Integrating medical information software using Health Level Seven and FHIR.

Abstract. This article describes the architecture of a framework for integrating medical information using Health Level Seven and FHIR. An iterative programming methodology was followed along with the incremental approach. The following steps have been done in order: the exchange format type is established, the terminologies, code systems and value sets, to be used are stablished, mappings that will be used are stablished, set the RESTful API over HTTP, gather all the FHIR resources required, set URLs for the search, set URLs for the operations, establish asynchronous usage, Design of communications with rest of systems, coding and testing and establish profiling. In conclusion, a framework was designed and developed to enable interoperability in different medical information systems, all this through the use of the international standards HL7 and FHIR, and taking into account certain lessons learned from previous works related to the area.

Keywords: HL7, FHIR, Interoperability, Web Services, E-Health, Integration, Middleware, Integrated Care.

1 Introduction

In order to improve the quality of healthcare, interoperability is considered one key requirement [1]. With the rapid increase in the diversity of models and the scale of health-related data, more and more problems are generated to comply with this characteristic. For this reason, *Electronic Health Records* (EHR), which make a large amount of data available to diverse actors, have become widely accepted. These actors include executives, doctors, researchers, inter alia, for various purposes [2].

However, databases that contain this type of information are difficult to consult, given the multiplicity of their relational tables and the lack of standardization, which significantly complicates interoperability between systems [2].

1.1 Motivation and context

The interoperability problems result in, patients restricted to a single provider of medical services, poor efficiency of resources, and, indirectly, the impossibility of the universality of medical services.

Other countries, such as India, have dramatically improved public safety with the implementation of appropriate interoperability standards, as accurate patient information can be accessed anytime, anywhere. Available standards can provide the semantic and syntactic meaning of the information, doing more understandable and increase interoperability opportunities [1].

Among existing health information standards, the Fast Healthcare Interoperable Resources (FHIR; HL7 standard that has been rapidly adopted by the healthcare community) framework appears to be the likely candidate to overcome this challenge. It is also compatible with an enriched information model that allows for achieving semantic interoperability of clinical data [3]. Furthermore, these standards are necessary to comply with objective 6 of the Sustainable Health Agenda of the Americas 2018-2030 (ASSA) [4] to allow the technical integration of the health information subsystems.

Instead of the traditional document-oriented approach, HL7 FHIR accepts a modular approach and represents atomic/granular health data as separate modular entities as ***Resources***. FHIR resources are managed through APIs and RESTful interface, two common terms of modern web applications [5].

With pandemic, being able to provide health care services where distance is a critical factor, at a time when health services are saturated, and where face-to-face care implies a risk, both for the health care provider and for the patients, it has been indispensable during the pandemic. The speed with which telemedicine services have been implemented globally has been very different. There are still great challenges to be solved in order to provide this type of care worldwide, one of them standardization [6].

This manuscript is organized as follows:

1. Introduction
2. Related works
3. Implementation of FHIR
4. Methodology
5. Case Study
6. Discussion
7. Conclusion

2 Related Works

A lot of research has been carried out to integrate the different data models from the different medical information systems. Saripalle et al. [5] explore and make a critical analysis of the use of FHIR to achieve interoperability in the health of patient history to design and realize a mobile interoperable prototype of patient health history that corresponds to the functional model HL7 PHR and enables bidirectional communication with OpenEMR.

On the other hand, Kilintzis et al. [7] present a methodology for the implementation of a data management framework for telemedicine, to support integrated care services for chronic and multi-morbid patients. This framework makes use of an ontology built on FHIR resources, to provide storage and representation of semantically enriched electronic medical record data following Linked Data principles. It should be noted that this solution was implemented within the framework of the *EU project WELCOME for managing data in a telemonitoring system for patients with COPD and co-morbidities* and was successfully implemented.

Kamel and Nagy [8] illustrate how FHIR can be used to offer radiology better clinical integration and a user-centered system. In Latin America, several efforts have also been made, such as the case of Argentina with Lopez et al. [9] where FHIR is being used to develop and implement a web platform for telemedicine for electronic consultations.

However, these constant investigations around health, have been focused on solving the problem of data integration from the different medical information systems, centering on solutions where what is required is new information that follows the standard used (in this case FHIR), leaving aside all the existing information that is in a specific format for each region, country and even each medical service provider. Finding this type of problem is common in Latin America where adaptation to these international standards is relatively new, such is the case in Ecuador where efforts to achieve interoperability of medical information systems are just beginning.

With this approach, Kiourtis et al. [10] propose to solve this problem by mapping data from the medical industry to FHIR through an alignment of ontologies. Besides authors focuses on a mechanism that can take full advantage of the data-intensive environment without losing the complexity of health.

However, these results are not entirely accurate due to their automatic processing and without human supervision, so the authors recommend it for real-time data flow scenarios since it is better and more efficient compared to others. Additionally, Mandirola et al. [11] explicitly conclusion the following statement:

> The lack of policies on standards increases costs and errors in system interoperability processes. Therefore, before defining the systems to be used, it is necessary to define the frameworks and policies that will allow the interoperation of the systems that are implemented. This includes messaging standards, terminology, identifiers, master tables, and integration engines.

For this reason, the proposal of this paper is to develop a framework in which this transformation is carried out through the experts of each of the systems. They also, define the policies of the systems, to establish the maximum precision of the transformation and can be used to exchange data with those of other medical organizations.

And it is the necessary step for a subsequent alignment of ontologies, which would allow in a moment to reach automation or semi-automation of interoperability. It is not part of this document the Identity Digital for EHR, the development of which is presented in another work related to the same project of which this work is part, known as Management of digital patient information with HL7, FHIR and Digital Identity, part of the subsystem ElectroHealth HUB..

The reason why this middleware is necessary in the real implementation is due to the lack of expressiveness in the attributes of the data schemas. Since these are often generated in an illegible way for any human being, as a personal data protection feature, thus avoiding any possible meaning semantic making impossible the idea of automatic process on them.

3 Implementation of FHIR

Currently, there are numerous implementation options for the HL7 FHIR standard, so this section will present a brief comparison with which the best implementation for this case was determined. This comparison took into account 5 key attributes:

- Cloud deployment Models: it describes the way the models are displayed.
- FHIR models: this attribute refers to all FHIR models that the implementation accepts, actual list is:
  - DSTU1, DSTU2, DSTU2.1, DSTU3, R4, R5
- Based on open source: this attribute describes whether the implementation is based on open source.
- Elastic server options: this attribute refers to whether the implementation has elastic server options.
- Serverless: this attribute describes whether the implementation can do without a server or not.

Of all the available options, 5 fit provisionally with the objective of this paper, these are:

- HAPI FHIR[1]: is a complete implementation of the HL7 FHIR standard for healthcare interoperability in Java.
- SMILE CDR[2]: Smile CDR is a complete, purpose-built clinical data repository designed around the HL7 FHIR standard that is used for storing health records.
- FHIR AZURE[3]: Azure API for FHIR enables quick connection to the current data sources, such as electronic health record systems or research databases.
- CLOUD HEALTHCARE API GOOGLE[4]: The Cloud Healthcare API enables data to be exchanged in a simple and standardized way between healthcare applications and solutions compiled on Google Cloud.

[1] https://hapifhir.io/
[2] https://www.smilecdr.com/
[3] https://azure.microsoft.com/es-es/services/azure-api-for-fhir/
[4] https://cloud.google.com/healthcare

- OPEN SOURCE FHIR API AWS[5]: open-source software toolkit that can be used to add capabilities of an FHIR interface to existing healthcare software.

Table 1 presents a summary of the functionalities of the different options proposed. It should be noted that SMILE CDR is built on HAPI FHIR, which is a complete repository of clinical data and specially designed according to the HL7 FHIR standard that is used to store medical records. In addition, this together with HAPI FHIR require a later phase where the place of hosting is determined, which entails a series of additional steps. On the other hand, Azure, Google Cloud, and AWS offer these services in a managed way, which facilitates their development and maintenance.

Table 1. Comparison between the different implementation options.

Platform / Attribute	HAPI FHIR	SMILE CDR	FHIR AZURE	CLOUD HEALTH-CARE API GOOGLE	OPEN SOURCE FHIR APIS AWS
Cloud deployment models	Needs server	Needs server	Cloud	Cloud	Cloud
FHIR models	DSTU1, DSTU2, DSTU2.1, DSTU3, R4, R5	DSTU1, DSTU2, DSTU2.1, DSTU3, R4, R5	R4, STU3	R4, STU3, DSTU2	STU3 and R4.0.1
Based on open source	Yes	Yes	Has an open-source option to deploy in their servers	No	Yes
Elastic server options	Depends on server	Depends on server	Yes	Yes	Yes
Serverless	No	No	Yes	Yes	Yes

[5] https://aws.amazon.com/es/blogs/opensource/using-open-source-fhir-apis-with-fhir-works-on-aws/

With the results of the comparison, HAPI FHIR was decided as the best implementation for this case, since it houses the majority of FHIR models together with SMILE CDR, but HAPI FHIR is free to use while SMILE CDR has a cost associated with its use.

4 Methodology

For this reason, proposal is the development of a framework to allow the integration of medical information software using Health Level Seven and FHIR where the data will be accessed and served through BlockChain [12], architecture is presented in Figure 1.

The system consists of two main parts: the first is one that is hosted on a server and will be in charge of handling the data and conversions, and the second, which is data extractor and provider, on which security layer is applied.

On the server side, there will be two controllers, one HL7 and the other FHIR, both of which will be in charge of transformation and interpretation of the different data stored in the databases of the external applications. The data will be exchanged through REST and XML endpoints.

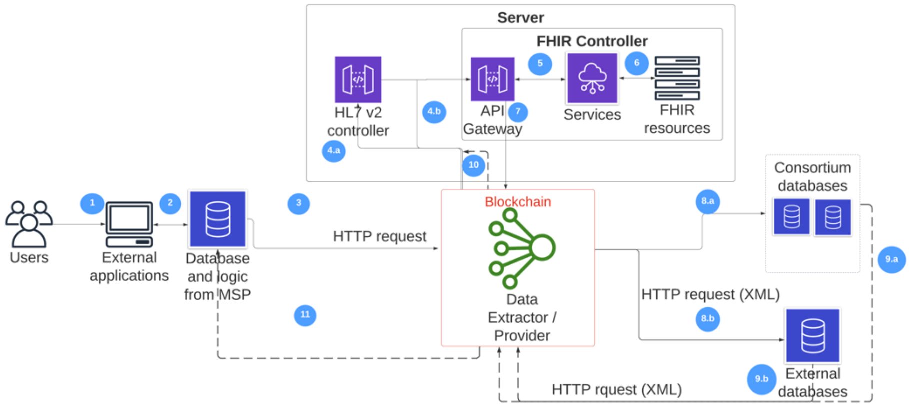

Fig. 1. Framework architecture.

For the elaboration of this paper, an iterative programming methodology was followed along with the incremental approach, this includes certain concepts concerning the development of systems with FHIR standards. For this, the required process Business Process Model and Notation (BPMN) must be taken into account, as well as its minimum data set that contains the minimum information to establish interoperation in any organization.

The reason why it was decided to use this methodology over others is that it maintains its center in the FHIR standard as well as with the FHIR development process [13] and has been mentioned in [1], which is established in the official standard description page. Figure 2 describes the proposed methodology.

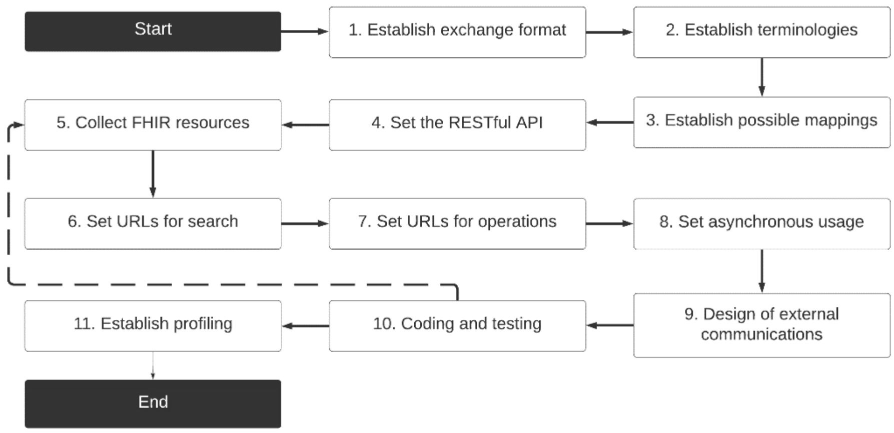

Fig. 2. Methodology proposed

Following this methodology, the following steps have been done in order:

1. Exchange format type is established.
2. Terminologies, Code Systems, and Value Sets, to be used are established.
3. Establish mappings that will be used.
4. Set RESTful API over HTTP.
5. Gather all FHIR resources required
6. Set URLs for the search.
7. Set URLs for the operations.
8. Establish asynchronous usage.
9. Design of communications with rest of systems
10. Coding and testing
11. Establish profiling.

5 Case Study

In the section previous has mentioned that finding this type of problem is common in Latin America, because of that it was decided to take Ecuador as the case study. Ecuadorian Ministerial Agreement NO. 00001190 [14] mentions universality where it is defined as "extend the coverage of the benefits of the health system to the entire population". Likewise, in the Ecuadorian ministerial agreement NO. 00001190 [14] the agreement for the approval of the use of HL7 and its implementation in all the institutions of the national health system is detailed.

Since the methodology is to be applied to the health-related data stored in a country, it is necessary to have a description of each of these resources. This description can be obtained from the document: *Expediente Único para la Historia Clínica* (Single File for the Clinical History) issued in 2007 through Ministerial Agreement NO. 0000116 of Ecuador from which the following documents were obtained:

- “Anamnesis”
- “Consulta Externa – Anamnesis y Examen Físico”
- “Consulta Externa – Evolución”
- “Evolución y prescripciones”
- “Examen Físico”

1. The exchange format type is established.

In this step the type of format for the exchange is chosen, possible ones include XML, JSON, and RDF.

In this case, the format chosen for the exchange will be XML because this type uses human language and is readable and understandable. Another reason to use this format is its compatibility with Java, which is the development language of this framework.

2. The terminologies, Code Systems, and Value Sets, to be used are established.

In FHIR the descriptions of certain attributes, such as diseases or family roles, among others, must be described in terminologies, which must be described on the public website.

As in the previous step, in this case, you can find several options that are valid for development, however, taking into account that the framework is focused on being deployed in Latin America and specifically in Ecuador, it has been decided to use the system code of ICD10 in its Spanish version (CIE10). Although to define the roles of the family members, the V3-RoleCode code system is used.

3. Establish the mappings that will be used.

In this step, the mappings necessary are defined for the conversion to other standards such as HL7 V2 and other data schemas.

For this case, it was decided to use [15] as a data converter from HL7 V2 to FHIR, since this document focuses on obtaining FHIR resources.

4. Set the RESTful API over HTTP.

Because FHIR is a standard, it is based on the standardization of resource structures and interfaces. This can be seen as a violation of REST principles, but it is critical to ensuring consistent interoperability between different systems. The same interactions are defined for each "resource type", with which resources can be managed in a very granular way [16].

The request methods that will be used mainly are the get, post, put and delete methods.

5. Gather all the FHIR resources required

In this step, the resources used in the medical information system are aligned with the FHIR resources, in this way a conversion scheme is obtained that will be used in the implementation of FHIR for the conversion of the data.

The conversion of each of the attributes described in the “Expediente único para la Historia Clínica” was carried out. Each of the attributes was aligned with either a field of an FHIR resource or a complete resource, depending on the case. It should be noted that if the required information is not specifically found, FHIR presents the option of making extensions to each of its resources, so if this is the case, this option should be chosen.

In this case, an example would be vaccines of a patient, these correspond to form 002 – “Anamnesis – consulta externa”, to the subcategory of “Antecedentes personales”, initially the name of the vaccine and a description would go, however, the medical information systems add the ICD10 code, plus an ID.

In FHIR the vaccines are under the Immunization resource so that the alignment would be as follows:

Table 2. Alignment of resources

Vacuna (Anamnesis)	Immunization
Id del paciente	patient
Fecha	occurrence
Id	identifier
Nombre	vaccineCode
Descripción	note
Código	vaccineCode

Additionally, the resource specifies the status of the vaccine, and the number of doses must be established since this is history, for the vaccine to be listed it must have been completed. Thus, this field must always go to complete, and if the number of doses does not exist, the number 1 will be specified.

For the case in which the alignment is not possible, as is the case of the maternal surname of a patient, extensions should be used, an example is presented in table 3.:

Table 3. Alignment of non-basic fields of resources

Paciente (Registro de Primera admisión)	Patient
Apellido Materno	patient-mothersMaiden-Name (extension of patient)

If no extension matches the field, one must be defined somewhere accessible on the internet and it can be used within FHIR.

In this phase, each one of the files required by the middleware is generated to include a new medical service provider in the conversion. For this, it was decided to use the model-based engineering (MDE) approach. Here new medical service provider enters the information of the conversion, previously obtained, list within the model generated for the resource.

This phase has as input the conversion list document and as output to:

- Generated conversion classes: the classes necessary for the operation of the middleware
- Generated data extractor: a class that has the specification of the endpoints from which the data will be extracted

Figure 3 shows the input list obtained for patient, left column represents the attribute description and right column the name in the database, while, figure 4 shows the model generated for the case of the patient. This model is similar to one of the classes. Each organization can have a definition of a patient within its system. In turn, these two entities describe each of the attributes necessary for the conversion. The medical service provider inserts the name of the equivalent attributes into its database. This process is repeated for each of the resources obtained for the middleware.

Apellido Materno	apll-mat
Apellido Paterno	apll-pat
Barrio	barr
Calle Principal	cll-prncpal
Calle Secundaria	cll-scndria
Canton Nacimiento	cntn-nac
Canton Residencia	cntn-res
Celular	cel
Correo Electronico	email
Direccion Contacto	drccn-cntct
Estado Civil	std-cvl
Fecha Nacimiento	fch-nac
Genero	gen
Lugar Nacimiento	lgr-nac
Nacionalidad	ncnldd

Nombres Apellidos Contacto	nmbr-apll-cntct
Numero Casa	num-cas
Numero Identificacion	num-id
Parentesco	prentsco
Parroquia Nacimiento	prrq-nac
Parroquia Residencia	prrq-resid
Primer Nombre	prim-nmbr
Provincia Nacimiento	prov-nac
Provincia Residencia	prov-res
Referencia Residencia	ref-res
Segundo Nombre	seg-nmbr
Telefono	tel
Telefono Contacto	tel-cont
Tipo Identificacion	tp-id

Fig. 3. Correlation list for Patient

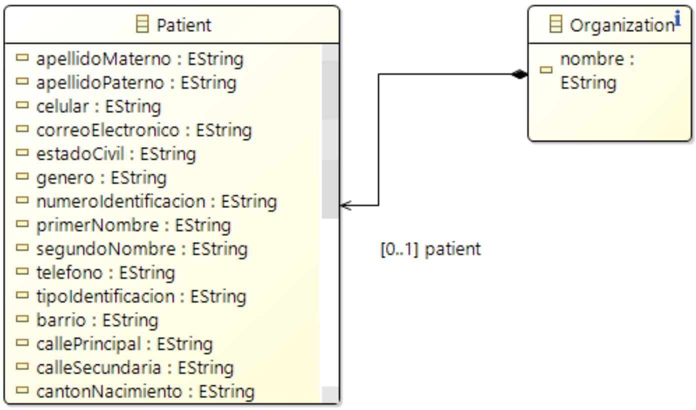

Fig. 3. MDE for Patient

6. Set the URLs for the search.

The search for resources is fundamental to the mechanics of FHIR. Lookup operations traverse an existing set of resources filtered by parameters supplied to the lookup operation [17].

The structure of the URLs for the search used is the one suggested by FHIR [17] and implemented by HAPI FHIR. This can be summarized in the following string:

```
GET [base]/[type]?name=value&...{&_format=[mime-type]}}
```

Where [base] is the base URL of the server, [type] is the name of the FHIR resource and the parameters are a series of name-value pairs encoded in the URL. On the other hand, for the POST method, it can be summarized as follows:

```
POST [base]/[type]/_search{?[parameters]{&_format=[mime-type]}}
```

In this case, the server is the one that determines the set of resources that matches the specified criteria and returns the results in a bundle with all the resources.

Following our example of the vaccine, the URL would be:

http://localhost:8080/fhir/Immunization?patient:Patient:1

7. Set the URLs for the operations.

“The RESTful API defines a set of common interactions (read, update, search, inter alia.) performed on a typed resource repository”[18].

Since the operations, in this case, are not an essential part of the functioning of the system, what was taken into account was that “Operations are executed using a URL derived from the FHIR endpoint, where the name of the operation is prefixed by a" dollar sign "('$') character” [19]. An example is:

POST http://fhir.someserver.org/fhir/Patient/1/$everything

The rest of the extended operations used in this case follow what is stated by FHIR [17]. Following the example case, it would be:

http://localhost:8080/fhir/Immunization/1/$evertything

8. Establish asynchronous usage.

The RFC 7240-based asynchronous requirement standard is adapted for this application and applies to all defined interactions and operations, although it does not take advantage of many of these applications. Servers can choose which interactions should support the pattern (if any), and servers can only support some operations that use the asynchronous pattern [19].

For this case, the use of the System is intended to be synchronous, for all resources, given that the amount of information is not too much and not too much processing will be carried out by the server, so asynchronous use is not defined for this case.

9. Design of communications with the rest of the systems

In this step, the communications with the systems with which the framework will be connected for the extraction and sending of data are designed.

In this case, the communication design is the one presented in figure 1. In this way, the data extraction from the different databases is modeled and encoded.

10. Coding and testing

Finally, all the schemes and data obtained in the previous steps are encoded.

The framework was coded and tested with various types of data structures from local medical information systems in Ecuador. Additionally, each resource was tested with Instance Validator[6], which is the HAPI FHIR instance validator.

11. Establish profiling.

The FHIR specification describes a number of basic functions, frameworks, and APIs that are used in many healthcare contexts. However, there are large differences between

[6] https://hapifhir.io/hapi-fhir/docs/validation/instance_validator.html

jurisdictions and across the health ecosystem where practices, requirements, regulations, training, and interventions are feasible and / or beneficial. For this reason, the FHIR specification is a platform specification: it creates a common platform or foundation upon which a variety of different solutions are implemented [20].

In this case, all the restrictions inferred from the Expediente único para la Historia Clínica are established, that is, only the resources obtained through this process will be used, without the possibility of adding the rest of the resources specified by FHIR, in addition to the use of The API will be restricted by two levels of access, the first will show information related to an external query, while the second level of access will show the rest of the details of each patient. As previously stated, ICD10 will be used in its Spanish version.

6 Discussion

The developed framework presents a viable flow to establish the necessary policies to enable the interoperation of medical information systems. This is one of the main problems in the area, exactly this occurs in step 11 of the proposed methodology, were once with all the necessary resources, the restrictions to be used in the systems are established. In addition, the proposed methodology allows the experts of each system to be part of the process, being they who ensure successful interoperability through the alignment of the resources used in the different systems. On the other hand, when developing the framework certain aspects of the area began to become more and more evident, as is the case of the difficulty that currently exists for medical personnel with the use of the ICD10 Because it is a code system, it certainly adds extra complexity when using the system during the day.

1. Limitations and upcoming improvements

One of the main limitations of the proposed methodology is the missing resources. For this reason, the proposed solution is a first step in the transition from the different data schemes of the different medical information systems, to the use of the FHIR standard. On the other hand, the alignment of the resources translated to FHIR must be available to each of the users of the Framework since certain labels do not coincide between FHIR and the resources of the medical information systems. Therefore, an immediate improvement to this methodology would be to automate this process of obtaining alignment documents.

7 Conclusion

A framework was designed and developed to enable interoperability in different medical information systems, considered the particularity of real case of study from Ecuador. In order to achieve through the use of the international standards HL7 and FHIR, and taking into account certain lessons learned from previous works related to the area. All this fulfills all the proposed methodology so that the systems that are part of the framework can exchange information between them safely and reliably.

However, when making this middleware, as in other documents, the existing difficulty in the correlation of the data has been found.

Likewise, the expressiveness of the attributes of the database schemas is very complex, which is why the use of this middleware is important, since this would eliminate this inconvenience through a much more rigid mapping that allows the medical service providers to work directly with this framework. It should be noted that this is the previous step for a real alignment of ontologies, which would allow the integration of greater semantic expressiveness in interoperability and that it can be proposed as future work.

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