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## HEALTH SYSTEMS INTEROPERABILITY: ANALYSIS AND COMPARISON

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**ABSTRACT:** *Promoting eHealth interoperability is a priority in Europe allowing organizations to enhance the quality and safety of patient care. However, this priority is very difficult to establish. Developing an interoperable system or controlling systems' interoperation has been approached from multiple points of view, with many dimensions and under various types of approaches.*

*Several studies and initiatives have been proposed in the field of e-health to identify interoperability dimensions and to define a framework of global and structured characterization. This is the aim of establishing reference architectures to facilitate the interoperability between health information systems. However, the lack of a common understanding and compromise on interoperability dimensions can be a major barrier to the development of interoperability.*

*The main objective of this paper is to make a survey on initiatives promoting interoperability within the health sector and propose a comparative analysis of the main frameworks for e-health interoperability.*

**KEYWORDS:** *Health system, e-Health, interoperability, framework, dimensions.*

### 1 INTRODUCTION

The use of e-health solutions has been developed over thirty years. It was first promoted by administrative and financial needs to become more and more a subject of innovation (Rialle 2007) (Caterina et al., 2011).

A comprehensive definition covering all facets of eHealth is found below:

*“e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies(...)”* (Eysenbach, 2001).

More specifically, as depicted by the figure 1, e-health promotes access to information of different professionals and patients and facilitates cooperation between professionals. It also helps to develop new modes of healthcare, thus increasing the quality of patient care (Black et al., 2011).

Indeed, as rightly pointed out by (Pagliari 2005) “In a broader sense, the term e-health characterizes not only a technical development, but also a new way of working, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology.

There are two types of benefits that can be derived from the use of e-health solution :

- Soft or qualitative benefits for patients: related to wellness, improved relations between patient and healthcare professional, increased patient comfort.
- Hard benefits: dealing with cost reduction, reduced number of hospital admissions, reduced number of trips between home and hospital for the patient, smaller number of emergency hospital admissions and decreased levels of hospital re-admission.

Even if these benefits are very interesting, we observe that the wide-scale adoption of e-health is still slow. And there are many reasons for that. One of the most important is about Interoperability which is considered as the highest cause of e-health project failures [ref]. This point is addressed as a main issue within this research.

In this paper, we survey and compare the main research works and initiatives dealing with interoperability in the health domain in order to identify the limitations and contribute to fostering the interoperability of health systems.

The paper is structured as follows. Section 2 deals with e-health interoperability research context, benefits and challenges. Then, section 3 surveys the main interoperability frameworks in the health domain. In section 4, we compare the presented frameworks and highlight, respectively, their relevance and coverage to the interoperability domain. Finally, we conclude in section 5 and suggest future research.

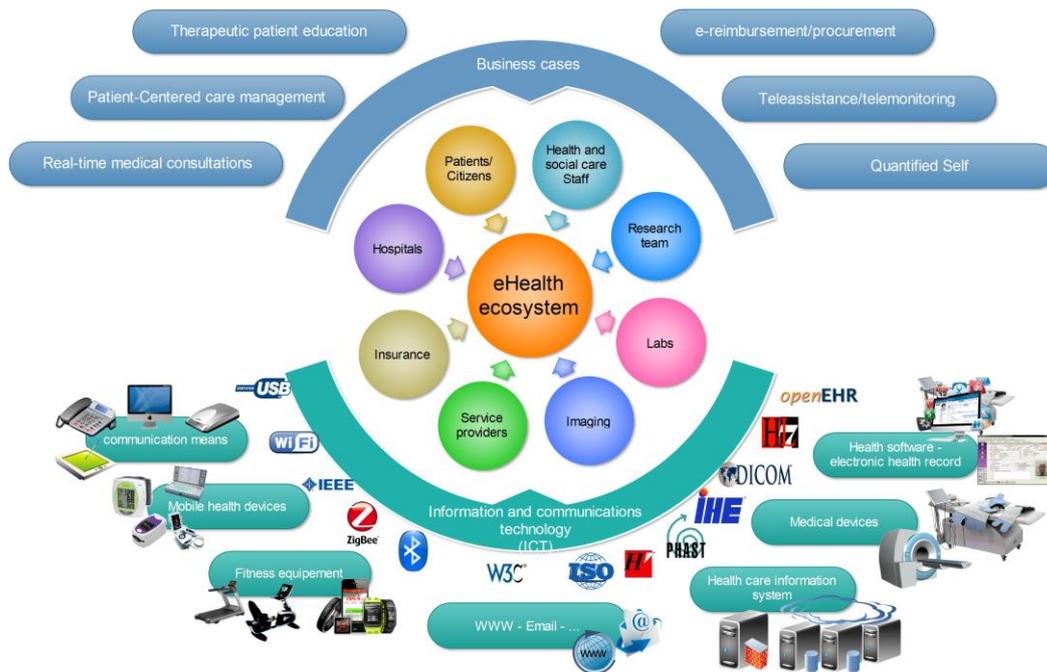


Figure 1 : eHealth ecosystem

## 2 E-HEALTH INTEROPERABILITY

A widely used definition of Interoperability is the one given by (IEEE, 1998), considering it as the *ability of two or more systems or components to exchange information and to use the information that has been exchanged*.

Many other definitions can be found in the literature, as detailed in (Guédria, 2012). In (Pingaud, 2009), the author pointed out that interoperability is the *capacity of natively independent systems to interact properly, i.e to behave in harmony, easily sharing a common objective, without having to deeply modify their own structure and behaviour*.

E-health interoperability is a fundamental prerequisite to further improve individual health care and well-being and ensure high quality and safe services.

The continuous improvement of the patients' health care, in terms of accessibility, coordination and continuity of care, requires better interchange and management of information flow; and cooperation between stakeholders involved in the health care management process of the patient. This requires having interoperable socio-technical systems.

Although this requirement for interoperability is recognized as a cornerstone for improving the quality of healthcare and the efficiency of the overall health system organization, it is however very difficult to achieve.

To this end, several standards and norms of exchange and data sharing have been developed to enable systems and applications often designed "in silo" to be interoperable by sharing common data (c.f figure 1). Among these norms and standards, we can mention:

- HL7 (Health Level Seven), standard dedicated to providing a comprehensive framework for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services (Dolin et al., 2006).
- DICOM (Digital Imaging and Communication in Medicine), open standard managed by an international committee (DICOM Committee), for handling, storing, printing and transmitting information in medical imaging (Mildenberger et al., 2002).
- PN13-SIPH standard result of the work of Interop / SIPH group within the Phast association. It focuses on the exchange of information directly related to drug supply: from the prescription till the drug circuit and administration of individual doses.
- H.PR.I.M (Harmonie et PRomotion de l'Informatique Médicale), a standard for biology exams transmission between laboratories, health organisms and prescribers (Cordonnier, 2001).

Beyond the multiple norms and standards, that cover the majority of the health domain, there are various instances that prompt stakeholders to share and make use of interoperability standards. Among these instances, we can mention:

- IHE (Integrating the Healthcare Enterprise), is an international initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information (Vegoda, 2002). IHE promotes the coordinated use of established standards such as DICOM and HL7 to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE could better communicate with another one, are easier to implement, and enable care providers to use information more effectively.
- Continua Health Alliance (Whitlinger, 2010), is an international not-for-profit industry organization enabling end-to-end, plug-and-play connectivity of devices and services for personal health management and healthcare delivery. Its mission is to empower information-driven health management and facilitate the incorporation of health and wellness into the day-to-day lives of consumers.

These norms and standards seem to reach a satisfactory level of maturity. Similarly, organizations working on repositories have gained notoriety within the health ecosystem.

However, the contrast between the multiple standards contributing to interoperability and lack of ownership by the players in the health field is clear. Thus, for instance, exchange formats are still often unique to each provider. However, developing an interoperable system or conduct system interoperation should be considered with multiple perspectives, various dimensions and with different types of approaches.

Several research work and initiatives have been proposed in the literature to identify the dimensions of interoperability and to define a framework that provides organizing mechanism and knowledge of the domain in a structured way (e.g. Nehta (NEHTA, 2007), HIS-IF (ASIP, 2010), eHealth EIF (European Commission, 2013), PHS (European Commission, 2011), etc.). However, the lack of a common understanding and a consensus on these dimensions remains a challenge.

In the following section, we analyse the most relevant interoperability dimensions in healthcare domain through a survey of the most known interoperability frameworks.

### 3 SURVEY OF INTEROPERABILITY FRAMEWORKS

In this section, we display the main interoperability models and frameworks relevant to the health domain.

#### 3.1 eHealth European Interoperability Framework (eHealth EIF)

The eHealth EIF framework (European Commission, 2013) was developed in the context of a research program funded by the European commission for the interoperability development. It is an application of the generic European Interoperability Framework (EIF) (European Commission, 2010) to the domain of eHealth. eHealth EIF aims at providing a set of recommendations and specifications to connect eHealth systems. It identifies four levels of interoperability: legal, organizational, semantic, and technical. An overview of these different EIF concepts is given in figure 2.

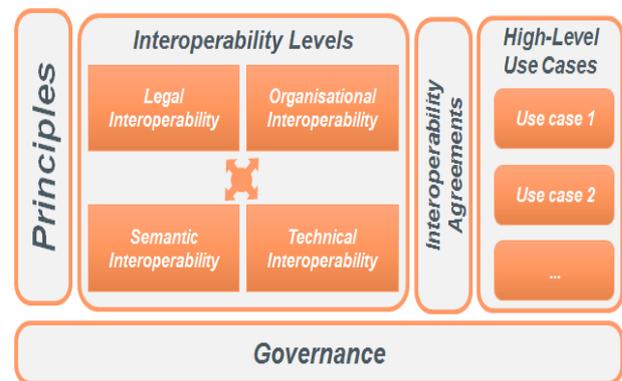


Figure 2: Structure of the eHealth EIF (European Commission, 2010)

- Legal interoperability aims to “align legislation so that exchanged data is accorded proper legal weight”.
- Organizational interoperability aims to “coordinate processes in which different organizations achieve a previously agreed and mutual beneficial goal”.
- Semantic interoperability aims to precise “meaning of exchanged information which is preserved and understood by all parties.”
- Technical interoperability aims to “discuss technical issues involved in linking computer systems and services”.

For each interoperability level, the organizations involved should formalize cooperation arrangements in interoperability agreements.

Interoperability governance “covers the ownership, definition, development, maintenance, monitoring, promoting and implementing of interoperability frameworks in the context of multiple organizations working together to provide (public) services.

Six principles were defined based on the generic EIF: security and privacy, transparency, preservation of in-

formation, reusability, technological neutrality and adaptability, and openness. Two additional principles have been added to this list: patient centricity and an approach based on use cases. The eHealth EIF proposes a list of ten high-level use cases to the eHealth Network. For more details, please see (European Commission, 2013).

### 3.2 Health Information Systems Interoperability Framework

The Health Information System (HIS) Interoperability Framework is a reference framework created by ASIP Santé (Agence nationale des Systèmes d'Information Partagés de Santé<sup>1</sup>) for the purpose of:

- Encouraging the development of services for the electronic sharing of personal health information.
- Creating interoperability conditions between HIS systems that meet privacy and security requirements.

This reference framework specifies the standards that must be used for the electronic sharing or transmission of personal health information using HIS systems. The model also specifies how to implement these standards in order to facilitate the deployment of interoperable HIS systems in agreement with privacy and security requirements.

The HIS Interoperability Framework (IF) reference is divided into modules, as shown by figure 3. Modules are distributed across 3 interoperability layers, defined as follows:

- Content layer (semantic and syntactic content): Specification of exchanged or shared content in terms of structure and vocabularies;
- Service layer : Specification of content sharing or exchange services, their rules and usage parameter; and
- Transport layer: Specification of exchange protocols used by services.

The service and transport layers are often referred to as a group as the "Technical Base" of the framework because they are both developed in a technical development track with vendor participation. The content layer is mostly focused on user input and requirements and is developed separately (ASIP, 2010).

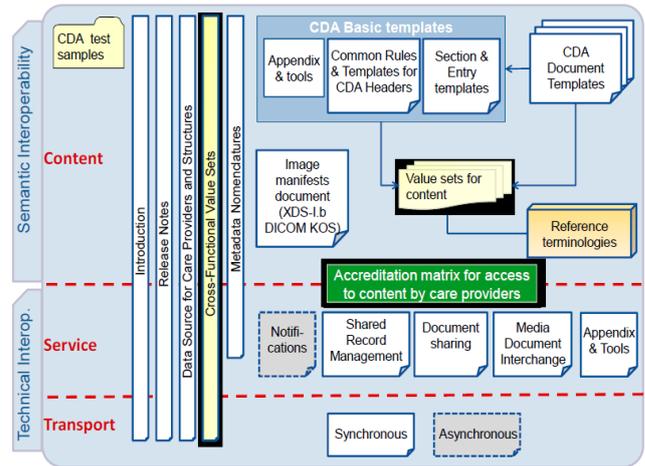


Figure 3: Organization of the HIS Interoperability framework (ASIP, 2010)

### 3.3 eHealth Interoperability Framework (eHealth IF)

The ehealth interoperability framework (NEHTA, 2007) was developed by the National E-Health Transition Authority (NEHTA) initiatives in Australia. It defines three levels of interoperability across health organizations (see figure 4):

- Organizational layer which provide a shared policy and process framework across the eHealth interoperability agenda covering each NEHTA initiative. It includes the Business Processes, standards plan, security policies and Privacy.
- Information layer which provide shared building blocks for semantic (information) interchange including Foundation Components, Value Domains, Structures, common Assemblies, Relationships and Metadata.
- Technical layer is concerned with the connectivity of systems for information exchange and service use. Solutions are based on open standards providing a level playing field for competitive provision of technical solutions.

<sup>1</sup> <http://esante.gouv.fr>

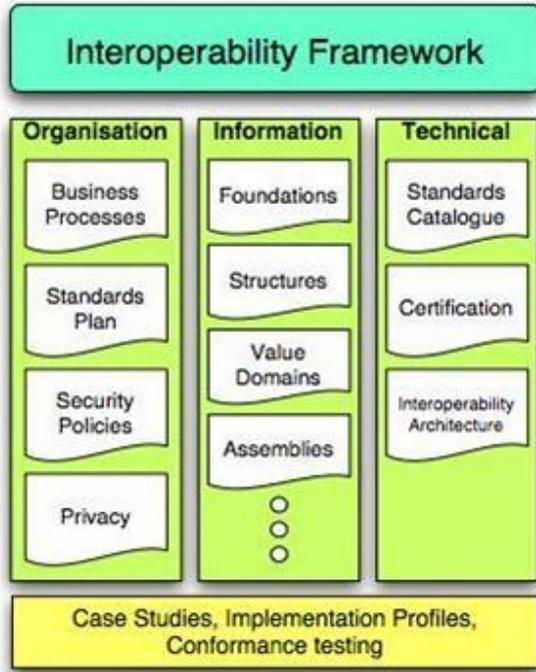


Figure 4: eHealth Interoperability Framework (NEHTA, 2007)

### 3.4 Personal Health System Framework

Personal Health Systems (PHS) assist in the seamless provision of quality controlled, and personalized health services to individuals regardless of location. They consist of: 1) *Ambient and/or body devices* (wearable, portable or implantable), 2) *Intelligent processing of the acquired information and coupling of it with expert biomedical knowledge* to derive important new insights about an individual's health status, 3) *Active feedback* based on such new insights (European Commission, 2011).

As can be seen in figure 5, the PHS Interoperability Framework (PHS IF) can be subsumed into two smaller frameworks: 1) *technical & implementation framework*, including standards, profiles and guidelines for their implementation based on elaborated business use cases, identification & authentication mechanisms, security protocols, testing and certification, etc., and 2) an *institutional / organizational framework* encompassing policy issues (e.g., governance, reimbursement), legal and regulatory aspects such as data protection, liability, etc. (European Commission, 2011).

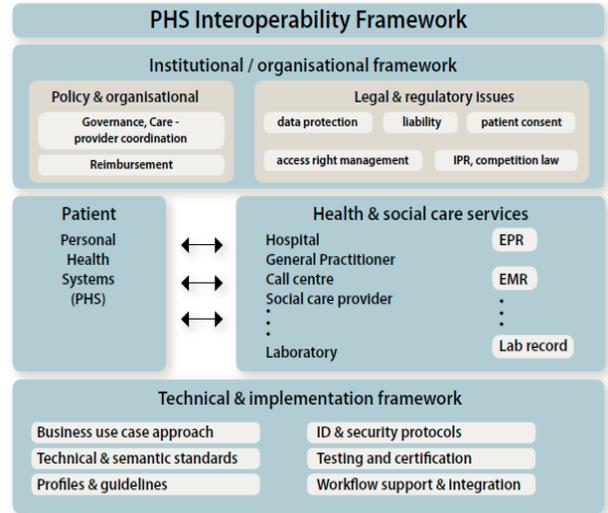


Figure 5: PHS Interoperability framework (European Commission, 2011)

## 4 COMPARATIVE ANALYSIS

This section develops a comparison of the interoperability frameworks in the health domain. This comparison will be based on interoperability dimensions defined by the European Interoperability Framework (EIF) and the Framework of Enterprise Interoperability (FEI). Our choice is motivated by the generic nature of EIF and the fact that FEI is defined within the general perspective of an enterprise-as a system, where a health organization can also be considered as an enterprise.

The EIF defines four levels of Interoperability While taking into account the political context: Legal Interoperability, Organisational Interoperability, Semantic Interoperability and Technical Interoperability, as depicted by figure 6.

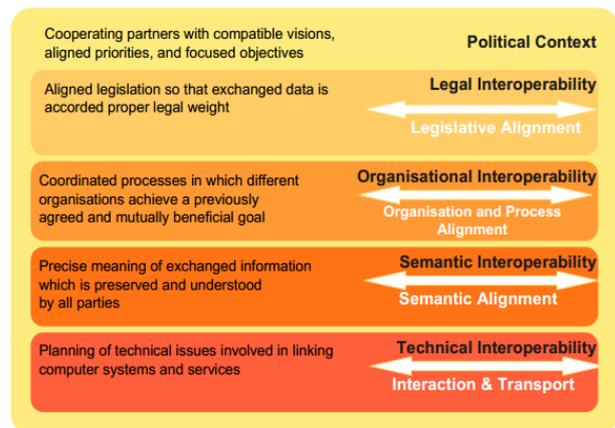


Figure 6: EIF Interoperability levels (European Commission, 2010)

The FEI (Chen, 2013) was developed within the frame of INTEROP European Network of Excellence (NoE) (INTEROP, 2007) (Chen et al., 2007). It defines a classification scheme for interoperability knowledge according to three dimensions: *interoperability barriers*, *interoper-*

ability approaches, and enterprise interoperability concerns, as depicted by figure 7.

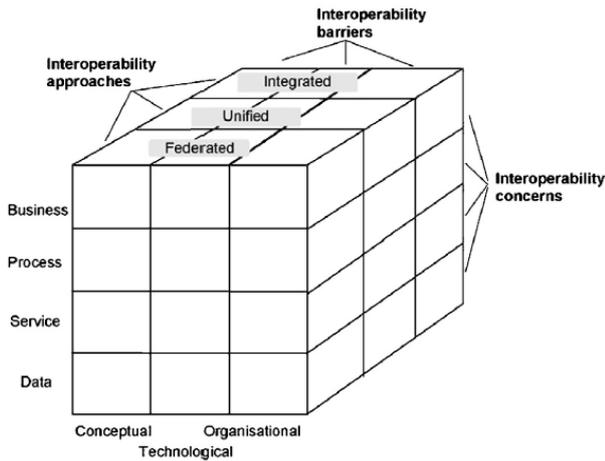


Figure 7: FEI Interoperability dimensions (Chen et al., 2005)

It is worth noting that Interoperability Barriers defined by FEI are based on interoperability levels, defined by EIF (CompTIA, 2004). Hence, FEI Interoperability Barriers will be omitted in this comparative analysis to avoid repetitions.

Before comparing the reviewed health frameworks towards criteria from EIF and FEI, it is important to give a general overview of the domain covered by these frameworks. This is given by table 1.

	eHealth EIF	HIS IF	eHealth IF	PHS IF
Interoperability dimensions	Legal Organizational Technical Semantic	Semantic Technical	Organizational Technical Informational	Legal Organizational Technical
Case study orientation	Yes	-	yes	Yes

Table 1: Coverage of health Interoperability frameworks

The comparison criteria are based on the four interoperability levels of EIF and two dimensions of the general framework FEI. The indications alongside each criterion in each table denote the corresponding coverage in each particular ehealth interoperability framework.

- √ indicates that the studied framework has adopted an approach for this criterion, without judging whether this approach provides full or partial coverage for the issue.
- X refers to the lack of a tangible approach to this issue
- ? characterizes a criterion when the information gathered by the studied framework specifications is inadequate to evaluate this criterion.

#### 4.1 Interoperability levels

EIF defines four levels of interoperability. Each deserves special attention when a new public service is established: *Legal Interoperability* is concerned with relevant legislation relating to data exchange, including data protection legislation, when seeking to establish a European public service. *Organizational Interoperability* is concerned with how organizations, such as public administrations in different Member States, cooperate to achieve their mutually agreed goals. *Semantic Interoperability* ensures that the precise meaning of exchanged information is understood and preserved throughout exchanges between parties. *Technical Interoperability* covers the technical aspects of linking information systems. It includes aspects such as interface specifications, interconnection services, data presentation and exchange, etc. Table 2 illustrates the coverage of the reviewed frameworks towards these four levels.

	eHealth EIF	HIS IF	eHealth IF	PHS IF
Legal	√	?	?	√
Semantic	√	√	√	√
Organizational	√	X	√	√
Technical	√	√	√	√

Table 2: Coverage of Interoperability levels

#### 4.2 Interoperability Concerns

They represent the areas concerned by interoperability in an enterprise. Four concerns are defined, namely *business interoperability* (work in a harmonized way to share and develop business between companies despite the difference of methods, decision making, culture of enterprises, etc.), *process interoperability* (make various processes work together. In the interworked enterprise, the aim will be to connect internal processes of two companies to create a common process), *service interoperability* (making work together various services or applications by solving the syntactic and semantic differences) and *data interoperability* (make work together different data models with different query languages to share information coming from heterogeneous systems). Table 3 illustrates the coverage of the reviewed frameworks towards the four enterprise interoperability concerns.

	eHealth EIF	HIS IF	eHealth IF	PHS IF
Business	X	?	√	√
Process	?	√	√	√
Service	?	√	√	√
Data	√	√	√	√

Table 3: Coverage of interoperability concerns

### 4.3 Interoperability Approaches

There are three basic ways to relate entities together to establish interoperations: *The integrated approach* (characterized by the existence of a common format for all the constituents systems), the *unified approach*, characterized by the existence of a common format but at a meta-level, the *federated approach*, in which no common format is defined. This approach maintains the identity of interoperating systems; nothing is imposed by one party or another and interoperability is managed in an ad-hoc manner. Table 1.4 illustrates the coverage of the reviewed frameworks towards these interoperability approaches.

	eHealth EIF	HIS IF	eHealth IF	PHS IF
Integrated	X	X	X	X
Unified	X	X	X	X
Federated	X	X	X	X

Table 4: Coverage of Interoperability approaches

## 5 DISCUSSION

The review of the different aspects and the frameworks coverage with respect to the dimensions defined by the EIF and FEI, enables us to identify the main elements in health interoperability that are taken into account by the existing frameworks and the elements that lack to be considered within these frameworks.

Legal, Organizational, technical and semantic levels are the main relevant dimensions that we find in the health interoperability domain. Some of them are missed, as shown by the tables 1 and 2.

The comparison has clearly shown that no one of the reviewed interoperability frameworks, in section 3, considers interoperability approaches and thus proposes a way to deal with a specific interoperability problem (see table 4).

Suggesting a unified framework that takes into account existing ones and integrating the required dimensions of interoperability would allow covering the whole domain of interoperability and going beyond existing approaches.

In order to facilitate the design of this unified framework, we believe that having basis on usage scenarios of the electronic patient record in an extended health pathway, particularly in supporting cross-border healthcare, is a very effective way to identify the dimensions of the future framework. These scenarios would be especially needful if considering cases where the patient data are, partially, supplied by information from medical devices. This is the approach that we intend to adopt in our future work to define the dimensions of the unified framework.

## 6 CONCLUSION AND FUTURE WORK

In this paper, we surveyed the main interoperability frameworks in the health domain. A comparative analysis of the considered frameworks was then proposed based on interoperability levels, as defined by the European Interoperability Framework (EIF) and Interoperability concerns and approaches, as defined by the Framework of Enterprise Interoperability (FEI). This comparison enabled us to identify clearly the missing interoperability aspects in existing frameworks within the health domain. Future work are planned to propose an integrated framework that would allow having a unified approach covering various existing interoperability dimensions and thus going beyond existing ones.

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