A Mobile App Architecture for Accessing EMRs Using XDS and FHIR

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***Abstract*—Enabling data exchange between electronic medical records (EMRs) and personal health apps has the potential to boost the secondary usage of health data, eventually increasing the quality of life. In this paper, the authors present a mobile app architecture that enables the integration of legacy cross-enterprise document sharing (XDS) and next generation fast healthcare interoperability resources (FHIR) compatible electronic medical record (EMR) systems with personal mobile applications. The realization of this architecture is achieved by linking EMR information from multiple providers at the point of care, with a personal health app for citizens, combining the benefits and potential of both XDS and FHIR.**

***Keywords*—FHIR, Interoperability, Personal Health Apps, Hospital Information Systems, Electronic Medical Record, Electronic Health Record, XDS**

I. Introduction

The application and advancement of electronic health systems focus towards allowing citizens to stay healthy, effectively manage chronic conditions, reduce comorbidities and improve the quality of their lives. As more and more health data are being collected and processed in healthcare information systems and personal health apps, the need for health data integration becomes imperative. The vision is to achieve better health services for all citizens and better patient outcomes. To this direction, several data models and interoperability profiles have been developed in order to provide standardized interfaces for the exchange of EMR data.

The need for an interoperable and adaptable personal health record (PHR) [1] can only be accomplished with the creation and implementation of modules that support the integration of data from different sources. These sources include home care services, wellness, applications (e.g. physical activity, water intake, sleep patterns and others), electronic health record (EHR), national electronic health (eHealth) services, and other connections to third party apps. To this day, some degree of standardized transmission has been achieved amongst eHealth systems and apps, but true semantic interoperability exists only in limited settings and EHR components [2]. The lack of interoperability leads to fragmentation and a lower quality of healthcare provision. In Europe, the European Commission has already identified specific Integrating the Healthcare Enterprise (IHE) profiles [3], providing detailed technical specifications with the potential to increase interoperability of eHealth services.

XDS is an IHE interoperability profile that facilitates the registration, distribution and access across health enterprises of patient EHRs [4]. It focuses on providing a standards-based specification for managing the sharing of documents between any healthcare enterprise, ranging from a private physician office to a clinic to an acute care inpatient facility and personal health record systems (PHRs). Systems involved in the XDS profile are enterprise-wide information systems such as Hospital Information Systems (HIS) that manage EMRs.

The secondary usage of collected data has the potential to boost significantly research collaborations and healthcare delivery, eventually improving the quality of life. The European Union (EU) is already moving towards the development of open standards specifications for a European EHR exchange format [5] in order to secure citizen access to and sharing of health data, taking into consideration the potential use of data for research and other purposes. The refinement of the exchange format is expected to consider the possibility offered by resource driven information models such as Health Level Seven (HL7) FHIR.

FHIR [6] is one of the latest, cutting-edge interoperability standards for electronic exchange of healthcare information. It combines the best features of HL7 v2, HL7 v3 and clinical document architecture (CDA) product lines, leveraging the latest web standards and focusing on implementability. However, although prominent, FHIR has not yet transitioned to the implementations available worldwide and to legacy, standardized interfaces that dominate existing implementations. As such, the need for integrating EMRs originating from primary care or any HIS, with personal health applications using XDS is evident.

To this direction, this paper presents an infrastructure developed exactly for enabling the integration of both legacy, XDS and FHIR compatible EMR systems with personal health applications enabling citizens to have a holistic view over their health data. More specifically, it presents a whole infrastructure consisting of the following components:

- PHR-C: A personal health app [7], enabling citizens to manage their own health record in an innovative way;
- ICS-M: A set of nursing and medical applications that are part of a HIS. ICS-M is already operating in more than twenty health units in Greece [8], supporting a multitude of medical specialties, such as those for pathology, cardiology, pediatrics, orthopedics, etc.; and
- Integration Server: The integration server responds to XDS and FHIR compatible service calls and is able to communicate with either FHIR compatible or legacy

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EMR systems, enabling data exchange and interoperability among systems.

Although there are already available FHIR approaches, and attempts to bridge the gap between CDA and FHIR [9], to the best of the authors' knowledge the developed infrastructure is currently the only one being able to enable interoperability between XDS compatible legacy EMRs and FHIR, effectively enabling access to the medical health record for the individuals.

The rest of this paper is structured as follows: Section II presents related work, and then Section III presents in detail the high-level architecture of the developed infrastructure and the various components included. Then Section IV elaborates on security considerations and finally Section V concludes this paper and presents directions for future work.

II. Related Work

The need for open and interoperable personal health apps [10][11] and EMRs has been evident during the last years.

Several reasons have been identified [12], so that:

- clinicians can provide safe and effective healthcare;
- researchers can advance our understanding of disease and healthcare processes;
- administrators can reduce dependence on single-source EMR providers;
- software developers can develop innovative solutions to address limitations of current EMR user interfaces and new applications to improve the practice of medicine; and
- patients can access their personal health information no matter where they receive their healthcare.

However, most recent EMR and PHR systems are institution-specific (limited to a certain organization) and the issues of interoperability and data protection have not been examined in detail [13].

Traditionally, XDS based solutions are used for enabling data exchange between EMRs [14][15]. For example, in [13] a service oriented approach (SOA) is presented for enabling the interoperability and security of PHR systems using web service based protocols and interfaces. These services allow data access from different systems that adopt IHE XDS profiles. Another approach to the same direction is the one proposed by the Smart Medical Information Technology for Healthcare (SMITH) consortium [15], for enabling data integration based on interoperability standards, adopting IHE modules. However, all these approaches traditionally investigate interoperability among EMRs and usually do not permit data access to the individuals.

Besides XDS solutions, several FHIR-approaches have been proposed to facilitate patient record access to individuals. In 2018, Apple introduced an update to its Health app including a feature for users to access their medical records through their devices [16]. The connection between the hospital information systems and the user application is handled using FHIR, whereas users can access their available medical data from multiple providers whenever they choose. Johns Hopkins Medicine, Cedars-Sinai, Penn Medicine and other participating hospitals and clinics are among the first to make this beta feature available to their patients.

Another recent attempt to use FHIR on EMR data has been described in [17]. As described in the case study, structured and unstructured medication data from Mayo Clinic's EHR were modelled into the *MedicationStatement* FHIR resources. For this data transformation, natural language processing (NLP) tools were used in order to recognize clinical elements. In that approach, the FHIR data modeling tasks were separated into two workflows: (i) modeling unstructured EMR data in FHIR using different clinical NLP tools, and (ii) combining information from structured data with the NLP output to build a complete FHIR resource. Another interesting approach is mHealth [18], a mobile health app that allows exchanging directly clinical and medical data with health care services through FHIR. The two sides exchange data through standard FHIR Resources such as *Patient*, *Observation*, and *CarePlan*.

Finally, the authors of [19] propose the development of an integrated patient generated data collection platform and an application, embedded in the EMR, using the FHIR and SMART technologies. The purpose of this implementation is to improve the data collection of heart failure patients (data collected from patients) and the distribution of these data to therapists. The application includes a provider interface, for direct interaction with EMR, a patient interface for entering data, a care partner interface for entering patient's data and finally a nurse/ care coordinator interface. The latter is a dashboard of the panel of the patients for whom they are responsible. The screen gives an overview of the status of all patients, along with any triggered alerts and questions submitted via the messaging feature.

Although the aforementioned FHIR approaches pave the way for enabling access to patient records through user devices, still most of the medical information in hospitals is only accessible through IHE compliant, legacy interfaces. As such, a solution being able to bridge FHIR and IHE interfaces is a key requirement for enabling the effective secondary usage of personal health data. The proposed approach tries to fill that gap by implementing an integration server, responding to both XDS and FHIR compatible service calls, enabling direct exchange of information among EMR systems and personal health apps.

III. ARCHITECTURAL SOLUTION

In the presented solution, communication and data exchange between the different components of the architecture are achieved by using RESTful services. In addition, the different types of clinical data, available by the hospitals, are transformed into the resources provided by the specification, including those clinical data that are of interest to users of personal health apps. In this work, the focus is on patient clinical documents stored in EMRs located in hospitals (i.e. laboratory results, discharge summaries, etc.). The goal of the proposed architecture is to provide to citizens the possibility to access their updated medical data online through the personal health app PHR-C. Since citizen medical data can be found in many hospitals there should be a repository where all these data will be collected and become available for the PHR-C. Also, since HIS and personal health apps can be from different vendors, the infrastructure components and the transactions should adhere to IHE specifications as they are supported by the majority of the hospital systems available in the market.

The actors involved in the procedure of exchanging clinical data between HIS and PHR-C are health professionals that update patient medical data in the HIS and the citizen as the user of PHR. Fig. 1 presents the high-level architecture of the designed solution showing the interactions between the PHR-C, the Integration Server, and two hospital information systems.

A. PHR-C

1) Presentation of the system

PHR-C [7] is a state of the art personal health app enabling individuals to store and manage their health data. PHR-C includes many apps focusing on problems/ diagnoses, treatments, procedures, laboratory results, allergies, immunizations, demographics, vital signs and measurements. Those data elements are able to capture individual health information, similar to the structure available in any HIS. In addition, there are apps for enhancing the communication between patients and doctors (appointments, reminders, offline messaging), whereas additional tools for monitoring the quality of life and the psycho-emotional status of the individual are also available. Some screenshots of the aforementioned system are shown in Fig. 2. In addition, the PHR-C enables access to the clinical data the hospitals have shared with a FHIR Server. As such, a user can retrieve his/ her data stored into the FHIR Server by submitting a read/ search request using the corresponding FHIR REST API calls. A FHIR parser module gets the response in FHIR format, parses it and stores into the local PHR database for future access.

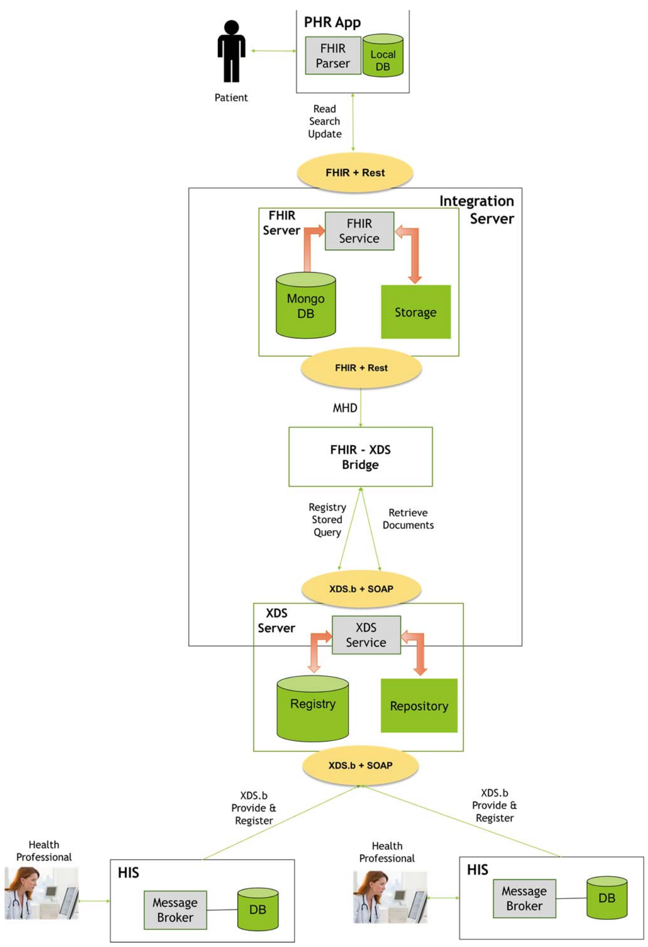

Figure 1. High-level architecture of the proposed solution.

2) Extending PHR-C with FHIR/ SMART

FHIR is an open standard, published by HL7 in 2014, with the goal of defining an agreed-upon specification of data format and a RESTful API that will allow service providers to develop applications and systems that operate in the modern healthcare ecosystem. FHIR defines a set of "Resources" that represent granular clinical concepts. The resources can be managed in isolation, or aggregated into complex documents.

In this work, the FHIR specification is integrated to allow for the interoperable operation and communication of PHR-C with other healthcare systems built upon FHIR. Initially, remapping was performed to the underlying modules and healthcare data that PHR-C handles to FHIR resources. For example, the allergies module of PHR-C, which handles the health information of patients' allergy intolerances, is associated to the *AllergyIntolerance* resource defined in FHIR. This allows a patient using PHR-C to view allergy reports aggregated from external healthcare systems implementing the FHIR specification, thus offering a global view of his/her health operation over possibly multiple health apps. Another example is the procedure module whose data have been mapped to the Procedure FHIR resource.

SMART on FHIR [20] on the other hand, aims to provide healthcare providers with a specification that allows for the development of reusable applications that run on the

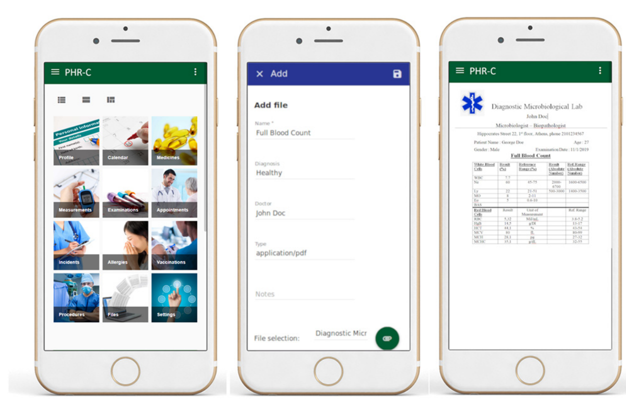

Figure 2. PHR-C health app screen shots.

healthcare ecosystem that use the well-defined and known web-based technologies present in the FHIR specification. The SMART on FHIR platform was integrated with PHR-C. This integration allows the utilization of the extensive library of applications released in the App Gallery of the SMART platform and as such it further increases usability of the presented platform. This is due to the fact that through SMART enabled apps, patients are given multiple new ways, already developed by the community, to view, access and transfer their health data. Besides patients, clinicians are also able to access, edit and monitor patient data.

B. ICS-M

This system provides the patient clinical data shared with the patient through PHR-C. When there is an update on the patient clinical data that are relevant to the patient, the HIS registers the clinical document to the XDS Server. Each software module can operate in one or more hospital departments in collaboration with one or more other software modules and be fully operational. All applications can exchange information, so that all records are stored uniformly and reviewed by all users with permission rights. ICS-M is part of the Integrated Care Solutions (ICS) software suite developed by FORTH. ICS can potentially incorporate a solution for every patient-centric healthcare system, in order to proactively manage clinical and administrative processes and activities. It is a secure platform. Its components can work individually or in cooperation with other ICS or third party software.

C. Integration Server

Integration server is the interoperability infrastructure that enables the sharing of clinical data between healthcare applications, such as HIS and personal health record systems, that may use different representation for their clinical documents in CDA or FHIR format or they are compatible with different standards and profiles (i.e. XDS profile, FHIR standard). Integration server handles the communication between the clinical systems, the storage of the clinical data and all the transformations needed between the different profiles and standards used for the clinical documents structure and the clinical systems interoperability.

1) XDS-Server

XDS [21] focuses on providing standards based specification for managing the sharing of documents between any healthcare enterprise, ranging from a private physician office to a clinic to an acute care inpatient facility and personal health record systems. This is managed through federated document repositories and a document registry to create a longitudinal record of information about a patient within a given clinical affinity domain. As depicted in Fig. 3, these are distinct entities with separate responsibilities:

- A Document Repository is responsible for storing documents in a transparent, secure, reliable and persistent manner and responding to document retrieval requests.

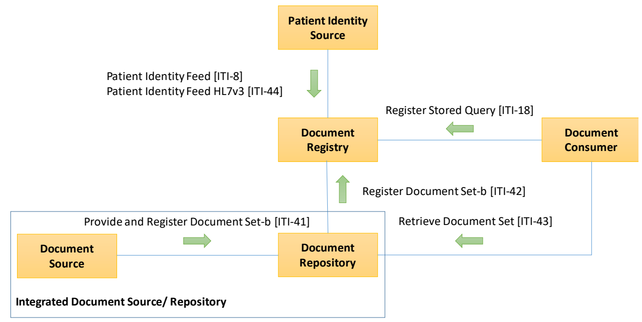

Figure 3. XDS actors and transactions.

- A Document Registry is responsible for storing information about those documents so that the documents of interest for the care of a patient may be easily found, selected and retrieved irrespective of the repository where they are actually stored.
- Document Sources that provide Document Sets.
- Document Consumers that access Documents.

In the proposed architecture, any HIS can act as the document source that registers and stores clinical documents in the XDS Registry/ Repository. The FHIR Server has the role of document consumer that requests documents from XDS Repository (upon request that comes from the PHR-C), makes the required mappings in order to transform clinical documents retrieved from XDS into FHIR documents and sends them to the PHR-C.

2) FHIR-Server

This component is responsible for storing all medical data and patient documents that will be consumed by the PHR-C. Any HIS can be the provider of these clinical data. The FHIR server provides a RESTful API that define a set of common interactions (read, update, search, etc.) performed on a repository of typed resources. More specifically, the FHIR server supports searching and reading operations on the following resources:

- Patient resource in order to provide demographics to the client;
- Document Reference resource to provide access to general patient documents in the form of PDF etc.;
- Clinical resources that represent lab results, discharge summaries and clinical guidelines.

The FHIR server also provides update functionalities to allow the patient to upload of documents, medication statements, and observations (e.g. from patient monitoring devices). As such, the FHIR Server provides:

- a complete RESTful server implementation for integration with external systems (i.e. PHR and HIS) on the operations mentioned above, which is compliant with the FHIR RESTful API specifications;

- a FHIR service that implements these service operations (read, search, update) as described in the specifications for a selected set of resources that are relevant to PHR-C;
- a database where resources, indexes and logging information are stored; and
- an XDS consumer module (FHIR to XDS bridge) that will be described in the next subsection.

3) *FHIR to XDS Bridge*

At their core, FHIR and XDS use different paradigms and methodologies in their specifications. While FHIR uses widely implemented and used RESTful APIs and methodologies to allow rapid implementation of under-constrained web services that run in resource-limited devices, the XDS profile is based on the SOAP messaging protocol to provide a more formally defined and secure framework for reliable and atomic transactions over the Internet.

To that end, due to the wide adoption of both specifications in the healthcare industry, it was considered appropriate that an implementation of a FHIR-to-XDS message translating system would greatly increase the usability of the PHR-C platform by allowing the retrieval of patient documents stored in an XDS repository. The implemented FHIR-to-XDS bridge retrieves documents related to the patient request, maps the retrieved documents into FHIR resources and stores retrieved clinical data into FHIR Server in order to become available for the PHR requests to the FHIR Server.

More specifically, the FHIR-to-XDS bridge that manages the FHIR-to-XDS message translation is implemented in a way compatible with any FHIR server. IHE Mobile access to Health Documents (MHD) profile [22] that defines one standardized interface to health documents for usage by mobile devices in order to access an XDS Repository, is used to implement the FHIR-to-XDS bridge. The translator system acts as an XDS Document Consumer and is responsible for mapping the attributes of FHIR request (e.g. the patient's ID to XDS-based SOAP elements) and then to send a transaction message to the XDS Document Registry to query for the requested patient documents. As soon as it receives the response from the registry, containing the location of all documents for the specified patient, it queries the repositories listed in the bundle to retrieve the corresponding documents. Finally, after receiving the documents, the translator service converts the retrieved documents to a *DocumentManifest* FHIR resource and sends it back to the FHIR server that requested it.

IV. Security Considerations

Strong and reliable identification and authentication of all users is key to guaranteeing trust in exchanges of data between EMR, HIS and PHR systems. In order to protect effectively sensitive data for all individuals, managing information security and privacy when linking EMRs with personal health apps should be compliant with the provisions of applicable national and international legislation as well as the standards of good practice. Appropriate mechanisms should be put in place regarding personal data security and security breaches, in conformity with the GDPR and the Network and Information Systems (NIS) Directive. Tailored to the security by design approach, appropriate security measures should be embedded in EMR systems, meaning that both at the time of determination of the means for processing and during the processing itself, appropriate technical and organizational measures are implemented to ensure the protection of sensitive information.

As described in [23] the three fundamental security goals, concerning the security and privacy of EMR systems, are confidentiality, integrity and availability. According to the ISO EN 13606 standard:

- Confidentiality refers to the process that ensures that information is accessible only to those authorized to have access to it.
- Integrity refers to the duty to ensure that information is accurate and is not modified in an unauthorized fashion. The integrity of health information must therefore be protected to ensure patient safety. One important component of this protection is ensuring that the entire information life cycle is fully auditable.
- Availability refers to the property of being accessible and useable upon demand by an authorized entity. The availability of health information is also critical to effective healthcare delivery. Health information systems must remain operational in the face of natural disasters, system failures and denial-of-service attacks.

EMR systems should include specific provisions for seeking explicit consent from citizens. In case of modification of the scope of use, citizen explicit consent should be requested for ethical reasons and for covering the unlikely scenario where personal data is inadvertently processed.

Security also involves accountability, which refers to people's right to criticize or ask why something has occurred. The preferred access control model in EMR systems is role based access control (RBAC). The most common authentication mechanisms are digital signature schemes based on public key infrastructure (PKI) and logins/ passwords. Auditing is particularly useful to identify suspicious access as well as common access practice.

Based on the aforementioned directions, FHIR does define exchange protocols and content models [24] that need to be used with various security protocols defined elsewhere. More specifically:

- In order to secure the communication, transport layer security (TLS) must be used for data exchange.
- It is recommended to use OpenID Connect [25] (or other appropriate authentication protocol) to verify the end user identity
- OAuth standard is recommended for user authentication and authorization. The SMART on FHIR profile on OAuth is a recommended method for using OAuth.

- FHIR defines audit event resources as suitable for tracking the origins, authorship, history, status, and access of resources.
- FHIR includes several specifically reserved locations for digital signatures. FHIR specification provides resources and datatypes to support signing of resources and documents.

The implementation described by the authors already adopts these guidelines, using TLS, OpenID and OAuth, recording also the necessary auditing information. Digital signatures and electronic consent (eConsent) will also be incorporated in the future.

V. CONCLUSIONS

Aging is one of the greatest challenges our society is facing. If demographic change is not resolutely addressed, it will cause serious concerns about the economic viability of healthcare and healthcare systems. A shift towards new models of care that will facilitate health and active ageing as well as prevention and management of chronic diseases is expected to increase patient empowerment and citizen involvement in health care decision making. Interoperability at all levels of health care delivery and healthcare information systems, is central for reliable and efficient collaboration towards digital transforming towards new models of care. Mobile technologies create a great opportunity for effective empowerment of patients.

This work described an infrastructure facilitating interoperability by enabling citizens to use a personal health app of their choosing for accessing their own medical record information (EMR data) stored at different sites. Although this work focuses on the technical and technological aspects, it is evident that further work is needed to address practical implementation issues, as well as regulatory ones.

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REFERENCES

[1] D.G. Katehakis, H. Kondylakis, L. Koumakis, A. Kouroubali, K. Marias, “Integrated Care Solutions for the Citizen: Personal Health Record Functional Models to support Interoperability”, EJBI, 13(1):51-58.

[2] A. Kouroubali, L. Koumakis, H. Kondylakis, D.G. Katehakis, “An Integrated Approach Towards Developing Quality Mobile Health Apps for Cancer”. In “Mobile Health Applications for Quality Healthcare Delivery”, IGI Global, Hershey PA, USA, January 2019, pp. 46-71.

[3] European Commission, “Commission Recommendation of 6.2.2019 on a European Electronic Health Record exchange format (Text with EEA relevance), C(2019) 800 final”.

[4] P. Mangesiusa, S. Saboorb, T. Healyc, T. Schabetsbergera, “Dynamic Creation of Patient Summaries: A CDA and IHE XDS Based Approach for Regional EHRs”. MEDINFO, pp. 170, 2017.

[5] European Commissin, “Commission Decision (EU) 2015/1302 of 28 July 2015 on the identification of ‘Integrating the Healthcare Enterprise’ profiles for referencing in public procurement (Text with EEA relevance)”.

[6] R.K. Saripalle, “Fast Health Interoperability Resources (FHIR): Current Status in the Healthcare System”, International Journal of E-Health and Medical Communications (IJEHMC), 10(1), pp. 76-93, 2019.

[7] D.G. Katehakis, et al., “Personal Health ICT Systems to Support Integrated Care Solutions.”, Technical Report. ICS-FORTH/472, 2018.

[8] D.G. Katehakis, S. Halkiotis, A. Kouroubali, “Materialization of Regional Health Information Networks in Greece: Electronic Health Record Barriers & Enablers”. JHE Journal, 2(3), pp. 389-403, 2011.

[9] C. Rinner, G. Duftschmid, “Bridging the Gap between HL7 CDA and HL7 FHIR: A JSON Based Mapping”. Studies in health technology and informatics, 223, pp. 100-106, 2016.

[10] H. Kondylakis, et al. "Patient Empowerment through Personal Medical Recommendations." MedInfo 216 (2015): 1117.

[11] H. Kondylakis, et al. "iManageCancer: Developing a platform for Empowering patients and strengthening self-management in cancer diseases." IEEE CBMS. 2017.

[12] D.F. Sittig, A. Wright, “What makes an EHR “open” or interoperable?” Journal of the American Medical Informatics Association, 22(5), pp. 1099-1101, 2015.

[13] L. Jingquan, “A Service-Oriented Approach to Interoperable and Secure Personal Health Record Systems”, IEEE SOSE, DOI: 10.1109/SOSE.2017.20, 2017.

[14] C.H. Wu, et al., “Implementation of a cloud-based electronic medical record exchange system in compliance with the integrating healthcare enterprise’s cross-enterprise document sharing integration profile”, International Journal of Medical Informatics, 107, pp. 30-39, 2017.

[15] A. Winter, S. Stäubert, S. Ammon, et al., “Smart Medical Information Technology for Healthcare (SMITH) – data Integration based on interoperability standards”, Methods Inf Med, 57(Open): e92–e105. 2018.

[16] Apple Health Records: Available online: https://www.apple.com/healthcare/health-records/ (visited Jan 2019)

[17] N. Hong, A. Wen, F. Shen, S. Sohn, S. Liu, H. Liu, G. Jiang, “Integrating Structured and Unstructured EHR Data Using an FHIR-based Type System: A Case Study with Medication Data”. AMIA Summits on Translational Science Proceedings, 74, 2017.

[18] Y. Aliakbarpoor, S. Comai, G. Pozzi, “Designing a HL7 compatible personal health record for mobile device”s. In Research and Technologies for Society and Industry (RTSI), pp. 1-6, 2017.

[19] T. Bergquist, R.W. Buie, K. Li, P. Brandt, “Heart on FHIR: Integrating Patient Generated Data into Clinical Care to Reduce 30 Day Heart Failure Readmissions”, AMIA, pp. 2269–2273, 2017.

[20] J. C. Mandel, D. A. Kreda, K. D. Mandl, I. S. Kohane, and R. B. Ramoni, “SMART on FHIR: A standards-based, interoperable apps platform for electronic health records,” JAMIA, vol. 23, no. 5, pp. 899–908, 2016.

[21] IHE, Cross-Enterprise Document Sharing interoperability profile: https://wiki.ihe.net/index.php/Cross-Enterprise_Document_Sharing (visited Jul 2019)

[22] Mobile access to Health Documents (MHD): https://tinyurl.com/y5hklvyz (visited Jan 2019)

[23] S. Haas, S. Wohlgemuth, I. Echizen, N. Sonehara, N. Müller, “Aspects of privacy for electronic health records”, Int J Med Inform, 80 (2), pp. e26-e31, 2011.

[24] FHIR Security: https://www.hl7.org/fhir/security.html (visited Jan 2019)

[25] OpenID Connect: https://openid.net/connect/ (visited Jan 2019)