Electronic Health Record Application Support Service Enablers*

M.S. Neofytou, K. Neokleous, A. Aristodemou, I. Constantinou, Z. Antoniou, E.C. Schiza, C.S. Pattichis, *Senior Member, IEEE*, C.N. Schizas, *Senior Member, IEEE*

***Abstract*— There is a huge need for open source software solutions in the healthcare domain, given the flexibility, interoperability and resource savings characteristics they offer. In this context, this paper presents the development of three open source libraries - Specific Enablers (SEs) for eHealth applications that were developed under the European project titled "Future Internet Social and Technological Alignment Research" (FI-STAR) funded under the "Future Internet Public Private Partnership" (FI-PPP) program. The three SEs developed under the Electronic Health Record Application Support Service Enablers (EHR-EN) correspond to: a) an Electronic Health Record enabler (EHR SE), b) a patient summary enabler based on the EU project "European patient Summary Open Source services" (epSOS SE) supporting patient mobility and the offering of interoperable services, and c) a Picture Archiving and Communications System (PACS) enabler (PACS SE) based on the dcm4che open source system for the support of medical imaging functionality. The EHR SE follows the HL7 Clinical Document Architecture (CDA) V2.0 and supports the Integrating the Healthcare Enterprise (IHE) profiles (recently awarded in Connectathon 2015). These three FI-STAR platform enablers are designed to facilitate the deployment of innovative applications and value added services in the health care sector. They can be downloaded from the FI-STAR cataloque website. Work in progress focuses in the validation and evaluation scenarios for the proving and demonstration of the usability, applicability and adaptability of the proposed enablers.**

I. Introduction

Although the use of eHealth tools and services has risen significantly in the last decade, and the health care stakeholders have seen their benefits, a 2010 survey [1] of public, private and university hospitals in Europe showed that: (i) 81% have one or more electronic patient records systems in place, but only 4% grant patients online access to their health information; (ii) 71% use online eBooking systems for patients' appointments with medical staff but only 8% offer patients the opportunity to book their own hospital appointment online; (iii) 43% of hospitals surveyed exchange radiology reports electronically; (iv) only 30% use ePrescription for medicines; (v) 8% telemonitor patients at home; (vi) 5% have some form of electronic exchange of clinical care information with healthcare providers in other EU countries.

Furthermore, it is noted that there is a huge increase on demand for open source software in health care. More and more healthcare providers are asking for flexibility in their systems so that these are not static or unadaptable, thus avoiding expensive and fixed solutions. The open source software combined with the cloud infrastructure may facilitate the desired interoperability among the healthcare providers, thus increasing physician diagnosis and supporting patient mobility and support anywhere and anytime.

In order to address the need for open source software, linked with recent ICT technological trends, the FIWARE [3] project "Open APIs for Open Minds" was funded under the EU "Future Internet Public-Private Partnership – Internet Enabled Innovation in Europe" program (FI-PPP) [2]. This is an open initiative aiming to create a sustainable ecosystem to grasp the opportunities that will emerge with the new wave of digitalization caused by the integration of recent internet technologies. FIWARE is divided in several pillars where each one of them is focused on a specific scientific area. One of the main pillars is the "Future Internet Social and Technological Alignment Research" (FI-STAR) project dedicated to the development of a cloud based platform with open source libraries that can be exploited for eHealth applications [4].

Targeting towards the enrichment of the FI-STAR framework [4] for use in the health care domain, the EHR-EN software library that is the topic covered in this paper addresses the following two objectives. Firstly, to build (i) the Electronic Health Record specific enabler (EHR-EN), (ii) the patient summary specific enabler based on the "European Patients Smart Open Services" (epSOS) project [5]-[7] (epSOS-EN), and (iii) the Picture Archiving and Communications System (PACS) specific enabler based on the dcm4che open source software [8] (PACS-EN). The above three FI-STAR platform enablers will facilitate the deployment of innovative applications and value added services in the health care sector. The second objective is to validate and evaluate the EHR-EN, epSOS-EN, and PACS-EN FI-STAR specific enablers by developing proof of concept collaboration scenarios, which will finally prove and demonstrate the usability, applicability and adaptability of the proposed enablers in agreement with the EU "eHealth Action Plan 2012-2020 Innovative healthcare for the 21st century" [9].

Following the eHealth action plan initiatives, many eHealth applications were introduced to the market, however there is still the need for more innovative and patient centric applications that will rely on new technological achievements and state of the art architectures. To facilitate the development of this concept, the EU has promoted accelerator programs for SMEs and start-ups organizations to develop innovative applications and businesses in the

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M.S. Neofytou, K. Neokleous, A. Aristodemou, I. Constantinou, Z. Antoniou, E.C. Schiza, C.N. Schizas and C.S. Pattichis are with the eHealth Laboratory, Department of Computer Science, University of Cyprus, Nicosia, 1678, Cyprus (e-mail: mneoph@ucy.ac.cy)

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eHealth market, especially by using the FIWARE technology, i.e. FIWARE generic enablers, specific enablers and/or domain specific platforms [10].

In line with the above, the architecture and the communication protocols for the three SEs that have been developed are presented here, as these can be exploited for the development of eHealth applications.

The EHR SE supports an electronic patient record service application (see section II). It is implemented as a BACK END API in such a way that it can be configured to be linked with the epSOS SE and the PACS SE. The related supported protocols, standards and technologies used in the implementation are in agreement with the epSOS large scale pilot [5]. Moreover, the EHR SE covers also basic interoperability profiles supporting the connectivity and the exchange of data between different health agencies or different departments of the same health agency.

The patient summary epSOS SE (see sestion III) is based on the epSOS project [5]. It supports pilot solutions that offer cross-border eHealth services to European citizens. It focuses on developing a practical eHealth framework and ICT infrastructure that enables access to patient health information from different European healthcare systems. It aims at improving the quality of healthcare for citizens when travelling to another European country.

The PACS SE (see sestion IV) is based on the open source software the dcm4che [8]. It supports the picture archiving and communication between the EHR SE and the epSOS SE.

II. Electronic Health Record – EHR SE

The EHR SE is designed to capture the data that accurately represents the state of the patient at all times [11]. The EHR SE is implemented as a BACK END API and can support the basic functionalities of an electronic patient record system as well as it can be linked with the epSOS SE for exporting both the basic and the extended versions of the patient summary. Moreover, the EHR SE can be linked with the PACS SE, for a more robust and optimum exchange of medical imaging data between systems and healthcare providers. The related protocols, standards and technologies used for the EHR SE implementation are in agreement with the epSOS large scale pilot. More precisely, the EHR documents to be exchanged will be defined by adopting HL7 Clinical Document Architecture (CDA) V2.0 [12] with reference to Integrating the Healthcare Enterprise (IHE) [13] PCC (Patient Care Coordination) by adopting IHE X* profiles [13]-[18].

The EHR SE database schema covers the following tables: patient data, patient medical devices, medical devices, patient medical implants, medical implants, pharmacy, scheduling, coding, vital signs, surgical procedures, insurance data, admission type, admission data, diagnosis, medication, vaccinations, pregnancy history, lab analysis, allergies, social history, and functional status [19].

The architecture of EHR SE is shown in Fig. 1. The core component of EHR SE is the EHR repository. The EHR repository stores the EHR data and provides APIs for the retrieval, insertion and update of such data. The EHR SE is also connected with three more specific enablers of the FI-STAR platform: the timing service SE, which is used for updating the server time, the storage generic enabler (GE) for backup support and the security and privacy SE for user authentication. More details and the link for downloading EHR SE can be found at the FI-STAR project catalogue [20].

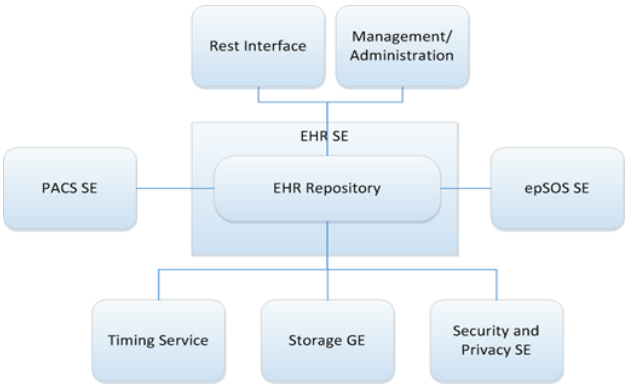

Figure 1. EHR-SE architecture

III. Patient Summary – epSOS SE

The purpose of the patient summary is to make critical patient data readily available anywhere that the patient seeks treatment (away from his/her home town or healthcare provider). It is a prerequisite concept for cross-border healthcare as it is defined and instructed by the EU directive: Directive 2011/24/EU [6].

The basic concept of the epSOS system is the mobility of the patient. The patient can travel and visit different health providers and basically the patient summary follow the patient supporting the interoperability of the systems and the health procedures. Thus helping the physician in offering to the patient better services based on more informed decision making. The patient summary epSOS SE architecture is shown in Fig. 2. It is based on the following components. (i) Management/Administration component: This component is responsible for the configuration and monitoring of the epSOS SE. (ii) Rest Interface: Responsible to establish communication with third parties. (iii) Storage component: Responsible to communicate with the Storage GE for storing and retrieving the collected data. (iv) OpenNCP client connector component: Responsible to communicate with the openNCP client connector. (v) Timing Service component: Responsible to communicate with the Timing Service SE for having a common time stamp. (vi) The security component is responsible for authorization and authentication of the requested access to the epSOS SE. (vii) Event Management: Responsible to communicate with the Event Management SE. The epSOS SE BACK-END API covers the connection to the OpenNCP [7] (National Contact Point portal) server. The NCP is the middleware for connecting countries or individual medical centers supporting the exchange of patient summary data. More specifically, the epSOS SE includes a repository in which data are stored and retrieved using specific APIs. Furthermore, the epSOS SE offers the functionality to develop the client site and the client

connector to a local NCP portal as it is defined by the epSOS large scale project [5] and following the recommendations and guidelines offered by the OpenNCP platform [7] (see also Fig. 4). The connector provides methods that use the aforementioned APIs for retrieving the documents requested by the OpenNCP platform. More details and the link for downloading epSOS SE can be found at the FI-STAR project catalogue [20].

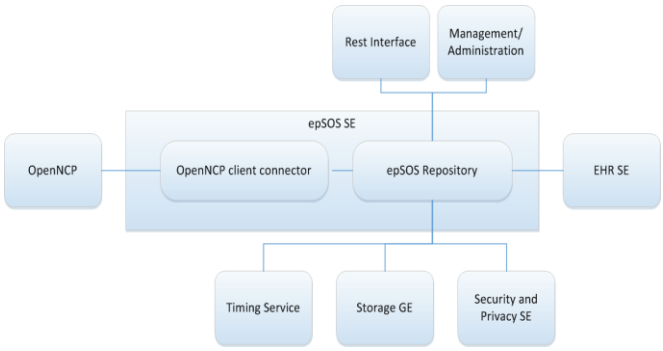

Figure 2. epSOS SE architecture

IV. Imaging Platform: Picture Archiving and Communication System – PACS SE

The PACS SE is developed and implemented based on the very well-known open source PACS software package dcm4che [8]. The dcm4che supports the exchange of images based on the Digital Imaging and Communications in Medicine (DICOM) standard 2011 and it implements also the related IHE profiles [13]-[18] (following successful certifications from IHE Connectathons). The dcm4che is installed in several sites worldwide and basically it acts as a DICOM server providing the following functionalities: (i) archive content administration including the functionalities of store/query/retrieve; (ii) application entity management; (iii) worklist management and administration; (iv) modality performed procedure step; (v) management and administration; (vi) audit repository based on IHE Audit Trail and Node Authentication (ATNA) audit logging.

Moreover, the IHE standards [13] that are implemented in the PACS SE are the following: (i) Patient Administration Management (PAM) (ID); (ii) Audit Trail and Node Authentication; (iii) XDS as document repository [17]; (iv) IHE XDS-I as an image document repository [17]. The imaging documents that are covered include the following: (i) imaging studies (images, measurements, results from analysis packages, presentation states); (ii) diagnostic reports for imaging studies; (iii) key image selections associated with the report content for their diagnostic significance.

The most important IHE profile is the ATNA. This profile establishes security measures, which together with the security policy and procedures provide patient information confidentiality, data integrity and user accountability. This standard covers the security domain and can scale from a department, up to an enterprise or affinity domain [18].

The PACS SE architecture is developed on the cloud-based FI-STAR platform with the use of associated specific enablers as can be seen in Fig. 3. It is supported by the timing service SE, the security and privacy SE, the storage GE and can be connected by the EHR SE and the epSOS SE. More details and the link for downloading PACS SE can be found at the FI-STAR project catalogue [20].

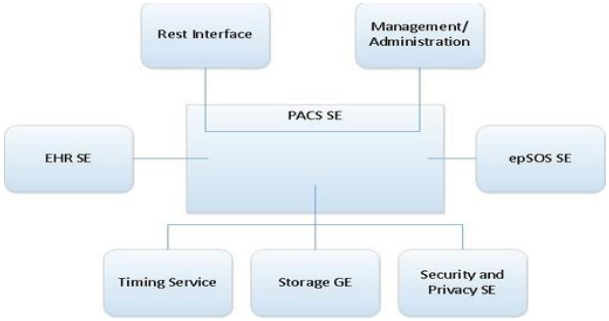

Figure 3. PACS SE architecture

V. Integrated Interoperable eHealth Services

Figure 4 presents a pilot FI-STAR based eHealth application using the EHR SE, the epSOS SE and the PACS SE. The FI-STAR eHealth application is exchanging patient info with: (i) other legacy systems via the national infrastructure hub, and/or (ii) patient summaries via the national infrastructure hub and its connection to the OpenNCP server (see section III) [21]. The IHE profiles supported by the EHR-EN specific enablers EHR SE, epSOS SE and PACS SE are also listed in Fig. 4. The support of these profiles passed the certification procedure at the IHE European Connectathon [22]. Specifically, the EHR-SE implemented the PDQv3 and XDS.b IHE profiles. The PDQv3 supports a consumer profile and lets applications query a central patient information server and retrieve a patient's demographic and visit information. The XDS.b Profile (Cross-Enterprise Document Sharing) is focused on providing a standards-based specification for managing the sharing of documents between any healthcare enterprise. For this profile, two actors were implemented. The first is the consumer, which finds documents associated with a patient from a registry and then retrieves them from the repository. The second actor is the source, which is responsible for submitting a document for a patient in the repository. The implemented profiles were tested with registries and repositories implemented by other companies participating in the five day connectivity and interoperability marathon. In total, 10 different companies took part in the performed tests with the EHR-SE and 20 tests were performed which were all successful. Concluding Remarks

Motivated by the need for open source software solutions in the healthcare domain, given the flexibility, interoperability and resource savings characteristics they offer. In the last 20 years a significant effort was placed towards the development of EHR systems based on open source code with various rates of success. The most popular open source EHR software systems are briefly outlined below:

- OpenMRS is a community-developed, open-source, enterprise EMR framework. Extensible and scalable EMR based on Java [22].
- OpenEMR is an open source electronic health records and medical practice management application that can run on numerous platforms. OpenEMR features include patient

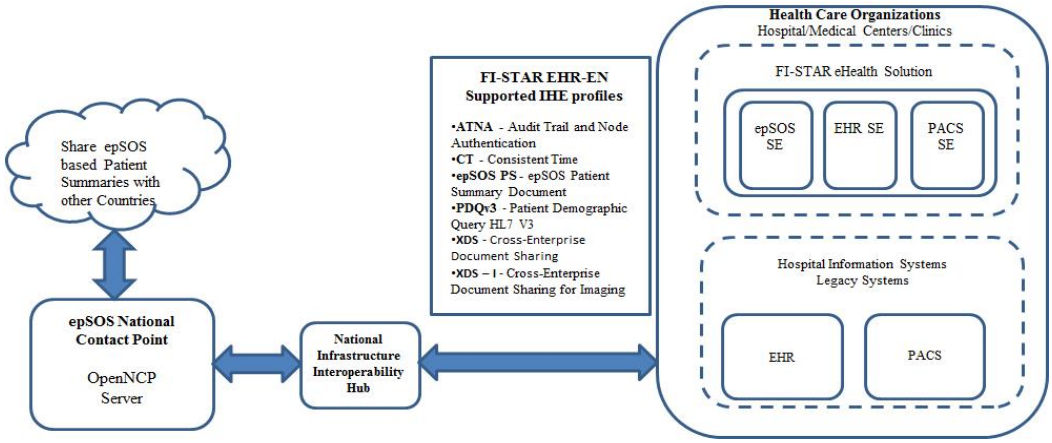

Figure 4. Integrated interoperable eHealth services based on the IHE profiles. A FI-STAR eHealth solution is demonstrated showing its connection with Hospital Information Systems (HIS) legacy systems, and the exchange of patient summaries using the OpenNCP server.

demographics, patient scheduling, electronic medical records, prescriptions, medical billing, clinical decision rules, patient portal, reposts, and other [24].

• FreeMED is a practice management and electronic and computer records system. It allows the tracking of medical data, in detail, with preservation not just of the diagnosis but the reasons for medical encounters [25].

• GaiaEHR is a modern open source electronic health record developed using PHP and Ext JS [26].

• GNU Health is a free, centralized, highly scalable health and hospital information system [27].

This paper presents three open source software libraries, namely the EHR SE, epSOS SE and PACS SE. These were developed in the context of the FI-STAR platform and were designed to facilitate the deployment of innovative applications and value added services in the health care sector. The three enablers can be downloaded from the FI-STAR cataloque [20]. The proposed three enablers are currently under evaluation and lessons learnt and step by step cookbook recipes will be generated for providing the guidelines for the more efficient and effective use of the enablers both by the medical experts and the patients. Targeted exploitation for the use of the proposed EHR SE, epSOS SE and PACS SE as well as the FI-STAR platform is anticipated, especially in EU countries that have fallen behind in the adoption of eHealth tools and services as prescribed by the eHealth action plan 2012-2020 [9].

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