harmonized development of regional healthcare networks.

The conceptual architecture of the Technical Committee for Health Informatics of the European Committee for Standardization (CEN/ TC 251) [2] and the Reference Model of Open Distributed Processing (RM-ODP) (Health Care) [3] both converge towards a multi-tier architecture, and identification of common components.

Our work focuses on instantiating such an architectural framework as well as specifying & developing the essential common components. Special attention is given to the need for allowing these components to operate in a variety of technological environments (i.e. execution architectures). A high-level abstraction of the reference architecture adopted is shown in Figure 1.

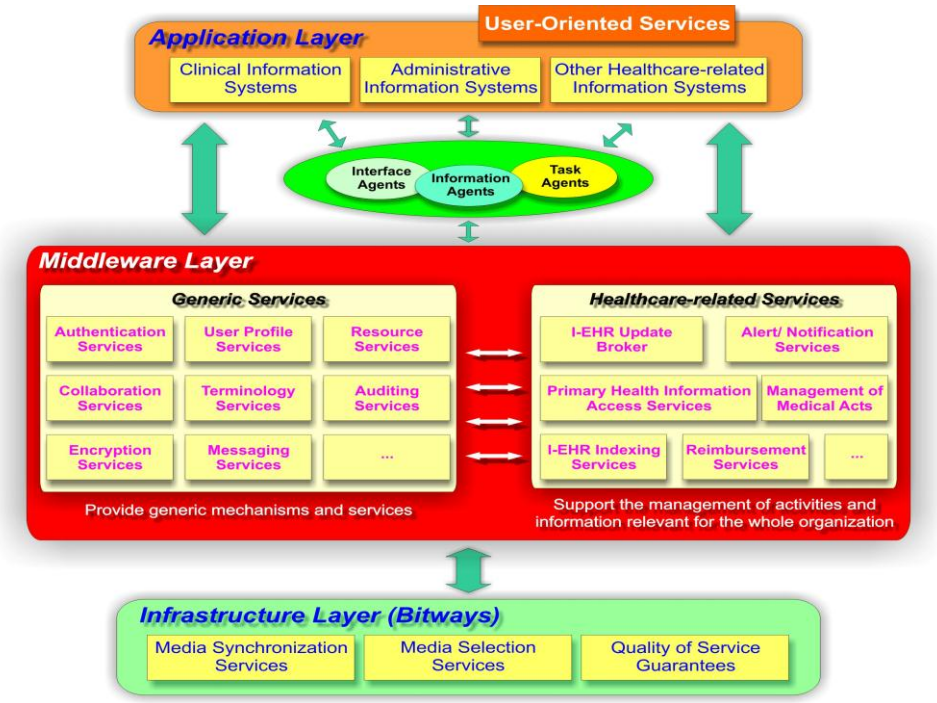

Figure 1: Reference Architecture, based on Components, as Used in HYGEIAnet, the Regional Health Telematics Network of Crete.

Essential components that have been identified [4] to be required for the proper delivery of integrated health telematics services include:

- **Public interfaces** (like e.g. Health Level Seven - HL7, and Digital Imaging and Communications in Medicine - DICOM) for the efficient communication of information. These interfaces can support functional integration of healthcare processes in and across individual healthcare facilities, promoting cost-effective healthcare delivery and continuity of care.

- **Collaboration components** for allowing general practitioners and medical experts to share patient-related information in the context of a tele-consultation session.

- **Patient Identification (ID) components** for identifying patients based on their demographic data and correlating their IDs across different ID domains.

- **Authentication components** for certifying the role and authority of both users and services (or applications) within a regional healthcare network. This type of component requires the existence of a properly certified regional certification authority.

- **Encryption components** for the secure communication of sensitive personal information over the regional healthcare network, as well as over the Internet.

- **Auditing components** for recording all HII component and/ or end-user application and services' interactions. The produced information can be also used for both charging, as well as data mining purposes.

- **Resource Location components** for identifying availability of related resources, such as organizations, devices, or software and the means for accessing them.

- **I-EHR indexing components** for locating fragments of primary health information maintained by different clinical information systems.
- **Primary Health Information Access components** for direct access to the primary healthcare information systems where the complete, original (physician generated), clinical information is kept.
- **User Profile components** for tracking the long-term interests of users and maintain personalized preferences.
- **Terminology components** for the association of existing coding schemes, and to enable the transformation of information from one form or representation to another.

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 today are used extensively for storing enterprise data, technologies for the integration of information related to the Electronic Health Record (EHR) also involve *directories* for creating distributed, hierarchical structures of accessible resources (with the most promising being X.500 and Light Directory Access Protocol – LDAP of the International Telecommunication Union - ITU), *distributed object computing* to implement advanced modular functionalities (like e.g. the platforms of Common Object Request Architecture - CORBA or Java Two Enterprise Edition - J2EE), *Internet* and *Java* to glue pieces of information scattered throughout the world, *portable devices* and *mobile communications* to enable access from anywhere at any time, *eXtensible Markup Language (XML) technologies* to allow for dynamic browsing according to personalized preferences and authorities, together with *Human Computer Interaction (HCI) technologies* to support universal access for all.

HYGEIAnet: A Case Study

The development of HYGEIAnet, which is the regional health telematics network of Crete (see Figure 2), is a systematic effort toward providing an integrated environment for health monitoring and healthcare delivery, as well as medical training and health education across the island. The objective of the effort is to put in place the people, the resources, the culture and the processes necessary to ensure that healthcare professionals and managers have the information needed to promote the core purpose of the healthcare system, which is to care for individuals and improve public health.

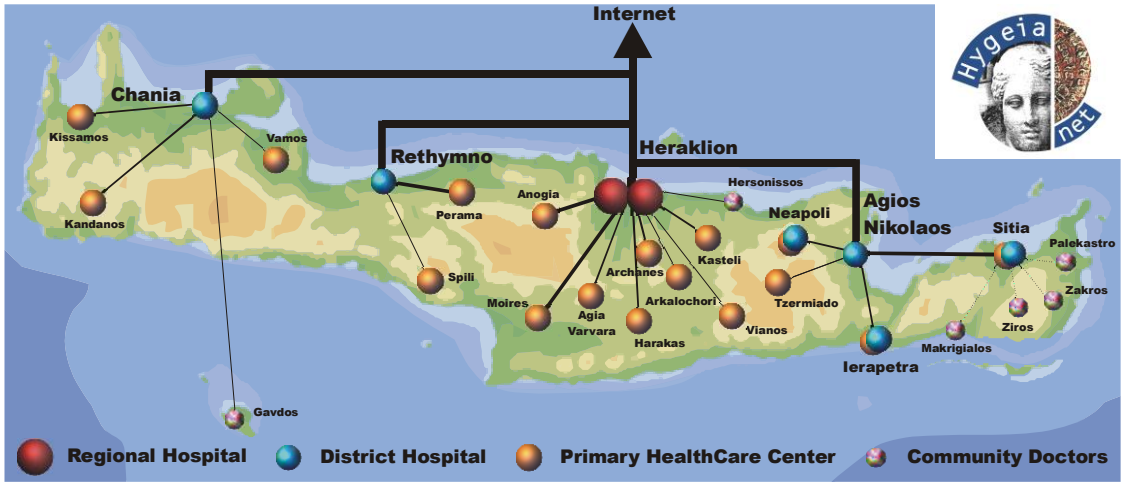

Figure 2: The HYGEIAnet Topology.

A driving concept of the efforts during this design and development of HYGEIAnet was the belief that '*health telematics systems and services should be dictated by health needs and not be technology-driven*'. As a result

emphasis was given to the development of systems and services providing support to important application areas and responding to well identified user needs.

Sub-domains that have attracted attention so far include:

- **Home Care**, where a number of health telematics services have been tested, mainly involving asthma suffering children [5].
- **Pre-hospital Health Emergency Care**, where an integrated system has been developed, and is currently operational to provide telematics tools and services for the optimal planning, and response management of pre-hospital health emergencies [6].
- **Primary Care**, where all the primary health care centers of the island have been equipped with an integrated information system comprising of: an electronic health record for primary care, a laboratory information system and an image management and communication system. These modules are functionally integrated, based on international standards (HL7, DICOM), thus resulting in a single integrated information system supporting all activities of the organization [7].
- **Hospital Care**, where autonomous administrative, financial, laboratory and clinical information systems have been developed or purchased and installed in most district or regional hospitals of the island.
- **I-EHR**, where the developed environment [8] provides a decentralized view of the patient's medical record, by dynamically composing information that resides in a variety of selected, heterogeneous clinical information systems.
- **Telemedicine**, where a number of synchronous and asynchronous telemedicine services are in use for cardiology [9] and radiology, based on the WebOnCOLL collaboration component [10].
- **Health Monitoring and Surveillance**, where a health care monitoring information system is been specified [11] and implemented and tools for the analysis and reporting of primary health data will be provided in the context of an operation center.

Applications and services, in all the above-mentioned sub-domains, (re) use the same HII components for message communication, for locating available health resources, for identifying patients, for communicating their sensitive information, for achieving role-based access to patient information, etc. All applications and services consist of the same ingredients, only to be *"assembled"* differently in order to provide integrated, user-oriented telematics services and uniform access to all available, networked information sources.

In the framework of HYGEIAnet and the HII currently under development, all clinical information systems are considered information sources, which are to be integrated under a common reference architecture and technological infrastructure based on a multi-layer architecture and a number of middleware services. This reference architecture is the base upon which an execution architecture is being implemented in order to support seamless integration of information.

Conclusion

The primary areas of focus of the second phase that HYGEIAnet is now proceeding are consistent with both the original plan and with those of the first phase. The context for each of the initiatives is evolving rapidly, and it will be critical to continue to adjust the focus for each, as those context changes in the years to come. Through the deployment of HYGEIAnet, which today is considered as a model for the development of integrated regional health networks in Europe, the focus has been put on:

- the design of a conceptual architecture for the next generation integrated regional health telematics networks,
- the definition of a reference architecture and framework for the integration of heterogeneous, autonomous and decentralized systems,
- the provision of appropriate middleware services and mediation tools,
- the adoption and/ or definition of public and stable interfaces and protocols, together with
- the consideration of the related medico-legal issues.

Quite a big number of components have been identified so far, capable of supporting the ICT "migration" strategy at a regional level. Our experience has shown that re-usable components make the delivery of new systems easier and faster, while at the same time they allow for a more efficient management of the ICT infrastructure. As gained experience necessitates the continuous advancement of systems and services, modular (isolated) functionalities make coping with this evolution easier. Still, decisions have to be formulated about how and when to upgrade the platform itself and whether the expected benefits and savings outweigh the costs involved.

To efficiently address the challenges of large-scale system design and development, teams that are trained and seasoned in distributed object technology are required. The bigger the scale of scope of the envisaged system gets, the more the number of the required enabling components becomes and the more evident is the need to realize their potential.

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