# Design of a Tele-Expertise Architecture Adapted to Pervasive Multi-Actor Environments. Application to eCardiology

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**Abstract**

*The aim of this paper is to present an open and generic medical tele-expertise architecture which may be implemented intra and inter hospitals in any medical or call centre and at home. This architecture is based on TCP/IP Internet technology and on the XML meta-language for data representation, storage and communication. It is composed of a main application installed on a web server for the intelligent management of the messages exchange and of distributed client applications for sending and receiving the tele-expertise requests via HTTPS. A message contains the communicating parties, the Electronic Health Record (EHR) and any attached files like SCP-ECGs or DICOM images. In order to guarantee the reception of the message in due time, the expert should be able to receive anywhere different kinds of notifications by means of different types of devices that depend on the available technologies (Pager, SMS, PDA, etc.). This new infrastructure is being experimented within the Lyon area in a setting that includes an emergency department, regional and general hospitals, the Cardiology Hospital of Lyon and patients homes.*

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## 1. Introduction

There is an increasing demand for new eHealth solutions improving patients safety by enabling the dissemination of the Electronic Health Record (EHR)[1] and reducing the overall cardiac mortality and morbidity by monitoring the patient and the citizen health status, wherever they could be, at home, at work, on travel [2,3]. Master words are spreadability and pervasiveness. Pervasive computing is a new, interesting topic in computer science. The expected outcome is to provide computer-based assistance anywhere and at anytime [3]. The EPI-MEDICS project [4] developed such a pervasive solution for the early detection of patients and citizens at cardiac risk, sending automatically an alarm message, the embedded patient EHR, the last recorded ECG and the reference ECG, if any, to an emergency or a competence centre or an alarm server. This message will then trigger a set of actions involving different health care actors with different levels of responsibilities. But human skills and expertise are still requested, whatever the degree of intelligence that has been embedded in the wearable devices.

The aim of this paper is to present the design of a pervasive tele-expertise architecture that facilitates health information exchange in order to decrease the patients and citizens risk.

## 2. Tele-expertise uses cases

### 2.1. Examples of tele-expertise scenarios

There are different circumstances where healthcare providers might request an expert opinion about a patient's health record in almost real time.

Let us suppose that a patient living in the country side has some chest pain and visits or receives at home his attending physician. The ECG seems abnormal, and the general practitioner (GP) wants to have an expert advice from a cardiologist or from a competence center. The GP will forward the ECG together with clinical signs and parts of the patient EHR to an expert who will be asked to review the ECG tracing and to send back his opinion to the initiator of the request.

Another typical multi-actors scenario is the emergency scenario where a patient is admitted in an emergency department of a general hospital. The interpretation of the ECG tracing may be not clear for the non-expert medical staff. Abnormalities are detected, but are they significant for an immediate admission to an intensive care unit and/or for a preventive treatment? A solution is to send a digital ECG to a cardiologist at the department of the nearest cardiology hospital for an expert opinion.

In the following section we describe the users' requirements for these tele-expertise scenarios.

### 2.2. Users requirements

Healthcare actors need a set of professional tools which are easy to use, from the recording of the ECG up to the transmission/reception of the EHR. The existing systems such as electronic mail are not compliant with the experts' needs. They don't provide data entry facilities to create a medical request. Furthermore, the recipients' addresses are fixed and cannot be dynamically changed according to decision rules. Indeed, such systems do not provide facilities to perform automatic, intelligent and secured redirection of the messages according to the availability of the recipients and to the request's subject. Moreover, such a distributed system should guarantee the integrity and the protection of means for easying the exchanged data.

Another requirement is to provide integration of the architecture into the user's technological environment. Indeed, the user may be in turn nomadic or sedentary, at home as well as at his working place. The solution should also be open enough to support multiple situations as well as the heterogeneity of operating systems and devices (PDA, PC, Tablet PC, etc.). The advisor physician is not necessarily always in front of his workstation, even if he is in the hospital. In order to guarantee the reception of the message in due time, he should be able to receive anywhere different kinds of notifications by means of different types of devices that depend on the available technologies (Pager, SMS, etc.). The physician should also be able to read and process the message anywhere with different types of workstations.

In addition, a professional EHR editor integrating the user's specificities and preferences according to the clinical scenario of use, should be provided to the communicating parties.

Figure 1 shows an UML sequence diagram which represents a typical tele-expertise scenario. The emergency physician records an ECG, builds the corresponding EHR and uploads it on a server. Then, the server processes the message and notifies the recipient expert.

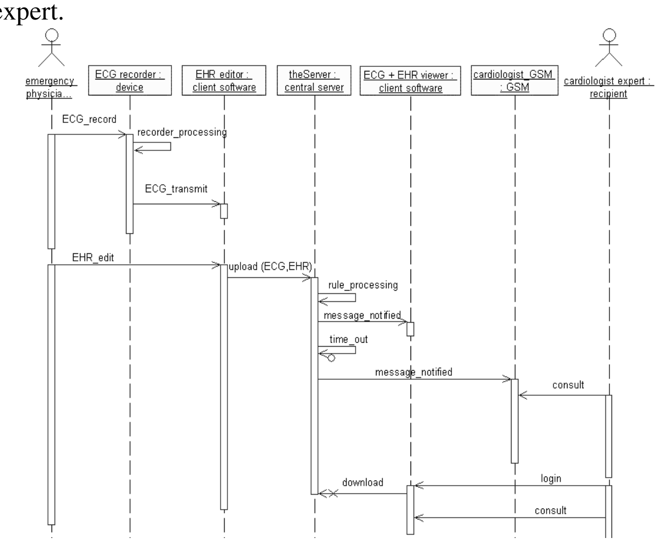


Figure 1. Example of a medical data exchange during an emergency scenario.

# 3. Architecture design

To comply with the previous requirements, we have designed a client-server type architecture based on Internet technology (figure 2). It is composed of a main application installed on a web server that provides an intelligent management of the messages exchanges and a set of distributed client applications for sending and receiving the tele-expertise requests via HTTPS (HTTP with a Secure Socket Layer). The requests are represented in the XML meta-language. The architecture is designed to support the pervasive paradigm. The tele-requester may use a standard digital ECG recorder or a Portable ECG Monitor (PEM) [4] with Bluetooth and GPRS transmission capabilities.

A tele-expertise request can be considered as a Message Body Instance (MBI) describing a given clinical situation of a patient. A message contains the communicating parties, the EHR and the attached ECG files. This message may be built offline and is then uploaded on the web server. The XML messages are stored in a relational database and processed by the server-side application which is endowed with decision-making rules in order to guarantee the reception of the message by a relevant and appropriate party. The expert can be notified by SMS and can consult the message either with his PDA or with a PC.

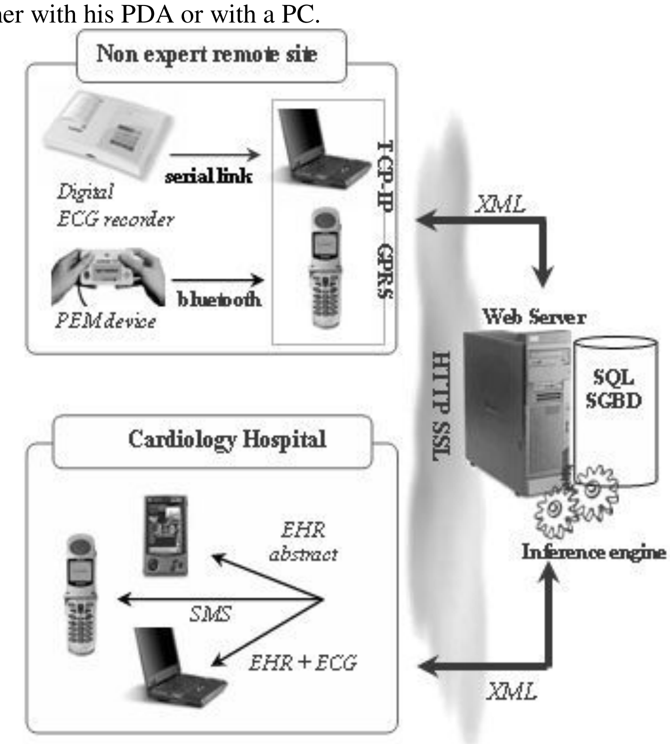


Figure 2. The tele-expertise architecture.

The transactions between the requester and the recipient are performed via a central server that implements an inference engine which is able to interpret rule sequences. For each sequence, a notification is sent to the recipient. This notification indicates the request's subject and the sender identity. Each notification is restricted in its life time, which is pre-established. The recipient is faced to two choices: he can accept or not the request. In this last case the inference engine will apply the next rule. The same yields if the message has not been read or if the validity period is over. To take into account the different possible tele-expertise scenarios, we made an inventory of all the rules we could have to implement. This set of rules finally reduced to a set of four generic rules:

- Launch a warning through a beeper or through a SMS (Short Message Service) addressed to the concerned healthcare professional.
- Transfer (forward) the message to another healthcare professional.
- Transfer the message to an hospital department.
- Send the message to a specialized call centre or to an emergency centre.

To comply with the users' requirements concerning the EHR editor, we design a generic software that is adaptable to each specific user. In this context, we use the macro data concept. A macro-data is a compound or complex data defined as a set of heterogeneous data which are organized in a logical and structured manner according to an utilization model [5]. For each user, it is then possible to define a specific model which is structured in a XML format. This model includes:

- The user's demographic data (name, age, sex, etc).
- The medical terms that are appropriate to the user's status (emergency physician, cardiologist) and/or the patient pathology.
- A graphical interface for the edition and display of the EHR and the ECG.

# 4. Software design

## 4.1. Rules server management

A web-based interface has been developed to define the messages delivery rules and their flow control (figure 3). This set of rules may be defined for each patient or each patient class.

If the message is not read by the specified recipient within a predefined time, the server has the possibility to redirect the message towards an SMS, a beeper, another physician, a medical department or an emergency centre. For each case, the system administrator has to define the sequence order and the maximum allowed time receiving an answer to the notification. The system administrator has the possibility to define these parameters for five priority levels of the messages: routine request, non urgent request, within one day, prompt answer and emergency.

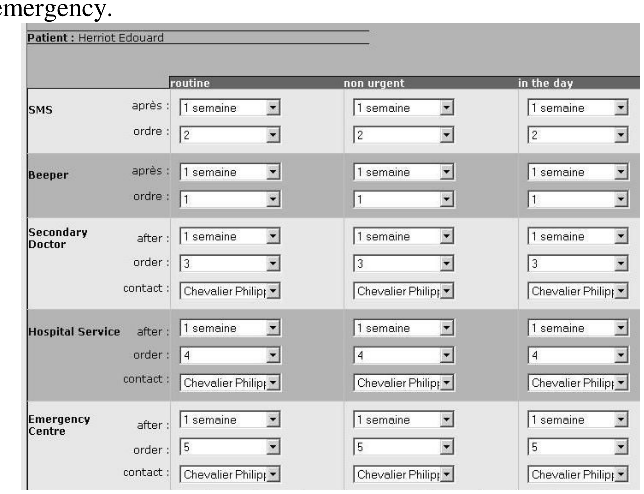

Figure 3. Sample screen of the user interface for the rules definition.

## 4.2. Tele-expertise request client software

To edit and display the messages, we have chosen to implement a client software instead of using a web browser (figure 4). Thus, the user can be nomad and work in his personal environment without being connected permanently to Internet.

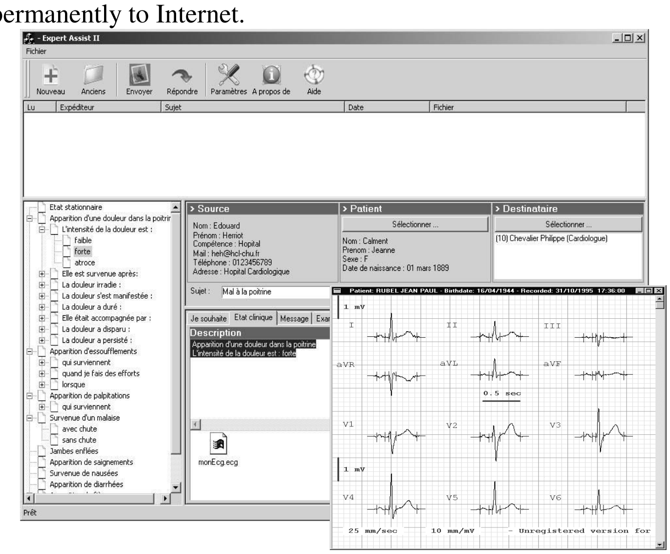

Figure 4. Sample screen of the client software displaying part of an EHR encapsulating an ECG.

The interface is dynamically built according to the user authentication by interpreting an XML file stored in the database on the server and duplicated on the workstation in a local folder. This file is specific to each user. It contains the user's administrative information, a tree structure representing the medical terms that are appropriate to the user's category, and the description of the layout of the graphical user interface.

## 5. Evaluation results

This new infrastructure is being experimented within the Lyon area in a setting that includes an emergency department, regional and general hospitals, the Cardiology Hospital of Lyon, patients homes, and the informatics department of the Lyons hospitals which hosts the servers.

To facilitate the recording of digital ECGs and their automatic transmission, we have used the Portable ECG Monitor (PEM) [4]. The PEM is an intelligent and portable "new concept ECG recorder" that is able to detect cardiac arrhythmias and ischemia and generate different levels of alarms that will be forwarded to the relevant health care providers. It is characterized by professional recording capabilities, a reduced number of electrodes, wireless data exchange capabilities and the use of the XML standard to encapsulate data.

Preliminary evaluation results of the whole system have evidenced the following features:

- Compatibility with several heterogeneous telematic means.
- Adaptability of the graphical interfaces and their compliance with the user needs.
- Possibility to encapsulate EHR and ECG in the same document to visualise both.

In addition, such a tele-expertise architecture allows to complete the global medical patient record and to guarantee the traceability of the exchanges. The expected outcome is to improve patient care.

## 6. Conclusion and discussion

Our architecture is based on a central web server. This solution facilitates the system's maintenance that can be performed via any Web browser. Secured remote connections and exchange of information of different origin are achieved by the HTTPS protocol. The implementation of a client software allows to guarantee the user's professional specificities and customization needs. The tele-expertise medical records may be built and displayed offline. All messages are written in XML and may encapsulate the patient ECGs encoded according to the SCP-ECG format in order to facilitate the reviewing, the printing and the forwarding for a tele-expertise request. This architecture provides a significant step towards the provision of new, improved, intelligent, ubiquitous, user friendly health care services available any-where, any-time.

In order to guarantee future evolution, reusability and interoperability, we perform data exchange by using the XML standard. XML provides a syntactic framework that has a widespread acceptance. Its flexibility is particularly suited to rapidly evolving environments. Furthermore, most development environments provide XML support and useful industrial tools are being built around this technology [6].

Our architecture provides a generic framework for easy integration of additional new and specific modules that will be more and more intelligent and provide increasingly reliable message transaction processes. For example an intelligent agent could determine the patient clinical status category and define itself a transaction rule.

Finally, such an architecture will promote the interactivity between the various actors of the healthcare system and should probably have a good impact on the quality of life. The pervasive technology yields for fundamental changes in working's habits. Communication between healthcares professionals and patients is becoming part of medical practice.

## References


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