CHIEM

A Centralized Health Information Exchange Model

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***Abstract*—Electronic Health Records (EHR) contain information from healthcare providers involved in a patient care. The common approach to achieve an interoperable EHR is the exchange of information between each provider by the implementation of message protocols. Traditional EHR systems are based on diverse standards, implementation languages, and information models. As consequence, EHR systems are fragmented and unable to exchange data. Data integration and interoperability are the major challenges faced by traditional EHR systems. Therefore, in this work we propose a Centralized Health Information Exchange Model (CHIEM). All healthcare providers would be able to obtain an updated and integrated EHR for a given patient by making a single request to a central system. The CHIEM architecture is cloud based, and the information model relies on archetypes that represent healthcare concepts from community defined minimum set of data (MSD). The main goal of the CHIEM is to provide a single point of request to healthcare providers, including those without an EHR system that are interested in obtaining an integrated electronic health record of patients.**

Keywords—EHR; information exchange; archetype; cloud computing; minimum set of data; CHIEM

I. INTRODUCTION

The technical and semantics heterogeneity among electronic health records (EHR) systems are barriers to data integration and interoperability in healthcare environment. Data integration from different system sources demands a high grade of data interoperability. Most healthcare information systems persist data in proprietary formats [1].

In this article, we propose a centralized interoperable architecture model named Central Health Information Exchange Model (CHIEM). Healthcare providers would be able to obtain an updated and integrated EHR for a given patient by making a single request to a central system. The Central Health Information System (CHIES) is the central system in the CHIEM, it acts as an intermediary when gathering data related to a patient. With this approach, none of the provider should be concerned heterogeneity of the EHR systems within the healthcare ecosystem.

In our proposed model, the problem is reduced to a single point communication between each EHR system and the CHIES. The model can be scalable by adapting new source system members in a transparent way. Shared information is standardized and stored in a central repository managed by the CHIES.

The central repository and the services provided by the CHIES are maintained in a cloud based infrastructure. This ensures availability and scalability of the system through features offered by cloud computing. In this sense, the model is reliable with a single robust centralized architecture, rather than depending on the availability of multiple systems and services maintained by different institutions.

There are various works that treat this problem already [1, 5, 8, 10]. Our model contemplates a larger scope when considering healthcare centers without EHR systems, and bases data exchange in a standardized minimum set of data (MSD) defined in the healthcare community.

The rest of this article is organized as following. In section II we give a background related the proposed model. In section III the CHIEM is described in detail. In section IV related works are discussed. Finally, conclusion and future works are presented in section V.

II. BACKGROUND

In this section we will expose a background literature regarding the definition of our proposed model.

A. Cloud computing implication

One of the dominant paradigm in nowadays internet service is cloud computing. In [2] cloud computing is defined as a large pool of virtualized resources (hardware, development platforms and/or services). The key feature in cloud computing is that resources, such as hardware and software, can dynamically adapt their configuration based on traffic load basis. Cloud computing is often classified in three type of services: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [2].

B. Information model: the two level approach

In OpenEHR standard, system implementation is unbound from the complexity of clinical information workflows and the semantic model within clinical domains. OpenEHR proposes a two level modeling approach. The first level is the information Reference Model (RM), and the second is the high level formal modeling of clinical content. Only the first level is implemented by software development [3], while the second

level is achieved through definition of archetypes and templates.

Archetypes constitute an expression of semantic domains, independent of the technology, and used to guide the database schemes, software logic and GUIs definitions. Grouping archetypes conforms templates, which define particular workflows within a given institution [3]. The Reference Model defines data types and data structures to support archetypes.

C. *Minimum Set of Data*

There is a set of data considered necessary and common for user's community across healthcare centers, thus standardization of this set is a priority [7]. This set is called Minimum Set of Data (MSD). The MSD is the core of health related data required by a determined group of common users, in our case, healthcare specialists. Each user group can extend or enhance the MSD according to their needs [7].

III. THE CENTRALIZED HEALTH INFORMATION EXCHANGE MODEL

The CHIEM architecture is composed by a central cloud service and multiple communication interfaces to exchange data with the involved EHR systems.

The CHIES is a central server in the cloud and has its own EHR repository (Fig. 1). CHIES architecture relies on an IaaS service. IaaS provides virtual computational resources and allows easy scalability by increasing resources as the system demand grows [2].

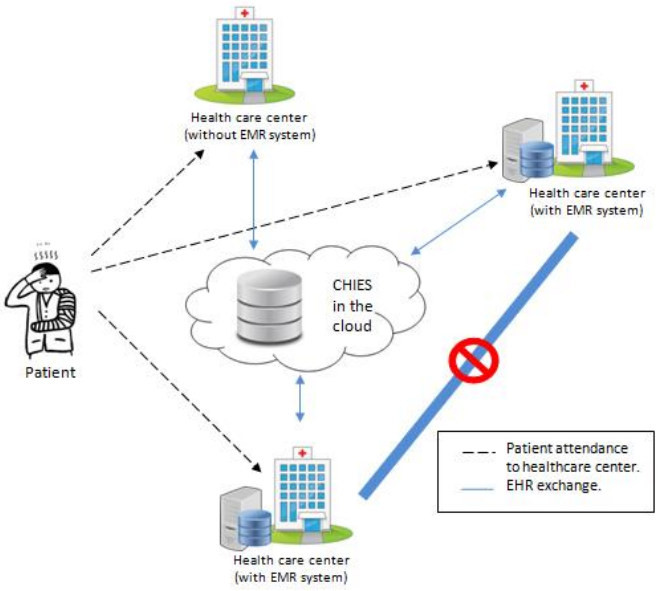

Fig. 1. CHIEM architecture based on star scheme.

Data stored in the central repository is standardized. New EHR entries must be mapped to the CHIEM information model to be persisted. Services provided by CHIES are offered through internet within a secure channel communication. Services include interfaces to query and add information.

Integration of a new member that may act as consumer/producer of information takes two steps:

- Defining the protocol to be used in the data exchange.
- Implementing CHIES interface to consume data.

In the first step, the data exchange protocol in each case should be defined. The CHIES needs to know and learn how to communicate with each EHR system. This will allow to consume data from the external EHR systems. Standardization of data to be stored in the central repository will be done in the CHIES. Moreover, when retrieving information from CHIES, EHR systems would be able to receive data in its local format.

The second step involves the implementation of the interface offered by CHIES to consume information. The services offered in CHIES to query data are generic, adapting the communication protocol according to the negotiation done with each EHR system in the first step.

Once these two requirements are met, external EHR systems would be able to start collaborating in the integration of the patients EHRs, and also consuming all EHR information stored in the central repository.

As seen in Fig. 1, the CHIEM architecture is structured in a star scheme basis. CHIES is in the core of the star, and each healthcare EHR system acts as a node connected to the core.

The main advantage in this approach is that interoperability agreement among healthcare centers is not necessary. To exchange and consume patient's data, just a communication channel to the central system is necessary, avoiding a peer-to-peer communication connection between each pair of healthcare centers.

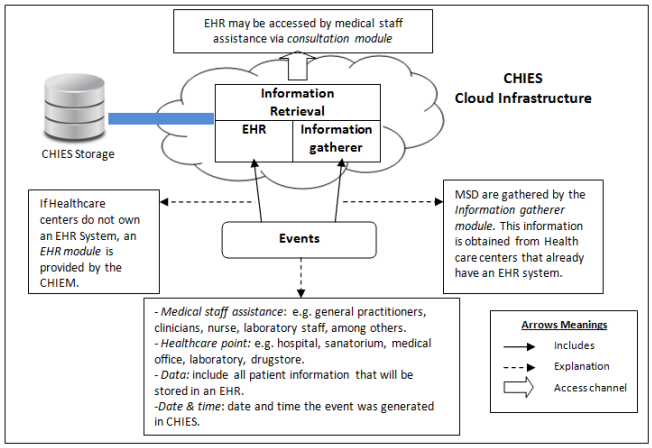

Fig. 2. CHIEM is based on event information basis..

The proposed system is based on events. In this work we consider an event as a broad way of defining information within the CHIEM that is generated when a document needs to be stored in the central repository.

W4 [6] defines an event in terms of a four-tuple questions (who, where, what, when). Based on W4 approach, an event is composed by four general characteristics: author, healthcare point, data, date & time.

An overview of the services offered in the proposed model is presented in Fig. 2. The three main services are: information gatherer, information retrieval and EHR. Each of them is described below.

A. The information gatherer

The objective in this module is to gather patient information that is distributed across healthcare EHR systems. The actual scenario is that each EHR system has its own data representation and communication protocol. The CHIES consumes data that is based on the Minimum Set of Data (MSD) from each external system. To simplify integration of external sets of data we propose an Exchange Information Stack (see Fig. 3). The Exchange Information Stack consist of five major layers. The first layer corresponds to source EHR systems. Source EHR systems are the external system running into different healthcare centers. These systems are generally a proprietary implementation with particular data representation and models [1].

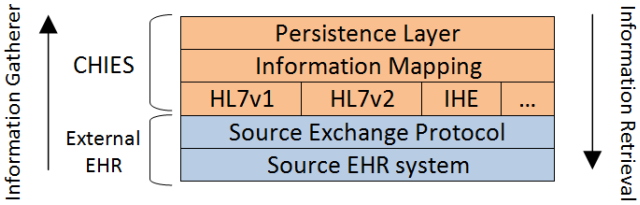

Fig. 3. Exchange information stack.

According to [11] EHR systems contemplate data exchange. Thus, it is assumed that a communication protocol is already implemented in these systems. There are many heterogeneous information models and exchange protocols that need to be integrated. The source exchange protocol layer corresponds to each external EHR implemented protocol. CHIES will be able to communicate with each protocol. A requirement to external EHR systems is that the set of data to be exchange should be aligned with the MSD established in the community. The first two layers counting bottom-up in the exchange information stack corresponds to external EHR systems. The next three upper layers are related to the CHIES model. The central system would be able to implement the necessary external protocols to communicate with each source EHR systems. This concept is illustrated in the third layer.

The main objective of the information gatherer module is to integrate the recollected data. This is achieved in the information mapping layer. In order to obtain a repository with a homogeneous information model, integration must include standardization of data. We assume that external EHR systems to be integrated in our data scheme are adapted to the community definition of the MSD. It constitutes the basic information to be exchanged among all healthcare EHR systems. Although MSD definition may change in time, CHIEM will dynamically adapt to this changes by employing the two level modeling approach [3].

We base our information model in the OpenEHR standard [5]. Archetypes are defined to capture a set of data that conform healthcare concepts. Groups of archetypes are used to define more complex concepts or workflows. As the MSD varies in time, changes can be easily reflected in our model by simply modifying definitions in the archetypes. Archetypes and workflows are used to capture the semantic meaning of the stored data. None of the logic or implemented software to store data should be affected by this changes. The lower level in the two level approach is called the Reference Model (RM) and constitute the support to map the concepts within archetypes to the storage in a generic way.

Data integration is composed of three process: conformance of the MSD within each healthcare EHR system, mapping of each concept within the MSD to the archetypes and, finally, storage of archetyped concepts through the reference model (RM). This last process is performed in the persistence layer.

B. Information retrieval

The information retrieval module purpose is to provide access to the full set of patients EHR gathered from external sources and stored in the CHIES. External EHR systems can obtain the integrated EHR of a patient by performing a single request to the CHIES information retrieval service.

The process for retrieving data from the CHIES is based in the exchange information stack (see Fig. 3) in up-to-bottom direction. First of all, data is extracted from the persistence layer in the CHIES according to the request from the external EHR system. Then, the information mapping layer matches the CHIES data format to the external format and performs data exchange according to the protocol used by the external system. Finally, the response is receive in the source EHR system.

Retrieval information services will be offered via REST, URIs and HTTPS.

We will base our REST approach in the querying mechanism proposed in [9]. OpenEHR Reference Model objects stored in the central repository are available as resources identified by URIs. URI templates can be used to specify URI structures with variable parts as in:

http://ehr.chies/ehr:{ehr_id}/{object id}@{version}

These paths extracted from archetypes are the basis for queries into the data. Responses are converted to the different external EHR systems representations.

C. EHR module. SaaS for healthcare centers

The EHR module aims to accomplish the delivery of an EHR system service for those healthcare centers that currently do not own one, or would like to migrate from its current system to CHIES service. The EHR module will be offered as a cloud computing Software a Service (SaaS) modality. The service run entirely in the cloud, and just a regular internet connection and a capable device with an internet browser would be needed to access it. New instances of the EHR module will be created for each new healthcare center client. Each healthcare center client will be able to define its own workflow by grouping available archetypes.

With the SaaS modality, healthcare centers will have an EHR system at disposal. Hence, installing a large IT

infrastructure to implant this system will not be necessary for them. This will allow big savings not just in IT equipment, but also in trained employee required for the datacenter management and maintaining. Another advantage of SaaS is the shorter time to deploy the system to production. Instead of acquiring, installing and configuring an own technological infrastructure, with the cloud approach just a few steps configuration will be required to deploy the system. The SaaS modality will facilitate the spread of EHR systems to healthcare centers that are isolated or have economic resources limitations [1, 5].

With the EHR module, data collected in these healthcare centers will already be in the standardized information model. Therefore, the mapping process is not needed. Data will be in the corresponding archetype format, ready to be stored in the central repository through the reference model.

The EHR web client will also implement the retrieval service interface. Thus clients are going to be able to query patients records stored in the central repository.

IV. Related works

In this section we will discuss some of the related works and proposals that pursue integrating health information of patients.

A system called Lifelong Personal Health Record (LLPHR) is described in [8]. In LLPHR, clinical records are gathered through logical links to records stored in each healthcare system. Integrated EHR is accomplished by gathering the EHR pieces from each external EHR system at request time. LLPHR relies directly on each healthcare system, which endanger availability. Besides, not every healthcare center will probably own an EHR system in order to share their data. CHIES tackles this issues by centralizing patient EHRs in a single robust scalable server and providing an EHR module for healthcare centers that lack an EHR system.

CHISTAR [1] is a proposed system to integrate EHR. This proposal also implements the two level approach and applies a cloud based architecture. This system uses a semantic matching to receive data from external systems [1]. Received data is not backed by any defined set of data within the community (a MSD). In CHISTAR there is not a consideration within its integration engine for potential healthcare centers that may also contribute to the patient clinical history but do not own an IT infrastructure to mount an own EHR system. CHIES offers this feature through SaaS EHR module web client for the mentioned entities.

Other related works are discussed next. In [10] the authors propose the use of archetypes to build a semantically rich Virtual Health Records (VHR) for Clinical Decision Support (CDSS). The work in [4] demonstrates the feasibility of Semantic Web technologies for enabling interoperability between different healthcare providers, aggregating data from multiple resources and providing a medical decision support service. In [5] the author shows how an OpenEHR architecture based EHR system can be introduced in practical terms and how this could lead to interoperability within an emergency department. Moreover, [2] discusses the concept of cloud computing, and evaluates the opportunities and challenges of this computing model in healthcare services improvement. Our proposal consists of a two level modeling approach with a cloud based architecture to integrate patients EHR from heterogeneous EHR systems. Moreover, our model also considers the integration of data from healthcare centers that currently do not have IT infrastructure to implement an EHR system. The exchange data is based on the MSD defined by the community.

V. Conclusion and future works

Interoperability of healthcare system has become a challenge to nowadays health informatics. To overcome this issue we proposed a centralized health information model. Combination of cloud computing paradigm, two level model approach by OpenEHR and community defined minimum set of data, allow the creation of a generic and scalable framework. Integration of EHR can be accomplished through a strong effort to facilitate the interoperability among external EHR systems with the centralized health information system. Our model adapts to existing external systems protocols, and proposes an EHR system module via SaaS to include patient's data from healthcare centers that do not own the necessary IT equipment to mount an EHR system. Future works include a module of Personal Health Record (PHR) to allow patients to access their health record, manage privacy politics and upload of information regarding their health (e.g. blood pressure measures, weight check, among others).

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