A study of standards involved in telemedicine systems

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Abstract—**Telemedicine applications are becoming very popular due to the advances in information technology and the ever expanding Internet and World Wide Web infrastructure. But this popularity sometimes leads to chaos, in the sense that a percentage of these applications are built using proprietary techniques instead of using open Internet and medicine standards. This issue limits the capacity of an application to interact with other standardized or non-standardized telemedicine applications. When implementing one of these applications, it is important to consider which valid and widely accepted standards should be used. This study elaborates on the proposal of a starting point when trying to conceive a telemedicine application over the Internet.**

I. Introduction

THE purpose of any telemedicine application is to deliver long-distance healthcare services. The technology involved in this objective may go from a telephone landline for voice interaction to a better, more versatile infrastructure, and this is where Internet has played an important role. There are hundreds of telemedicine applications being developed today that use Internet as middleware. Internet and the World Wide Web serve as a robust platform on which complex and versatile telemedicine applications can be deployed [1]. These applications can use simple technologies like a modem connection and a digital camera for teledermathology [2]. Others use more sophisticated techniques like a video stream and a remote controlled robot for telesurgery. These are examples of point-to-point applications. The specification of the protocol used in the communication may be private or public, but this is not important as long as no more participants are involved. But what happens if the application needs the cooperation of more participants in the near future? Or if other participants would like to reuse some of the services provided by the applications already developed? This rules out the use of any private specification and calls for an implementation using public and open standards. They ensure interoperability between different developers.

The purpose of this paper is to analyze the different domains that cover a telemedicine application over Internet and to recommend what standards should be used in order to ensure cooperation and interoperability.

We will center on the study of a system for cooperative telediagnosis where we categorized the standards in three domains which are the communication between components, the web interface and the medical data structure.

The Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C) [3] are considered as the main sources of standards in the communication and the web interface domains. The mission of the IETF is "to produce high quality, relevant technical and engineering documents that influence the way people design, use, and manage the Internet in such a way as to make the Internet work better". These documents, commonly known as request-for-comments (RFC) cover aspects such as routing, transport, security, etc. The W3C's mission is "to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure long-term growth for the Web". The W3C does not actually develop Internet standards. It develops standards for the World Wide Web, a hyper text platform that works over Internet.

The following sections describe a brief scenario of a system for telediagnosis and the different domains (communication, web interface and medical data structure) identified in the development of the system with their corresponding standards.

II. Scenario

We are studying the standards involved in a system for the cooperation of different entities specialized in medical diagnosis. The entities are both human (physicians) and artificial (expert systems). There are other two elements of the study which are the web interface for user access and the system core.

The web interface is the point of access that the human entities use to interact with the services of the system. Web interfaces are the common solution of thin or lightweight clients used in Internet, intranet and World Wide Web applications. The use of platform-independent rich clients like JAVA Applets or Macromedia Flash was discarded because they need the installation of additional software which is available for only a few Internet enabled devices. This is surpassed by the popularity of web browsers and web interfaces which are used to display patient data[4], to review medical information and news [5] and to monitor patients at home [6], just to name a few examples.

Manuscript received June 30, 2006. This work is supported by the Office of Science and Technology of the Autonomous Government of Valencia (Spain) as a part of the research project GV05/158 titled "Cooperative Diagnosis System Applied to Urological Dysfunctions" (2005-2006).

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The system core is the component in charge of coordinating the information flow between all entities. It is also in charge of gathering all the individual diagnoses and deciding on the most probable one.

The diagnosis process starts when a medical specialist uses the web interface to request a diagnosis to the system core which forwards the medical data to all diagnosis entities. The artificial entities receive the information directly from the system core, analyze it and return a diagnosis to the system core. The human entities use the web interface to do the same. The system core gathers the diagnosis from all entities and later decides which of them is the most likely to be correct. The final decision is then forwarded to the medical specialist that initially requested the diagnosis. The interaction between system components is shown in Fig. 1.

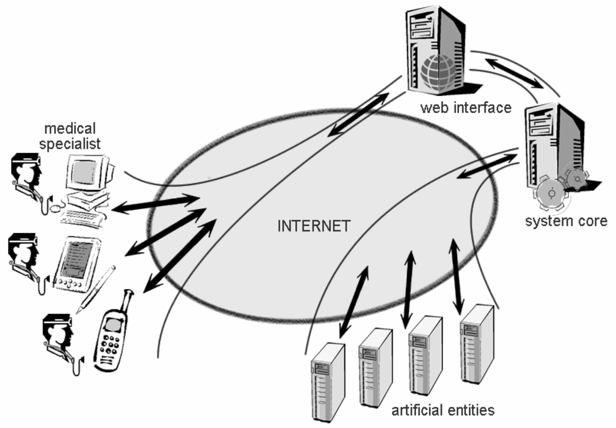

Fig. 1. Distribution and interaction of the system components for cooperative telediagnosis.

III. COMMUNICATION

In the system, there are two types of communication taking place over Internet. The first one is between the web interface and the devices used by the human entities to access it. The second one is between the system core and the artificial entities.

Most of the standard communication protocols used in Internet are developed by the IETF. The most important protocol stack is TCP/IP. Any Internet application uses some protocol that is generally built over TCP/IP.

When it comes to accessing a web interface, the preferred communication protocol used is HTTP. It is supported by most commercial and open web servers and web browsers. It is even supported by a wide variety of mobile devices like PDAs and smart phones that access Internet through Wi-Fi and GPRS/UMTS networks, making any web interface highly available.

HTTP is known as a plain-text protocol making it vulnerable to all types of attacks like invasion of privacy and data alteration, completely unacceptable situations in a telemedicine system. The commonly adopted standard in web security is the SSL protocol which uses a combination of symmetric and asymmetric cryptography to secure a communication between a web server and a web browser. A web server that uses SSL needs to have a digital certificate issued by a certification authority like Verisign or Thawte. This certificate lets a web browser verify the authenticity of a website, thus adding more confidence to the user.

The artificial entities behave like independent software or hardware components that provide a diagnosis service. This is why the communication scheme between the system core and the artificial entities can be based on the techniques used in distributed component architectures. From this point of view the system core acts as the client and the artificial entities act as the components.

The method used in component interoperability may be tied to the programming language or platform used in their implementation. JAVA for example provides two methods which are RMI and EJB, this second one being the most recent. Some older platforms from Microsoft include the technologies of the Component Object Model standard, but the most recent one is the Remoting scheme from the .NET platform. If the components are developed on any programming platform like JAVA or .NET, future components will need to be developed with the same technology if they want to interact with each other. JAVA components cannot interact directly with .NET components and vice versa because each platform implements proprietary communication protocols. This is why the Object Management Group developed the Common Object Request Broker Architecture (CORBA), a set of protocols that enable component interaction between different platforms. CORBA provides a solution for platform independency, as long as a platform came with a CORBA implementation. If a specific platform did not provide one, it could not be used to develop components that could interact with others that are CORBA enabled.

The lack of a CORBA implementation on some platforms led to the creation of web services which are software components that can be accessed using standard Internet protocols like HTTP. They use the Web Service Definition Language (WSDL) to describe the details of the services they implement and they are accessed by using the Simple-Object Access Protocol (SOAP). Both WSDL and SOAP are based on XML, the leading standard in the specification of consistently structured documents that are both machine and human readable. Most of the web service standards are developed by the W3C, the Organization for the Advancement of Structured Information Standards and the Web Services Interoperability organization.

JAVA, .NET and other programming platforms come with a set of tools, libraries and integrated development environments that facilitate the creation and the use of web services, therefore reducing the need of knowing the details of the WSDL and SOAP specifications. The popularity of web services has increased significantly in the healthcare sector [7].

Web services are also vulnerable to attacks if they are not secured. SSL can also be used if they use SOAP over HTTP. However, this secures the connection between machines, but not between applications. Malicious software installed on the client or on the host machine can still view sensitive information. The recent standard that enables security at the application level is WS-Security. It is based on security tokens to support authentication and authorization between components, XML-Encryption which ciphers the data contained in a web service message to ensure confidentiality and XML-Signature which uses digital signatures to ensure message integrity.

IV. WEB INTERFACE

The web interface involves three aspects which are information structure, accessibility and quality of content.

We used the Hyper Text Markup Language (HTML) to structure the information in the website. HTML is the most common standard used today in this area. Recently, the W3C developed XHTML which is a redesign of HTML but based on the consistency of XML. The latest specification is version 1.0. This specification is supported by a wide variety of web browsers available on all kinds of devices like personal computers, laptops, PDAs and smart phones.

Previous versions of HTML used embedded attributes in the document structure in order to define visual aspects of the web interface like font size, family and color, border width, etc. Although some web browsers still support this, the W3C has developed a standard called Cascading Style Sheets (CSS), a specification that can define styling and visual aspects of a website. The latest version of CSS is known as level 2 revision 1 or CSS 2.1. Most recent web browsers also support this specification. A CSS file can be defined separately from an XHTML file so the same information can be displayed differently according to the viewing device like a computer screen or a printer.

Different CSS files could be created for each of the device used to display the interface thus separating information content from information style, but this would mean that if a new device wants to be supported, another CSS file would have to be specified. This can be avoided by using only one CSS file that includes simple styles so any web browser of any device can display the web page. For example, sizes are defined in terms of relative measurements, like percentages, and not in terms of fixed measurements, like millimetres or pixels. The final presentation of the web interface is shown in Fig. 2.

Website accessibility refers to making the information in a website accessible to all types of users either experienced, non experienced, but specially to users with disabilities. In this subject the W3C created the Web Accessibility Initiative which defined the Web Content Accessibility Guidelines (WCAG), a set of rules that help make the information in a website accessible. This guide includes recommendations like the use of CSS to organize information in a webpage instead of using tables, the description of all images so visually impaired users can know its contents, the restricted use of some colors that may affect users which are color blind and the linearization of tables (when the cells of a table make sense if they are displayed as sequential paragraphs).

Quality of content refers to the audit and verification process applied to information related to a profession. Since the web interface includes other mechanisms of cooperation in the form of news, forums and articles, the information deposited on the website needs to be accompanied by a quality of content certificate.

In Europe there is an action plan called eEurope 2005 which groups a set of policies developed by the European commission that stimulate the creation of advanced information services in the public sector, one of them being healthcare or eHealth. In November of 2002 a document was published under this action plan which stated quality criteria for health related websites [8]. This document mentions the importance of information transparency, privacy, responsibility and accessibility. It also mentions a few implementation examples. It states that the oldest and most qualified implementation is the certification issued by the Health On the Net (HON) foundation [9]. This foundation issues the HON code of conduct, a seal that certifies the

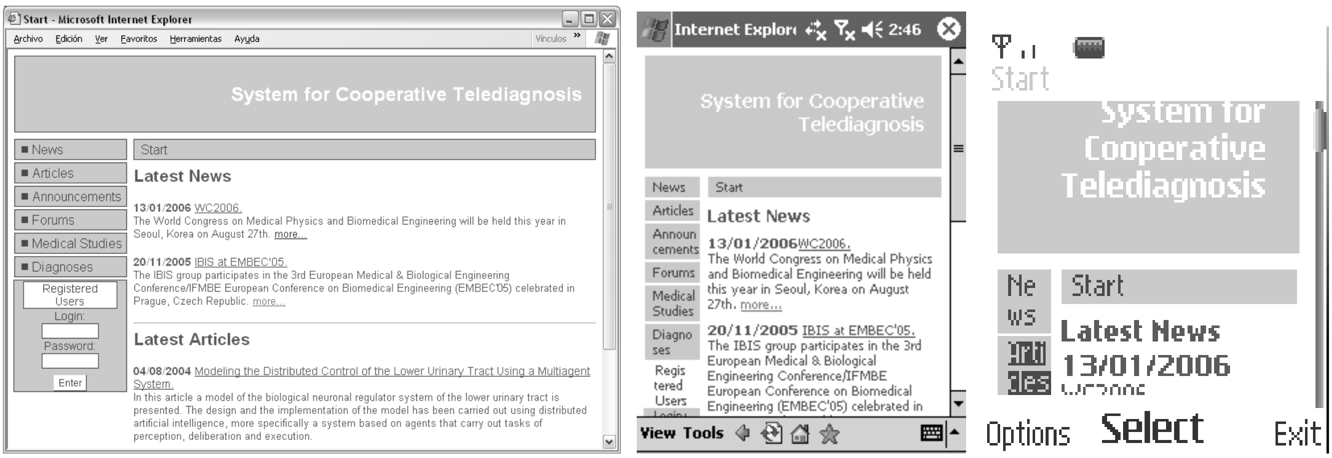

Fig. 2. Visualization of the web interface in different devices: personal computer (left), PDA (center) and smartphone (right).

compliance of eight quality principles which are authority, complementarity, confidentiality, attribution, justifiability, transparency of authorship, transparency of sponsorship and honesty in both advertising and editorial policy.

V. Medical Data Structure

The standards involved in the medical data structure domain are not as popular as the standards involved in the Internet domain.

The International Organization for Standardization (ISO) defines a category called "Health informatics" which groups all standards related to healthcare and informatics. The technical committee TC 215 of the ISO is in charge of developing the standards in this category. Its mission is the "standardization in the field of information for health, and Health Information and Communications Technology (ICT) to achieve compatibility and interoperability between independent systems". To this day the TC 215 has developed 29 standards in fields such as "interoperability of telehealth systems and networks", "public key infrastructure", "point-of-care medical device communication", etc. However, no standards related to medical examination data structure were found.

The technical committee TC 251 of the European Committee for Standardization is in charge of the standardization of health informatics in Europe. It has published a number of drafts in various fields of health informatics like "electronic health record communication", "exchange of information on medicine prescriptions" and "medical data interchange". The standards of the ISO/TC 215 or CEN/TC 251 do not come with open-source implementations or examples.

The World Health Organization created the eHealth Standardization Coordination Group which published a document containing the most important and relevant standards in eHealth [10]. In this list there are two standards relevant to the medical data structure domain which are DICOM and HL7.

DICOM (Digital Imaging and Communications in Medicine) is a standard developed by the National Electrical Manufacturers Association of the United States [11]. It specifies the method and formats used in the exchange of images between medical imaging devices. Although the first version of DICOM only supported the point-to-point exchange of real-time digital images, today it supports offline transmission and associated data. DICOM defines a proprietary protocol over TCP/IP for the exchange of information over communication networks and portable storage like CD-R and file systems like the ISO9660. It also defines information objects that represent digital images and associated data. It defines service classes that model the relationship between the information objects and the actions or commands that may be executed on them. Other DICOM specifications include data structure, storage, message exchange, file systems, security, access to persistent objects using Internet standards like HTTP and Multipurpose Internet Mail Extensions. Some examples of DICOM enabled applications include the exchange of radiological images through e-mail [12] and a server built on JAVA for the storage of patient information and images [13].

DICOM, although focused on interoperability, targets medical imaging systems. The system developed does not include any digital images, only plain-text data of medical tests and results. Also, DICOM specifies its own proprietary interoperability protocol over TCP, making it necessary to implement it in future components.

HL7 (Health Level 7) is an organization accredited by the American National Standards Institute [14]. The seven refers to the application layer of the Open System Interconnection reference model. This organization creates standards for the exchange, management and integration of electronic healthcare information. The latest specification of the HL7 standard is version 3. This version defines the Reference Information Model (RIM) which describes how to represent the data of different clinical domains including administrative, pharmaceutical and clinical care. The RIM is the foundation for the Clinical Document Architecture (CDA) which specifies how to exchange clinical documents between healthcare applications. In the latest version of HL7, this is done by combining the RIM and XML. The ISO/TC 215 is also working on its own version of HL7 and is known under the identifier ISO/HL7 FDIS 21731.

The website of the HL7 organization provides a few documents that show how to use the RIM in order to model clinical data. The RIM comes with a methodology that shows how to represent the messages that travel in between the components of a healthcare information system.

The RIM of HL7, although conceived as a model for the numerous events and entities included in a hospital information system, possesses classes that can be used to model the process of requesting a diagnosis and providing a response. This is done by using the observation class of the RIM. Test results and diagnoses can be modeled both as observations [15]. By modeling the medical data structure as observations, other HL7 complaint systems could use the system directly to request a diagnosis. HL7 is used for example in the creation of a compliant clinical patient record system [16] and the implementation of a system for the creation and validation of HL7 messages [17].

There is another initiative worth mentioning in this subject and is known as Integrating the Healthcare Enterprise (IHE) which is sponsored by many organizations related to healthcare and possesses an European branch [18]. This initiative does not create standards. Instead it recommends the adoption of existing standards according to the clinical need. This is done though the development of "integration profiles" which address different clinical needs and recommend what standards to apply in order to eliminate ambiguity and to enable interoperability. The profiles are grouped in technical frameworks including radiology, cardiology, laboratory, and information technology infrastructure. Each profile is made of three elements which are actors, options and transactions. Actors are complete clinical information systems or individual components in them. An option is a functionality that an actor implements and that is available for other actors to use. A transaction is an event that involves two or more actors where some standardized messages are exchanged. A transaction takes place when an actor invokes an option of another actor. Fig. 3 shows an example of the representation of these three elements.

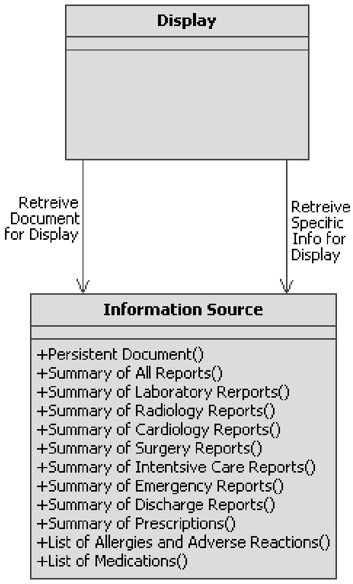

Fig. 3. Retrieve Information for Display profile: representation of actors (boxes), options (functionality inside actors) and transactions (connections between actors).

An integration profile shows how actors and transactions are combined and the options that an actor should implement. The nine integration profiles mentioned the information technology infrastructure technical framework (ITI TF) recommend what standards should be used in order to ensure interoperability between clinical information systems. Table I shows a list of these profiles and the standards they recommend.

The IHE looks promising. Not only does it mention health informatics standards, it also mentions how and where they must go. The ITI TF spans over a lot of domains, most of them needed in a full enterprise clinical system, and promotes the use of open Internet and HL7 standards.

VI. Conclusions

Compliance of standards is fundamental for the interoperability among systems from different developers. In the development of a system for cooperative telediagnosis these standards must include the communication, the web interface and the medical data structure domains. For the first and second domains there are clear dominating standards like XTML and CSS for web site implementation and web service standards like WSDL and SOAP for component interoperability. HTTP is the commonly used protocol on both cases which can be secured with SSL. A higher level of security can be reached if web services are used in conjunction with the WS-Security specification.

There are institutions that issue conformance labels according to the accessibility of web sites and the compliance of a code of conduct like the one issued by the Health On the Net foundation.

For the third domain, the medical data structure, there are several standards that sometimes address the same issues. An initiative like the IHE tries to solve this ambiguity by referencing open Internet and medical standards like those of the IETF, W3C, HL7 and DICOM. IHE not only specifies what standards should be used, but also where and how.

TABLE I
INTEGRATION PROFILES OF THE IHE INFORMATION TECHNOLOGY INFRASTRUCTURE TECHNICAL FRAMEWORK

Integration Profile	Recommended Standards
RID: Retrieve Information for Display	HTTP, WSDL, HL7-CDA, PDF, JPEG
EUA: Enterprise User Authentication	Kerberos, HL7-Clinical Context Object Working Group (CCOW)
PIX: Patient Identifier Cross-reference	Correspondence between patient IDs in different systems
PSA: Patient Synchronized Applications	HL7-CCOW
CT: Consistent Time	Network Time Protocol (NTP)
PDQ: Patient Demographics Query	Retrieval of patient demographic and visit-related information
ATNA: Audit Trail and Node Authentication	Certificate-based authentication, Public Key Infrastructure (PKI), TLS, Security Audit and Access Accountability Message XML Data Definitions for Healthcare Applications (RFC-3381)
PWP: Personal White Pages	Access to information on human workforce
XDS: Cross-enterprise Document Sharing	Electronic Business using XML (ebXML), SOAP, HTTP, SMTP

References

[1] P. B. Angood, “Telemedicine, the Internet, and World Wide Web: overview, current Status, and relevance to surgeons”, *World Journal of Surgery*, vol. 25, no. 11, pp. 1449-1457, Nov. 2001.
[2] M. Papageorges, P. Herbert, “Telemedicine using standard internet technologies (telemedicine for less than $1000)”, *Clinical Techniques in Small Animal Practice*, vol. 16, no. 2, pp. 102-107, May 2001.
[3] World Wide Web Consortium. [Online]. http://www.w3c.org
[4] M. Kuntalp, O.Akar, “A simple and low-cost internet-based teleconsultation system that could effectively solve the health care access problems in underserved areas of developing countries”, *Computer Methods and Programs in Biomedicine*, vol. 75, no. 2, pp. 117-126, 2004.
[5] C. Kahn, “Design and implementation of an internet-based health information resource”, *Computer Methods and Programs in Biomedicine*, vol. 63, no 2, pp. 85-97, 2000.
[6] L. Rasmussen, K. Phanareth, H. Nolte, V. Backer, “Internet-based monitoring of asthma: a long-term, randomized clinical study of 300

asthmatic subjects", *Journal of Allergy and Clinical Immunology*, vol. 115, no. 6, pp. 1137-1142, 2005.
[7] R. Anzböck, S. Dustdar, "Modeling Medical E-services", *Lecture Notes in Computer Science*, vol. 3080, pp. 49-65. 2004.
[8] Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions (2002, November), eEurope 2002: quality criteria for health related websites.
[9] Health On the Net foundation. [Online]. http://www.hon.ch
[10] eHSCG stadards list. [Online]. Available: http://www.who.int/ehscg/resources/en/ehscg_standards_list.pdf..
[11] Digital Imaging and Communications in Medicine (DICOM) PS 3. National Electrical Manufacturers Association. 2006.
[12] U. Engelmann, B. Schütze, A. Schröter, G. Weisser, M. Walz, M. Kämmerer and P. Mildenberger, "DICOM E-mail: Germany's minimum standard for teleradiology", *International Congress Series*, vol 1281, pp 926-931, May 2005.
[13] J. Bernarding, A. Thiel and A. Grzesik, "A JAVA-based DICOM server with integration of clinical findings and DICOM-conform data encryption", *International Journal of Medical Informatics*, vol. 64, no. 2-3, pp. 429-438, Dec. 2001.
[14] Health Level 7 (HL7). [Online]. http://www.hl7.org
[15] G, Schadow, D.C. Russler, C.N. Mead, C.J. McDonald, "Integrating medical information and knowledge in the HL7 RIM", *in 2000 Proc. AMIA Annual Fall Symposium,* pp. 764-768.
[16] J. S. Hooda, E. Dogdu, R. Sunderraman, "Health Level-7 compliant clinical patient records system", in *2004 Proc. ACM symposium on Applied computing,* pp. 259-263.
[17] E.-W. Huang, S.-H. Hsiao and D.-M. Liou, "Design and implementation of a web-based HL7 message generation and validation system", *International Journal of Medical Informatics*, vol. 70, no. 1, pp 49-58, April 2003.
[18] Integrating the Healthcare Enterprise (IHE). [Online]. http://www.ihe-europe.org/