Towards Interoperability for Telemedicine Systems

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Abstract. The analysis, the modeling and the implementation of an intermediate system for facing the syntactic interoperability problem within an e-health domain for telemedicine applications and related medical information systems is the target of this work. The proposed architecture provides a unique service for interoperability utilizing distributed functional entities and specially structured messages. It facilitates different medical information systems and telemedicine application to visibly handle real world events and information, without any interference in the basic structure of these systems. The performance of the proposed system has been tested using special mechanisms and the evaluation was also performed. The extracted statistics validated the high degree of system's effectiveness and efficiency.

Keywords: telemedicine, interoperability, messaging, medical information systems.

1 Introduction

In recent years telemedicine applications have proved their necessity in the provision of qualitative healthcare. The evolution of telemedicine services is its expansion to cover the various areas for remote provision of health care.

In a physically integrated e-health domain, telemedicine applications are not autonomous as far as their interoperability is concerned [1]. Cooperation with other departments within a medical unit and therefore communication with other medical information systems, such as Radiology Information Systems (RIS), Laboratory Information Systems (LIS), Health Electronic Record (HER), is required [3].

The main aim and the next step towards interoperability is the integration of all systems and applications, thus allowing them to operate as a single entity, facilitating their communication and efficiency in transferring and exchange of administrative and medical data. The purpose of this is two-fold: a) the creation of updated and consistent medical files and b) the support of the necessary mobility both for patients and medical personnel. A basic requirement is that the medical files information is immediately available and manageable from all systems, when this is required by the workflow for the provision of medical care within and outside a medical unit. To achieve the necessary integration and as a result of the above requirements, interoperability among telemedicine and the other medical information systems must be ensured.

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From its general definition, interoperability for telemedicine systems is considered as the ability of different functional entities (applications and data stores) of related systems to (a) exchange information (functional), (b) exchange information that is processible (syntactic) (c) exchange information that is comprehensible (semantic) [2].

For the functional layer, interoperability solutions are provided by the telecommunication networks. In the syntactic and semantic layers there exist gaps due to the existence of many different standards used from the various medical information systems and the freedom in the development and their use [5].

This paper proposes an architecture for syntactic interoperability among telemedicine and other medical information systems, which can be extended to the semantic layer, *provided that the application entities employed will include the necessary translation mechanisms*. Firstly, design considerations and modeling of the proposed architecture are presented, then the implementation and the valuation issues follow.

2 Basic Design Considerations

For providing interoperability service efficiently, a model for the system's architecture was designed taking into account the conditions of the environment described as: (a) telemedicine systems are totally distributed systems, (b) different types of networks are utilized in order to connect two distant points and various means might be interposed, (c) communicating systems and networks should respond and transfer data the faster possible, (d) the communication between a telemedicine system and other information systems within the healthcare enterprise is frequently local, but distant communication is also required for providing its special healthcare services.

The above requirements were taken into account for specifying the basic design considerations of the proposed architecture meeting the special conditions that arise from the environment where telemedicine applications are applied:

- The proposed system follows the distribution of telemedicine systems in various domains and shares its functionality to different sites that participate in communication and exchange of information.
- The proposed systems described not only the functional aspects of the designed architecture but also the syntax of the application messages that are transferred. These messages that have a special structure are able to be adopted from different networks and transfer valid information.
- The proposed architecture and the distribution of functionality keep response times in a qualitative level as the added information that supports the functionality of the system is the less possible and it is not accessed from all functional system's elements.
- The service of structuring and transferring these messages is available to any application and data store that is related to telemedicine application without interfering to their implementation. The provided services elements are locally and distantly provided by special functional entities, properly designed and implemented in each site.

To cover these requirements the proposed system was analyzed and designed distinguishing two basic perspectives: (a) functional features of the system that are linked to the technical specifications of the implemented infrastructure and (b) the provided interoperability service.

3 Modeling Interoperability Service and the System Architecture

3.1 The Functional Aspect

From its functional perspective the proposed system is fully defined by the following aspects.

As users of this system are considered the applications and the data stores of telemedicine and other related medical information systems that are to exchange information, independently of the messaging protocol that they use. The specification of users' profile, the administration of sessions and the application of information security policies are supported by diverse information classes and by their conceptual relations.

The general architecture of the proposed system consists of an intermediate transfer system (TS) and dedicated interfacing entities for the users. The TS is the core unit of the system serving messages created by all users and supporting translating functions as well. The collection of all functional entities and its users, in common with their appropriate operational settings, constitutes a management domain.

During the session, the end-to-end user communication process is organized by a special service, named '*interoperability service (int service)*' that is following described. At any time instance, each user may be the originator or the recipient of a message. According to the needs of the session, any user may alternate its role.

The common structure of the exchanged messages is defined as well. These messages consist of two parts (Fig. 1): (a) the envelope part that constitutes four segments of fields; (b) the content part that includes the initial user's message. The envelope part is used to provide the *int-service* consistently and its structure is dependent on the telecommunication protocol that the user applies in the application layer.

```
<message>
    <envelope>
        <originator></originator>
        <recipient></recipient>
        <conditions>
            <protocol></protocol>
            <coding></coding>
            <message_type></message_type>
            <content_type></content_type>
            <priority_level></priority_level>
        </conditions>
        <identifiers>
            <session_ID></session_ID>
            <message_ID></message_ID>
        </identifiers>
    </envelope>
    <content>application message</content>
</message>
```

Fig. 1. XML structure of message

3.2 Int-service Design

Service of interoperability is designed as an end-to-end user communication service. The specification of service considers that:

- During any session, the *int-service* utilizes the functional entities of intermediate system in order to establish the appropriate communication path between users (originator and recipient).
- The operation of the *int-service* is accomplished through submission, transfer and delivery interactions. An interaction is considered as the 'means' by which the HT-messages are transferred between users' domains and TS.
- The creation of the communication paths and the performance of all interactions are achieved through the use of a complete set of service elements.

Interactions. The proposed specification of int-service allows submission, transfer and delivery interactions.

Submission interaction is the means by which an originating user's interfacing entities submit the message to TS. The envelope fields of the submitted HT-message (submission envelope) contain information that leads TS to select and apply the appropriate service elements. This information represents identification data of the originator and recipient, as well as special identifiers and formatting conditions for the application data that are included in the content part.

Transfer interaction is the means by which user's interfacing entities transfer the message to TS. During transfer interaction, TS reformats the content of messages, if the originator and recipient use different messaging standards.

Delivery interaction is the means by which TS delivers the message to a recipient's site. The envelope of the HT-message (delivery envelope) contains the delivery information of the HT-message. This information is similar to that of the submission envelope.

Service Elements. The features of the above interactions are implemented by sixteen (16) basic service elements, provided by the functional entities. The total service elements constitute the int-service and are organized in:

The *Message Transferring service elements* (10) are responsible for the transferring of the messages and handling the message addressing, identification and conversion as well as user capabilities negotiation.

The *Message Storing service elements* (4) handle the transmission and receipt conditions of HT-messages from or to the message storing entities.

The *Resource Verification service elements* (2) are responsible for the verification and maintenance of the connection between user interfacing entities and the TS.

4 Implementing the System

4.1 System's Architecture

The presented system has the structure that is depicted in Fig 2. The entities of the proposed architecture are of three types: (a) agents that are used for message processing

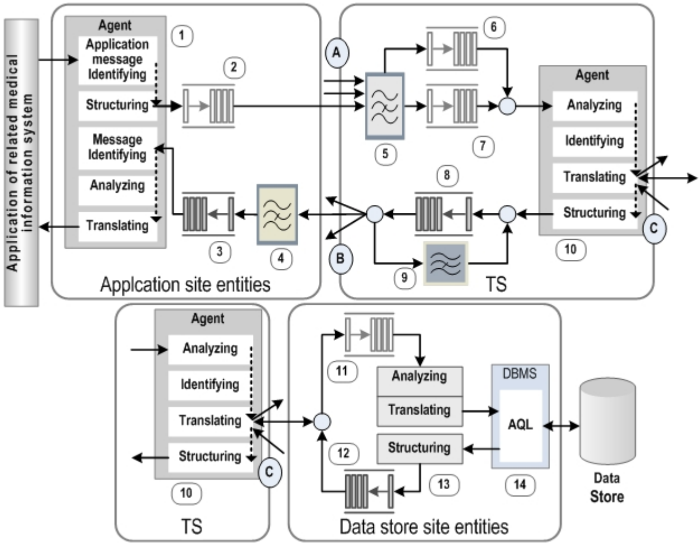

Fig. 2. The proposed architecture implements the various functional entities and supports the provided service

and include proper modules, (b) message stores that are used for message queuing and (c) filters that are used for error checking and message recover functions.

TS performs storing, transferring and reformatting processes of HT-messages using four entities; an agent (10), three message stores: (6) for application-to-application sessions, (7) for application-to-data store session, and a message store for outbound messages (8). Additionally, TS includes two message filters, (5) for inbound messages and (9) for outbound HT-messages.

The users access TS through individual and dedicated interfaces. Application's interfacing is performed by an agent (1), two temporarily data storage entities for the inbound and the outbound messages (3) and (2) and a message filter (4). Data store's interfacing is performed by another agent (13), two message data stores –(11) for inbound messages and (12) for outbound messages- and a special entity called Access Query Library (AQL) (14). AQL provides extra security mechanism protecting data store's hosted information and controlling the access to this information, with predefined queries that specify all the possible and allowed interactions that the parent data store might perform.

4.2 Special Mechanism Modules

Translation: Translation is one of the core functions of the proposed system. The entities of each sender's domain use the content part (payload) of the messages as carrier of their initially originated messages. If two users communicate applying the same messaging standard, there is no affect on the messages payload, in the transmission process. If users communicate applying incompatible standards, TS translates accordingly the messages payload from the standard format of the sender to this of the recipient, activating its "Translating" module.

Translation is performed utilizing: (a) "*Users' Catalogue*" that contains -in users' profiles- information about the special conditions that each user applies for the structure of the messages that they send and receive; (b) the "*Meta-data store*" that contains information about relations and correspondence for the general rules of message coding and structure that the different messaging standards of users apply; (c) the "*Translator*" that re-constructs the content part of messages using the information of the two previous units.

Translation depends upon the information in the envelope of the message. In the case of translation, the module retrieves the special conditions that the users apply from the Users' Catalogue and the general rules for message structures of messaging standards, from the Meta-data store. This information determines the 'final' structure of the payload of the transferred message. The 'new' payload is then forwarded to the next module, in order to construct the message and transfer it to its recipient.

Error handling: This mechanism operates at the application level of the utilized telecommunication infrastructure and includes: (a) supervision of the sessions' performance with the use of special fields of the messages' envelope; (b) check of system resources before starting every session from the users' interfacing entities; (c) administration of queues in message stores with priority in that messages that are signaled with special flags in their envelope; (d) use of filters for: correct routing of the messages, feedback in the case of failed forwarding and temporary storage of messages until the sessions regular termination. In special cases of system's failures, the system recovers its last normal operational status. Messages that arrive simultaneously in message stores are retrieved with priority. First are these that "belong" to sessions in progress and then the initially originated messages. If the messages are of the same case, these are retrieved with a random order. In any case of failure, TS sends special notifications to the originators.

Auditing: This mechanism is in function continuously and produces log files including tracing information of the sequential processes that are recorded. For each process the exact time details (timestamps) are marked so the extraction of the desired results is possible.

The auditing information that is recorded to the log files is divided in three main categories. The first includes the details of the connections between the different entities of the system and between the various computational systems. In the second category the details of sending a message are transcribed. The fields of this section of the log file describe the start and end of messages' transfer, the success or failure notifications, the re-sending procedure's details, filtering results and the identification data of message/session. The third category audits contain the receive process of messages including start and termination time points, filtering results, types of notifications and identification data of message/session.

5 Development Issues

The above described technical features of the system are basically developed as executable modules. These of the intermediate system are installed in an autonomous computational system. These of users' interfacing are embedded as autonomous software modules to the application programs and installed in the users' terminals.

The Users' Catalogue and the Meta-data Store have been implemented as independent relational databases that are hosted to the same database server.

For the development of users' interfacing and TS's modules Java language were utilized. HL7 messaging procedures were developed by means of the NeoTool Library. Databases were hosted by means of Oracle10g RDBMS and for access to the AQLs the ADO technology and SQL DML language were applied. DICOM services and message definitions were implemented using the CTN open source software (Washington University of Saint Louis).

6 Evaluation

The developed system was tested and evaluated using two medical information systems that are usually related with telemedicine applications in every day workflow. These are Laboratory Information System (LIS) and Picture Archiving and Communication System (PACS), administering medical exams, laboratory and imaging in respective. During the test, the telemedicine application was requesting the retrieval of the proper laboratory and imaging examinations of a patient, related to the same medical incident with the intention to create a unique record for this patient.

To measure the performance of the system the Auditing mechanism was used and the produced recorded information was properly processed in order to estimate the following quality factors: functionality, reliability, efficiency, maintainability and portability (according to the ISO 9126 model [6]).

Functionality, reliability and efficiency were estimated using the evaluation parameters recorded to the log files and the rest of the quality factors were studied based on the features of the designed and developed system. The first three factors were measured at the levels of 99,2 to 99.7 % verifying that the designed system meets the initially stated requirements at a very satisfactory level.

Maintainability and portability are measures of the difficulty in adjusting the system under new operational requirements. These two factors are answered by the methods and standards that were used to develop and evaluate the system. For maintainability, the evaluation mechanism enables the surveillance of the processes that occur and any fault can be easily diagnosed. For portability, the tools and the standards that were used for the implementation allow the easy installation of TS to different environments and compatibility with already used software solutions. A basic issue that is put forward concerns the technical features of the used hardware as messages' processing requires high computational power.

7 Conclusions

Nowadays, the healthcare information domain is oriented to distributed systems manipulating, with a uniform and unbounded manner, information created by medical applications with different specialties and capabilities. In this domain telemedicine applications keep a significant role and interoperability within this domain is a main issue. The presented system is an effort to overcome this problem, focusing on the syntactic interoperability. While most solutions face interoperability from the technical point of view, the current system contributes to the standardization approach, applying the specifications of a model for structuring a distributed system that shares its service to the different participating sites. This approach can lead to more viable solutions, while no constraint regarding the used messaging standards or technologies is set. Better administration, maintenance and surveillance of the provided *int-service* is achieved.

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