Krzysztof BOGUSŁAWSKI
FACULTY OF COMPUTER SCIENCE & INFORMATION SYSTEMS, WESTPOMERANIAN UNIVERSITY OF TECHNOLOGY IN SZCZECIN,
49 Zolnierska St., 71-210 Szczecin, Poland

Medical Expertise Ordering System - MEDEOS

Abstract

This article is about telemedicine solutions used in various medical specialties. In general, the functions are described in exemplary telemedicine applications in radiology, cardiology, pathology and dermatology. MEDEOS has been described as a system for exchanging the image data between different hospital units. This article briefly outlines the issues related to the problem with interface for the exchange of medical data and describes the elements of the System and its' basic assumptions. It also presents the security aspects of data exchange in the System.

Keywords: HIS, RIS, PACS, MEDEOS, DICOM, HL7.

1. Introduction

Telemedicine - is the latest form of the provision of medical services and health care that combines elements of telecommunications, information technology and medicine. Use of the new technology allows to break down geographical barriers and permits the exchange of specialized information by sending static and dynamic images (high-quality radiographs ECG, ultrasound, MRI). It allows diagnosing at a distance. Telemedicine is widely used in a radiological environment that uses it to carry out the descriptions of research at a distance. Modern technology, which uses fast processors and algorithms for digital signal processing and compression, enables transferring of high-resolution images, interactive audiovisual and real time transmission with exceptional accuracy [1].

2. Future telemedicine solutions

Given the current development of technology, without greater risk we can assume that in the near future, patients will be treated at home through home computer. Computer networks will connect patients, doctors, hospitals, internet pharmacies, and even the drug manufacturers. Medication ordered automatically by the health care networks will be delivered directly to the patient's home. Small personal devices will measure our body's vital functions, starting from blood pressure. The increasing usage of home diagnostic tools will lead to situation where doctors will not have to see their patients face to face. Initially, one of the biggest difficulties to accept by society would be the absence of prescriptions in their traditional form, as a prescription will simply disappear [2].

Another change, which can be controversial, is that the largest hospitals will cease to exist, and surgery will be carried in ambulances, in which the stretcher equipped with monitoring devices and supportive life functions will replace the role of the intensive care units, currently available only in hospitals.

Many people have doubts in such futuristic visions of the future. However, technological development shows that such a process cannot be ignored. Below are outlined possible directions of telemedicine developement.

3. Introduction to the MEDEOS System

There are multiple informatics systems in the hospital. The main system is HIS (Hospital Information System), whose mission is to support the so-called white and gray matter of the hospital. Another system is RIS (Radiology Information System), on which main doctor can order radiological examination and expertise. Image data are stored in the archive PACS (picture archiving and communication systems).

Right now the most urgent matter is to meet the needs of medical personnel, by delivering mechanisms to completely secure data exchange between hospitals. Therefore, many centers carries out various works on the development of a coherent communication interface between the existing systems [2].

This study is an attempt to define an interface for the exchange of medical data and in particular the image data between hospitals in order to perform remote diagnostics specialist [3].

Solution presented in this document is not a protocol, but rather a system. The name of Medical Expertise Ordering System (MEDEOS), called later the System, has been approved. This name refers mainly to the primary goal of operation systems, i.e. electronic ordering of interpretations of radiologic examinations, but due to its flexibility the System can perform other functions in the future as well.

The key principles of the System are:

a) **simplicity** – simple systems can be implemented at a low cost and are easy to maintain,
b) **flexibility** – to allow realization of new functions based on the same mechanism and
c) **security** - required when transmitting sensitive personal data.

Currently, the functionality looks as follows:

- a medical unit can electronically order execution of medical examination's interpretation from another unit
- the order can have digital files attached to it (usually DICOM images, but any file is allowed [4])
- an entity making the interpretation, if necessary, can make comments to the ordering unit, indicating what corrections are needed
- the ordering unit can correct the order and attachments
- when interpretation is ready, the ordering unit can download it and attach files to it
- data and communication are protected from access by unauthorized people
- personal digital signatures can be used by the ordering person and the person performing interpretation.

The full documentation of MEDEOS is made to be the basis for the implementation of the system, so the words MUST, SHOULD, MAY etc. have to be understand as described in RFC 2119 [6]. In this document we briefly mentioned principles of MEDEOS system.

4. Elements of the System

There are two kinds of actors: the **customer** who makes an order and the **consultant** carrying out the interpretation of the examination. There can be many customers and many consultants in one co-operation network.

Co-operation network is the collection of all nodes on which the System is running and which are prepared (configured) to communicate with each other. It consists of at least one client type node and one server type node. One node can have client and server functionality.

Other definitions:

- **order** - the commission of medical examination's interpretation created by the customer, sent to the consultant
- **interpretation** - interpretation of medical examinations performed by the consultant in response to the received order
- **attachment** - a file of any content accompanying to the order or the interpretation; usually in practice it will be a DICOM image [5], created as a result of examination, that have to be described by the consultant (attachments to the order) or where the consultant has made notes (attachments to the interpretation)
- **comment** - comments made by the consultant to the customer, indicating problems in performing the interpretation

- **client** - software sending orders to the server and downloading results
- **server** - software collecting orders and providing them to the consultant interface and software, collecting interpretations and providing them to a client
- **customer interface** - software providing user interface for customer and controlling the client
- **consultant interface** - software which provides user interface for consultant, downloads orders from the server and saves interpretations to the server

Customer interface and consultant interface are not integral part of the System, but are necessary for the comfort of the users. The System is open to many ways of implementing, both components and connects them with the client and the server. Appearance, integration with other hospital systems, method of GUI presentation and functionality of both components will be significantly determined by the needs of individual users.

5. Guidelines

The primary function of the System is to send orders to describe results of examinations from one medical unit to another. This is done as described below.

1. The customer, using the customer interface, enters information related to the order and selects which files should to be attached to it. Among the information about the order there is the name of the medical unit (the consultant) to which the order will be sent.
2. When all data has been collected, the customer starts the procedure of order sending. If a digital signature is used, the customer will be asked to sign the order with his own private key. The sending process SHOULD be performed in the background, so that the user interface is not blocked.
3. Based on the name of the institution to which the order is submitted, the client selects address of an appropriate server and sends all the data there. Data (content of the order and attachments) can be transmitted in many parts. One part is one file.
4. After the complete data is received by the server, a notification is send to the consultant about the pending order.
5. Consultant analyzes the order and creates a reply using consultant interface. There are two kinds of reply:
   a. **interpretation** - the interpretation of the examination result is created when the order has been completed successfully; the client can download it at any time,
   b. **comment for customer** - the comment is created when, for some reason, the consultant cannot create an interpretation; comment can inform the customer about necessary completions/corrections of the order; the client can download the comment at any time,
6. The client checks the server periodically for an interpretation or a comment. If any content is available, the notification for the customer is generated.
7. If the server returns an interpretation, the flow of the documents is finished. If a comment is returned, the customer selects additional data to be attached to the order and goes back to point 2.

Figure 1 shows a course of order execution in a graphical form. There are two simple commands on a client - server communication level: send file (PUT) and get file (GET). Commands can be realized by any transport method, such as: HTTP, WebDAV, FTP, or even PenDrive or CD. HTTPS is recommended as it allows easy implementation of security rules and simple integration with other software.

The System has to be secure, so that unauthorized people have no access to the transferred and stored data and even the entities cooperating in the same network cannot pretend to be each other.

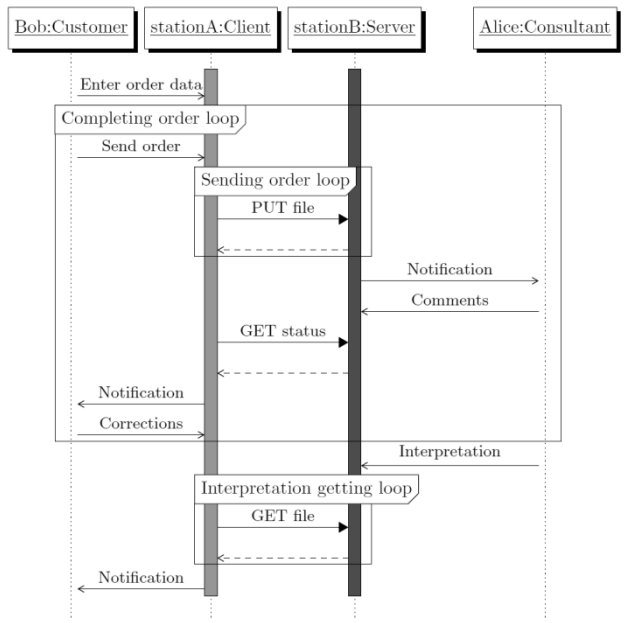

Fig. 1. Typical session customer - consultant

6. Client - Server Communication

Mechanism of communication has been developed considering HTTPS as a transportation method. Use of this method is probably the easiest way to implement rules described here. Because the System works by moving or coping files, it is possible to use any other way to dislocate files to make the System work. For simplicity, this document takes HTTPS as a base transportation method and filesystem as a storage. Except for special cases, the client-server communication SHOULD be performed by means of HTTPS.

The Client and the sever communicate using three standard HTTP methods: GET, PUT and DELETE. Implementation of those methods MUST comply to RFC2616 [7]. Client uses GET method to get the order state, comment and interpretation, PUT to send the order body and attachments and DELETE to remove the comments. The program implementing mechanisms of the System provides realization of the functions PUT and DELETE on the server side. Handling the GET method returns files from the filesystem, which is embedded into every http server, however, own implementation is often useful.

URL address consists of the following components:

- **protocol** - transport protocol; it SHOULD be HTTPS
- **server address** - domain name of the server
- **system name** - name of the System: "medeos"
- **service name** - in the future the System can realize various functions, ordering of examinations defined in the document is identified by the word "order"
- **client name** - name of the client who created an order; the name MUST be used for authorization of the clients; SHOULD be compared with Common Name from the certificate used by the client for communication by means of HTTPS
- **year** - year of creation of an order; this component guarantees that the list of orders can be shortened if the server operates for many years
- **order ID** - identifier of an order; order ID is selected by the client
- **resource** - path indicating a specific resource as the element of an order.

Example of URL: https://example.com/medeos/order/hospital-X/2016/32434/body.xml

The list of basic HTTP requests is presented below. If a digital signature is used, there are extra requests related to transfer of files with signatures. Components of URL, which are written using italics and enclosed between < and > chars, are variable elements and will be replaced by a string identifying a specific resource name/id.

GET /medeos/order/*<client>*/
Get a list of years during which the orders were submitted.

GET /medeos/order/*<client>*/*<year>*/
Get a list of all orders submitted to the server by a given client in a given year.

PUT /medeos/order/*<client>*/*<year>*/*<order id>*/*<attachment>*
Send attachment to the server. Parent directories (order id and year) are created on demand. If the given attachment does not exists it will be created or else it will be overwritten. Overwritten files SHOULD be moved to the order history.

PUT /medeos/order/*<client>*/*<year>*/*<order id>*/body.xml
Send order body to the server. Order body MUST be sent as the last file (after attachments and signatures are delivered). The appearance of body file is a signal that a complete order has been uploaded and server can send a notification to the consultant interface.

GET /medeos/order/*<client>*/*<year>*/*<order id>*/
Get the list of order files. It can be used to check if complete order has been uploaded.

GET /medeos/order/*<client>*/*<year>*/*<order id>*/response/
Get the list of files created by a consultant as a response to an order. If there is a file named „response.dicom", the interpretation has been completed and the results can be downloaded. If there is a file named „comments.xml", the consultant was unable to create interpretation and provides notices for the customer. If interpretation contains attachments, their names will be on the list.

GET /medeos/order/*<client>*/*<year>*/*<order id>*/response/response.dicom
Get an interpretation.

GET /medeos/order/*<client>*/*<year>*/*<order id>*/response/comments.xml
Get a comment.

GET /medeos/order/*<client>*/*<year>*/*<order id>*/response/*<attachment>*
Get an interpretation attachment.

DELETE /medeos/order/*<client>*/*<year>*/*<order id>*/response/comments.xml
Delete a comment. Removal of the comments file is a signal that customer has applied to consultants comments (has made corrections to the order) and the order can be send for consultation again.

All changes made by PUT and DELETE methods SHOULD be logged in /medeos/order/*<client>*/*<order id>*/history/log file.

7. Data Model

System operates on four entities: order body, attachment, interpretation and comments which are structured as a tree. The tree structure with files as nodes can be successfully implemented using filesystem as a database and this solution is referenced in following text.

A directory structure implementing the data model of the server is presented below. Locations and names of files are reflected in the URL addresses used by the client connecting by HTTP to a server. If a server does not use identical directory structure as presented below, it MUST map its structure to URL paths, so that the client cannot see the difference.

/medeos/order/<client>/ Directory to which only the given client has access. The name of the directory identifies the client.

/medeos/order/<client>/<year>/ Directory grouping client's orders. It is created on demand when the client makes PUT to a non-existing order directory in non-existing group.

/medeos/order/<client>/<year>/<order id> Directory with the order. It is created on demand when the client makes PUT to a non-existing order directory.
<attachment 1 >
<. . . >
<attachment N > Order attachments. When an order is created, the client MUST at first upload attachments to the server.
body.<sig_ext> Digital signature of the order made by the customer.
body.xml File named "body.xml" contains text of the order. The appearance of "body" file is a signal for consultant interface that the order has been successfully uploaded and can be executed by the consultant.

response/ A directory containing response from the consultant. It is created on demand, when consultant saves a response.
confirm.<sig_ext> Automatic electronic Signature made by the server, confirming the receipt of order and binding the event with date and time.
response.<sig_ext> Digital signature of an interpretation made by the consultant.
response.xml File "response.xml" contains the interpretation. The appearance of "response.xml" file is a signal for a client that a consultant has completed interpreting examination results. Client can download this file at any time and present its contents to a customer via customer interface. The emergence of "response.dicom" file, transits order state to finished.
comments.xml File "comments.xml" contains consultant comments for the customer. It can be created instead of "response.xml" file as a result of consultant's work. The appearance of this file is a signal for the client that the consultant cannot perform an interpretation for some reason. Client MUST download this file and show its contents to the customer using customer interface. When the order will be revised according to the consultant's comments, the file "comments.xml" MUST be deleted by the customer. It will be a signal, that order can be send to consultation again;
<attachment 1 >
<. . . >
<attachment N > Files attached to an interpretation. Interpretation attachments MUST be created before "response.xml" file,

history/ Order's history. This directory contains files deleted or over-written by the client. When client destroys any file, it is moved to this directory. New name of the moved file is constructed by adding a date and time to the original file name. Time SHOULD be represented in ISO format (YYYY-MM-DDThh:mm:ss.sTZD)

log file named "log" contains history of the order; it is an XML file. Every time any change occurs in order (a file is added, updated or deleted), a new entry, with information about an event, appears in the "log". This is the only file interpreted by the server.

Example of the directory structure with one order is presented in figure 2.

```
/medeos/order/spk1.szczecin.pl/1248/
                    156345-345.dicom
                    453346.dicom
                    body
                    dodatek.pdf
                    rtg12.dicom
                    response/
                        156345-345-v2.dicom
                        response.xml
                    history/
                        log
```

Fig. 2. Example of the finished (with interpretation) order. The interpretation has one attachment. Files, which names are keywords, are shown in bold

8. States Machine

A server, which is in fact a file server with predefined directory structure, does not analyze it's own or order's state as it is a task for the customer and the consultant interface. Possible order states are shown in figure 3. Transitions between states are triggered by the appearance (or disappearance) of files. Depending on the method of detection change, it may be necessary to provide atomicity to files adding to the order directory. The state change MUST occur only after the complete file is put into the structure.

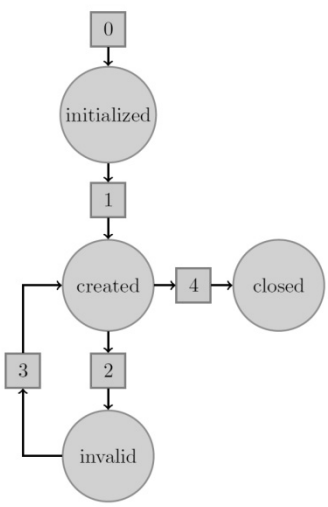

Fig. 3. Order's states. 0 - creation of new order's directory; 1 - creation of "body.xml" file; 2 - creation of "comments.xml" file; 3 - deletion of "comments.xml" file; 4 - creation of "response.xml" file

9. Conclusions

Discussed System fulfills the requirements of a simple and reliable method of medical data exchange. Authentication depends on the method of transport and is carried out only by the mechanism of transport. In the case of HTTPS and WebDAV over HTTPS, it will be a mutual authentication with the use of client's and server's certificates. For HTTP, and FTP it will be the logins and passwords. In the case of transport on the CD / USB Flash Drive (Pendrive) verification is made by administrator.

Implementation of the confidentiality of transmission depends on the method of transport. If the methods do not ensure the confidentiality, they should be realized at the lower layer (encrypted VPN).

10. References

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[5] ISO 17432:2004 - Health informatics -- Messages and communication -- Web access to DICOM persistent objects, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=38361

[6] RFC2119 (Request for Comments: 2119) - Best Current Practice - http://www.ietf.org/rfc/rfc2119.txt

[7] RFC2616 (Request for Comments: 2616) - Hypertext Transfer Protocol -- HTTP/1.1 http://www.ietf.org/rfc/rfc2616.txt

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Krzysztof BOGUSŁAWSKI, PhD, eng.

Krzysztof Bogusławski received the MSc, eng degree in the field of electrical engineering with specialization in automation and electrical metrology from Szczecin University of Technologyand the PhD degree in the field of Telecommunications from Warsaw University of Technology. He coordinated the following projects: "Telemedicine as a eHealth in Westpomeranian Region" RPO 3.1, "Telemedicine in the Euroregion Pomerania" - Interreg IVa. His current research interests include telecommunication, computer networks and telemedicine.

e-mail: kboguslawski@wi.zut.edu.pl