Interoperability Between Information Systems Concerning Electronic Records of Patients

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***Abstract*—The problematic over the interoperation between institutions in underdeveloped countries always presents good opportunities for science to contribute to substantial improvements in the real-world issues. The basic support systems such as the health institutions are among the ones that can most benefit from scientific advances. This paper reports an analysis done over the interoperability between health institutions, specifically regarding the interaction between medical centres and clinical laboratories where the main interoperability instrument is the patient record. This research was validated with a real practical use case that is presented in this paper. In order to make the information stored in different software applications of the national health system (SIS), more specifically in the Dr. Ayres de Menezes hospital, in the country of São Tomé and Príncipe, interoperable with the information systems of the clinical laboratories that support the hospital, two different applications were developed (Patient Management System and Clinical Analysis Laboratory Management System) to implement the interoperability between them. The Patient Management application requests medical exams from your Medical Appointment dashboard. The second application receives the exam request and after exams are processed and validated, the second system sends the result to the requesting application.**

To make the interoperability service effective, the SOAP protocol was used, which allowed the exchange of information synchronously between these two applications, allowing for faster transactions of patients' pathological data, and greater confidentiality of this same information.

Keywords— Interoperability, Information System, Clinical Analysis Laboratory Introduction.

I. Introduction

In recent years there has been an exponential growth of software to respond quickly and efficiently to various problems of organizations, especially with regards to data management. Health organizations such as hospitals, health centres and clinical analysis laboratories were also not indifferent to this growth [1,7]. It happens, however, that the same organizations use heterogeneous software, built with different infrastructures, platforms, and data formats [2], therefore, the synchronous sharing of this information becomes unfeasible and, consequently, leads to wasted time and data redundancy [3]. This is particularly important when referring to information systems in less developed countries. In particular, the analysed use-case of the hospital Dr. Ayres de Menezes in the country of São Tomé and Príncipe shows a scenario where there are some "islands of software" in some departments, but in others there is not even the presence of any software, as is the case of the emergency service for patient care. The medical consultation management process is done in a traditional way (paper-based), either for recording the patient's history and for requesting new clinical analysis.

Clinical analysis services are being increasingly required by the hospital's health technicians and by the patients themselves, who seek to monitor their health conditions. This fact reflects the importance that we must give to the automated and interoperable management of information right from the registration, collection of samples of biological products, and subsequent sending of the results to the user or the prescribing physician [4, 5].

In this context, the objective of this work is to implement the interoperability between the Clinical Analysis Management System and the Patient Management System, to facilitate and speed up the availability of information related to the patient's health status, in order to allow that health technicians can make decisions faster, thus avoiding some constraints or even the loss of human lives [6].

The remaining sections of this work are divided as follows: Section 2 talks about literature review, section 3 proposes an architecture for the solution, section 4 shows the Results of testing, and section 5 presents the conclusions and future work.

Motivation/Framework

As an employee of the Ministry of Health of the country of São Tomé and Príncipe, member of the Department of the Health Information System (SIS), which is responsible for coordinating the entire health information system in the country, the author was able to observe in locus several interoperability problems in the health service system in the country, namely data redundancy, lack of credibility, ambiguity, etc. In order to overcome this situation without major constraints for the users, the authors propose to implement an interoperability service that consumes the information systems in real time, establishing an interoperable platform to improve the health information circuit of the SIS. In order to carry out this claim, the research will develop a prototype that improves the information circuit between the medical office and the clinical analysis laboratory of the referred hospital. The sharing of information in real time between these two entities has proven to be crucial in the process of requesting clinical analysis and sending the respective results, as they constitute a significant basis for decisions regarding the patient's health status.

The current process of requesting analysis and sending the results is done in paper-handwritten form. This per se comprises numerous constraints when the physicians request a clinical analysis to the laboratory, and also on the route back concerning the results from the laboratory to the requesting physician. Some of the identified problems regard illegibility, loss of time, opening of the analysis result by third parties (companions, medical assistant, family, etc), leakage of information about the patient's health, therefore leaving the patient in a very exposed and vulnerable situation.

Research Question

How to improve the interoperability between information systems (Patient Management System and Clinical Analysis Laboratory Management System)?

II. Literature Review

The scope of this section consists in highlighting the articles selected for this work, conceptualizing terms or expressions that are directly or indirectly related to interoperability. And through the analysis of those papers, realizing the ways to implement technical level interoperability. Therefore, we start by highlighting the following definitions:

Information system

An Information System (IS) is a collection of dynamically interconnected components to collect, store, process data and provide information to support organizational decisions [9,20].

Interoperability

Interoperability is about the interconnection between information systems to provide meaningful data sharing [1, 6]. In IS, interoperability is seen as the ability of different systems and technologies to communicate, exchange and use information effectively and efficiently [15, 16].

In this review, interoperability has been broadly classified into different types [10, 11, 12]. And in this work, the authors describe the different types of interoperability, technical, syntactic, semantic, organizational, and legal [13].

Technical interoperability is related to the transmission of data between components or systems. It is associated with the hardware and software components, networks and equipment that allow machine-to-machine communication, including aspects such as open interfaces, data integration, middleware, data presentation, data exchange, accessibility, and security issues [4,14].

Syntactic interoperability is related to rules about the type of data that are exchanged, specifically, about how to group the data and in what order [4, 15]. This type of interoperability focuses on identifying elements and rules that structure the elements, well-defined syntax (i.e., structure of message content, size of headers, size of message body, fields contained in a message), and navigation between equivalent elements [4,16].

Semantic interoperability is related to the exact meaning of the data exchanged. In this type of interoperability, data are conceived as information to be shared, processed and well understood (without ambiguity) by the surrounding systems or person [16]. Thus, semantic interoperability is about ensuring that the precise meaning of the information exchanged is understandable by any other system that was not initially developed for that purpose [16].

Organizational interoperability is related to the coordination of distributed workflows and activities that are well understood by systems, organizations, or people interacting in business processes.

This type of interoperability is related to the ability of two or more components/systems to provide services to and accept services from other components/systems and use those services to support them to operate together effectively [4, 16].

Legal interoperability is the legal requirements and implications of making information items freely available [15].

The European Union (European Interoperability Framework – EIF) has classified interoperability in four levels, namely legal interoperability, organizational interoperability, semantic interoperability, and technical interoperability [15].

In this context, l*egal interoperability* points to a coherence or alignment between legal issues that, in the case in question, are diffused between different countries, member states and regions [10,15].

Organizational interoperability refers how business processes are aligned or integrated between different organizations and how relevant information is exchanged [10,15].

Technical interoperability covers the applications and infrastructure that link systems and services. Aspects of technical interoperability include interface specifications, interconnection and integration services, among others [10,15].

Semantic interoperability seeks to ensure the proper format and meaning of the data exchanged, so that the information is preserved and understood between the parties. In this view, semantic interoperability covers both, syntactic and semantic aspects.

The semantic aspect refers to the meaning of the elements and their relationships. It includes developing vocabularies and schemas to describe data exchange and seeks to ensure that the data is understood in the same way by all those involved in the communication. The syntactic aspect refers to the ability to describe the exact form of communication to be exchanged in terms of its grammar and format [10,15].

Based on the papers selected in the research process, for the health area, the most outstanding interoperability are technical, syntactic, semantic, and organizational [4,5].

Interoperability Benefits

Table 1 shows some of the benefits obtained from interoperability, namely the reuse of data that are in clinical analysis laboratory applications, the analysis results are sent directly from the clinical analysis laboratory system to the patient management system, reducing the possibility of error, greater celerity between request and sending analysis results.

Table 1: Interoperability Benefits

Benefits	Ref.
Cost reduction for healthcare institutions	[19][4]
Decreased errors and data redundancy	[4]
Greater accessibility to patient information by specialist physicians increasing the quality of diagnosis and treatment.	[19][4][20]
Increases process efficiency	[4][6][28][8]
Improvements in data quality.	[4][8]
Allows you to query data in real time from other systems.	[4][17][18]
Facilitates data security and integrity	[15]
Searching for medical exam histories is three times faster compared to standalone systems	[3]

In the research process, the authors found some systems that showed improvements in interoperability, namely as Mandala, a platform to support systems-of-systems (SoS) interoperability. Mandala [1] is a platform that aims to integrate heterogeneous software, without significantly changing its implementation or even knowing details about each system, using REST protocol web services.

Communicating the recorded patient data in the Personal Health Record (PHR) system with an electronic health record (EHR) in real time allows technicians (doctors, nurses, etc.) to make appropriate clinical decisions. It also allows patients to see any changes to your diagnoses or treatment plans. To achieve this goal, open-source standards were sought using levels of technical and semantic interoperability to allow the understanding and communication of data in almost real time. With regards to technical interoperability, this study used RESTful services for its implementation [7]

This study [7] used RESTful services to implement interoperability between Personal Health Record (PHR) system, and electronic health record (EHR) in real time. Communicating data in the PHR with the EHR in real time allowed technicians (doctors, nurses, etc.) to make appropriate clinical decisions. It also allowed patients to see any changes to their diagnoses or treatment plans. To achieve this goal, they looked for open-source standards using levels of technical and semantic interoperability to allow the understanding and communication of data in near real time.

Time is an irrecoverable resource. To evaluate the time that nursing teams would obtain with a computerized and strongly integrated system, a comparison was made between the expected time versus the real time spent in managing orders for two different systems, one integrated and one not integrated. The results show that nurses using the integrated system will complete their task on average five times faster than the expected time. They also showed that a tightly integrated system provides a three times greater speed gain for nurses compared to the non-integrated system [3].

To solve the problem of interoperability in health, a conceptual model of an integrated infrastructure such as Health Service Bus (HSB) was proposed, in order to facilitate the Service Oriented Architecture (SOA). A scenario-based evaluation of the proposed conceptual model shows that the adoption of web services technology is an effective way to achieve this interoperability [4].

DHIS2 is an open-source platform developed by the University of Oslo, this system allows for the insertion of aggregated data and individual data, through the form with the respective data of the diseases, namely tuberculosis, HIV, malaria, etc, with the objective of presenting statistics on this data in the form of graphs, tables and maps. DHIS2 provides an API that is fully open to encourage the development of external applications as well as integration with other applications [9].

III. ARCHITECTURAL PROPOSAL

The proposed system includes two distinct web applications, in the paradigm of client-server architecture, where they consume a service provided by a server, to achieve the interoperability over the data that is sent and received between them. The first system involved in interoperability, Patient Management System, has the following workflow:

- The patient is registered in the system and sent for triage;
- After verifying their health status, a risk level is assigned;
- The patient enters a queue to be seen by the doctors;
- In the act of consultation, the doctor can prescribe the prescription, hospitalize the patient or make the request to clinical analysis.

The focus of this research is on requesting clinical analyses through the first system, Patient Management.

The second system involved in interoperability is the Clinical Analysis Management System, which is instantiated in the Clinical Analysis Laboratory Centre.

We start by instantiating a SOAP server, where it was necessary to configure our server, in order to recognize the SoapServer method, which will be responsible for serving, this function being a service operation, we assign the access URI, so this will be the address for accessing the web service, once our server is instantiated, it is ready to be consumed by the web service in SOAP protocol.

Having published the service, we can start using the Patient Management System, we instantiate a SOAP Client (SoapClient), which also receives some parameters, and we need to pass some parameters inside a vector, namely Location and the URI, these are two different options, the first is the service location and the other is the access URI. These can be the same or different. In our case, the URI and Location have the same address, this is because these operations are being performed on the same machine (localhost).

IV. RESULT

We have the first system involved in interoperability, the Patient Management System, it should be noted that this has the following workflow, the patient is registered in the system and sent for triage, after verifying their health status a risk level is assigned, from the attribution of a risk level, the patient enters a queue to be seen by the doctors, in the act of consultation the doctor can prescribe the prescription, hospitalize the patient or make the request for analyses clinics.

Our focus is on requesting clinical analyses through the first system, Patient Management. The second system involved in interoperability is the Clinical Analysis Management System, which is instantiated in the Clinical Analysis Laboratory Centre.

The second application allows you to record the respective patient data, namely blood, urine, feces, for examination. After recording these data, the processing and validation of the results follows. At the end, the clinical analyst can send these results from the dashboard of his application, optionally, send the result to the requesting application.

Two web applications were built with different databases where it was possible to implement interoperability between them using the SOAP protocol.

In the first application, a Patient Management System, the doctor in the consultation process with the patient, through the consultation system dashboard, he clicks on the request analysis option, then he can enter the names of the analyses to be performed, and these data will be sent to another system. This second application, a Clinical Analysis Laboratory Management system, in turn, allows the clinical analyst to now see the names and procedures to perform the requested analyses.

After executing the procedures, it is up to the Lab professional to insert the respective result and click on send the result, and these data will be forwarded to the requesting system. At this point, the doctor, through his dashboard, can now click on the option view the analysis result, to see the results of the analyses. Fig. 1 illustrates an application server that provides the service to be consumed by these two systems, thus allowing interoperability between them.

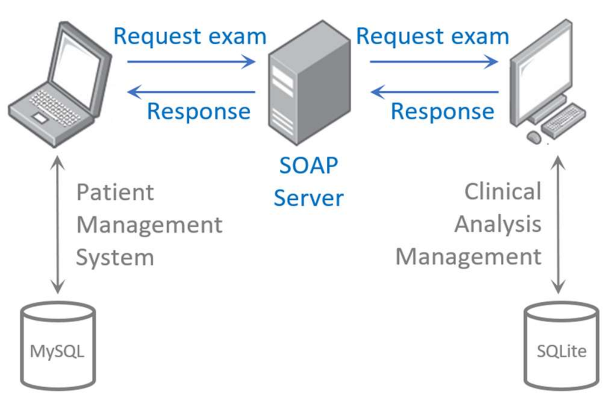

Fig. 1 – Proposed health interoperability environment

Advantages and Disadvantages of SOAP

The information presented in Tables 1 and 2 shows the argumentation over the pros/cons regarding the use of the SOAP protocol to handle interoperability in the proposed scenario.

Table 1: Advantages of the SOAP protocol

Description	Paper
SOAP web services provide built in security and compliant transactions that meet many business needs.	[21]
SOAP can use any existing transport means to send its request, from SMTP to even JMS.	[21]
SOAP is an industry standard, with well-defined protocols and a well-established set of rules.	[22]
It fits best for applications that are not installed in the cloud and low-request that may consume less bandwidth.	[22]

Table2: Disadvantages of SOAP

Description	Paper
SOAP adds considerable overhead, because it's in XML and because it adds a lot of metadata tags. Also, serializing and deserializing messages can be time consuming, making it a slower protocol.	[23, 24]
The data request is sent to a SOAP API, it can be processed through any application layer protocol, HTTP, SMTP, TCP etc. However, once the request is received, SOAP messages must be returned in XML format.	[21]
Difficult to implement and not so popular with web and mobile developers.	[21,24]
Strictly define standards to effect interoperability.	[21]
A browser cannot cache a completed request to a SOAP API, so it cannot be accessed later without resubmitting to the API.	[21]
Requires a lot of bandwidth for multiple requests.	[22]
SOAP is not natively supported on Android.	[22]

Project Estimate

For the evaluation of the project, the COCOMO II model [24] was used, applied to the RUP [23], estimating the effort, deadline and the average team for the Elaboration and Construction phases. The study was carried out in adjusted function points, the use cases were used to calculate the source instructions. In this way, the magnitude of the system is estimated and indicators such as the number of persons, the effort, duration and cost of the project are obtained.

It was obtained from the Patient Management Systems and Clinical Analysis Management System an Application Programming Interface (API) of interoperability between the same 69.6 Function Points (PF), it is developed by three persons with a productivity of 7 hours / PF with a journey of 6 hours daily.

Summary of calculations

After calculating the number of lines of code, the value of the effort calculation given by Bohem's formula [24] was used:

$$Effort\ PM = A \cdot Size^E \cdot \prod_{i=1}^{n} EM_1$$

$$Data: A = 2.94; B = 0.91; Size = 5.221$$

$$\sum_{j=i}^{s} SF_j = PREC + FLEX + RESL + TEAM + PMAT$$
$$= 24.623$$

$$E = B + 0.01 \cdot \sum_{j=1}^{s} SF_j = 1.1562$$

$$\prod_{i=1}^{n} EM_1 = 1.756$$

$$PM = 34.878\ Person/Month$$

$$Development\ Time\ T_{dev} = C \cdot (PM)^F$$

$$Data: B = 0.9; C = 3.67; D = 0.28$$

$$F = D + 0.2 \cdot 0.01 \cdot \sum_{j=i}^{s} SF_j = 0.32924$$

$$T_{dev} = 11.831 \approx 12\ months$$

$$Number\ of\ persons\ QP = \frac{PM}{T_{dev}}$$

$$QP = \frac{34.878}{11.831} = 2.93 \approx 3\ persons$$

$$Cost\ QPM = persons \cdot average\ salary\ (AS)$$

$$C = QPM \cdot PM$$

$$QPM = 1 \cdot AS = 1 \cdot 900€ = 900€$$

$$C = 900€ \cdot 34.878 = 31\ 390.2€$$

Depending on the calculations, the project has an estimated development time of approximately 12 months, the number of people involved is 3 people, with a salary of 900€ per month and a cost of 31 390.2€.

Tangible Benefits

- Reduction of physical files (papers, shelves, covers and envelopes of processes, etc).
- Increase in physical space.
- Reduction in the acquisition of new material to save the clinical process of patients.
- Easy access to information.

Intangible Benefits

In addition to the developed applications being a tool for daily use with a high level of functionality, usability, security and flexibility, it will allow real-time access to the information made available between the medical office (patient management system) and the clinical analysis centre (Clinical analysis management system) that is, through the use of interoperability, existing information will be reused, reducing the time in the execution of tasks, reducing ambiguity, greater credibility, etc.

Cost-Benefit Analysis

The system, implemented, will considerably alleviate working conditions and the disposition of information from different systems in real time, optimizing the delivery time of exams that were previously done manually.

In this cost-benefit analysis, taking into account the project cost, human effort and estimated development time, as well as the tangible and intangible benefits that were specified above, it can be stated that the implementation of interoperability between different computer systems in the Hospital Centre Dr. Ayres de Menezes in São Tomé and Príncipe is of added value.

V. Conclusion

Regarding the research question, to implement the interoperability between the two applications, we used the SOAP protocol, where it was possible to carry out a synchronous exchange of information, allowing greater speed in the request and sending of pathological data from patients, greater confidentiality of this same information.

Therefore, having solved the interoperability between the clinical analysis laboratory management system and the patient management system, it will reduce the execution time of tasks three times more compared to systems that do not have interoperability [3].

VI. Proposal for Future Work

We intend to implement REST and extend the integration of information contained in several islands of existing software, whether public or private, through the consumption of interoperability service in the national health service of São Tomé and Príncipe.

We also intend to implement a function that, with the interruption of the internet, it will be possible for users to continue the process of inserting and editing data, and subsequent synchronization of the data with the restoration of the internet.

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