# Implementation of Cloud-Based Personal Health Record Integrated with IoMT


Natasha Blazeska-Tabakovska[1] Andrijana Bocevska[2], Ilija Jolevski[3]
Blagoj Ristevski[4], Nikolaos Beredimas[5], Vassilis Kilintzis[6]
Nicos Maglaveras[7], Snezana Savoska[8]

[1,2,3,4,8] Faculty of Information and Communication Technologies – Bitola, University "St. Kliment Ohridski" – Bitola, ul. Partizanska bb 7000 Bitola Republic of North Macedonia
[5,6,7] Lab of Computing, Medical Informatics and Biomedical Imaging Technologies – Aristotle University – Thessaloniki, Greece

{[1]natasa.tabakovska, [2]andrijana.bocevska, [3]ilija.jolevski, [4]blagoj.ristevski, [8]snezana.savoska}@uklo.du.mk [5]beredim@auth.gr, [6]billyk@med.auth.gr, [7]nicmag@auth.gr



**Abstract.** The paper presents implementation challenges for the cloud-based Personal Health Record (PHR) for Cross4all project with the usage of healthcare sensors according to the concept Internet of medical things (IoMT). The purpose of the paper is to highlight the implementation obstacles and solutions for the proposed PHR base model connected with cross-border healthcare systems that introduce a PHR concept. The paper also intends to assess the needed effort for increasing digital and e-health competences of the participants, supporting strategy where the patient is the owner of data and the key point of data collection. The increased need for e-health and digital health literacy for project implementation in the region has to be one of the main prerequisites for the acceptance of the concept by medical professionals and patients. In the PHR system patients will also have the opportunity to upload scanned medical documents as PDF or DICOM Media about their diseases and treatments available for the doctors. The data of the patient will temporary be at the disposal of the selected medical professionals in order to have information for decision making. This type of patient-centric data integration has to bring many benefits for patients and medical staff in the process of improvement of patient care.



**Keywords:** Personal Health Record, Patient's Centric Data Integration, Cloud-Based PHR, Internet of Medical Things, Healthcare Sensors.


## 1 Introduction

Many hospitals, healthcare institutions, medical and clinical organizations as well as healthcare insurance companies and funds have induced digitization at their baseline to boost the quality of healthcare delivery. Driven by this phenomenon, the industry has transformed itself into a massive giant, accomplishing the mandatory requirements and further igniting its potential to refine the deliverables at minimal costs. While this transformation indeed brought about a revolution in the healthcare industry, it also invented the generation of huge amounts of data.

Nowadays, it is a widely known fact that these big data can hold many capabilities for the healthcare industry if it is processed and executed appropriately [1] [2]. The data is a reliable prospect for supporting a wide range of medical and healthcare functions, including clinical decision support, disease surveillance and population health management. This data is the key to optimizing the potential of the healthcare industry not just from the industry perspective but also from the consumer perspective. Also, it is a huge opportunity for data scientists to further improve healthcare standards, given the overwhelming amount of data being generated and stored. Their analysis is very important in many management and policymaking at state levels.

The other aspect of patient-centric data collection is also very important in order to provide fast reaction by the medical practitioners when a patient needs urgent medical help anywhere. The ability to have a single dashboard for patients' entire history has a big effect on the healthcare sector. In other words, the patients' centric data integration can bring many advantages for patients especially in the era of their increased movement possibilities. Electronic health records (EHR) and personal health records (PHR) have a big impact on cross-border e-health services. Being able to share lifelong EHRs of patients among different healthcare providers in different countries, provides better decision support.

The project Cross4all proposes patients' centric data integration, the cloud-based PHR has to be the central point of data collection for the patients integrated with IoMT, adding many possibilities connected to entering their document, sensors' data, prescription and referral data as well as omics and exposome data connected with patients.

The paper describes the implementation of a cloud-based PHR system available cross-border in a real pandemic environment, explaining many obstacles and solutions arising from the current situation in the process of implementation of Cross4all project. After the introductory section, the second section surveys the recent research. In the next section, the paper considers some points of project aim and purposes, prerequisites and security and safety standards, taken into account in the phase of software creation. The next section describes some real solutions for cloud-based PHR and obstacles that arise from the low level of digital health and m-health competencies of the project participants. The concluding section contains supportive concluding remarks and draws the possible action to solve particular obstacles, improve some issues in the project implementation and propose some project improvements.

## 2 Related work

The research of the area of integration of healthcare and medical data usually is connected with a large investment of healthcare providers in de-personalized decision support systems intended for planning state, municipality or hospital's medical and healthcare. This research area takes into consideration the data security and patients' privacy risks related to the secondary uses of EHR especially when EHR data are transmitted through a network and shared and exchanged with multiple stakeholders [3]. But, many researchers state that the data from EHR can be effectively used in different domains such as clinical research, public health surveillance and clinical audits to provide effective, timely and quality healthcare facilities to the patients as well as for clinical research [4, 5]. They also consider the patient's data reuse privacy in many details.

The concept of "health digital state" [6] is used by EHRs to improve health digital state (HDS) with intelligent support of the processes of diagnoses and treatment, enhancing the prediction of pattern of diagnosing progression and defining the precise medical treatment and therapy as well as personalized delivery of healthcare [7]. The situation is changed when the Internet of Medical Things (IoMT) platform for pervasive healthcare is taken into consideration. This platform has to provide interoperability, quality of the detection process, scalability in a machine-to-machine-based architecture and functionalities for processing huge data volumes, knowledge extraction, common healthcare services and connection with PHR/EHR [8]. IoMT devices use the semantics defined in OpenEHR for data quality evaluation and standardization of healthcare data. It also enables the application of big data techniques and online analytic processing (OLAP) through fast healthcare interoperability resource (FHIR) application programming interfaces (APIs). Also, many researchers provide IoT sensors as eHealth connected devices connected with EHR in hospital information systems (HIS), collected into a proper medical format (HL7 or FHIR) to make certain the data is structured and easy to understand [9].

Prados-Suárez et al. propose the use of EHR aggregator as middleware between systems that can incorporate several sources giving unified access following the FAIR (Findability, Accessibility, Interoperability and Reusability) principles. That provides translation between standards and of systems to any standard, including an integration layer acting as a single access point and offering a unified view of intended data sources and providing data reusability [10]. The knowledge-driven framework in the biomedical domain, able to transform disparate data into knowledge for clinicians and data practitioners helping in the complex tasks of extracting valuable knowledge from heterogeneous datasets is described in [11]. This framework can show the potential for uncovering patterns that can enable the explanation of treatment interactions and patient characterization [11].

We have to mention the efforts of tethered PHR that seeks to achieve interoperability by using open-source standards, achieving structural and semantic interoperability, presented as prototyped mobile PHR with HL7 FHIR standard implemented as well as SNOMED for captured data [12].

Warner and Levy consider several emerging paradigms for integration including non-standardized efforts between individual institutions and genomic testing laboratories [13]. According to their research, cancer genomic information integration into EHRs could be beneficial for patient-centered care, especially when machine learning algorithms and CDS software is used for cancer genomic-EHR integration and clinicians to be more inclined to let the genomic information in their patients' EHRs better guide the decisions they make if it is well integrated.

Several EU projects focus healthcare data integration on the patient-centric level, providing data integration through PHR where the patient is the data owner [14]. Many security issues are considered from the aspect of the patient and living country of the patient [15]. So, the proposed model of the integrated healthcare system has to be cloud-based, cross-border and based on the PHR with an e-health strategy. The main point is that data collection is possible to be done in a hospital, out of hospitals and HIS and perhaps it cannot be connected with EHR and country of living. The demands for this concept are increasing the e-health and health digital literacy in order to support the national and local medical and healthcare authorities [14, 16].

Some authors think that healthcare data integration has to be wider and has to provide wider data integration, not only for data analysis and healthcare decision making. An integration of healthcare data, medical, omics, sensors data as well as exposome data to provide data for prediction of the influence of health of environmental, social, stress factors to risk to health assessment was proposed in [17] and [18].

## 3 Prerequisites for cloud-based PHR concept implementation

The shifting priorities towards digital health care forced the need to use digital technologies in the healthcare sector and set a secure, standard method for cross-border healthcare data exchange.

The project Cross4all addresses the e-health challenges in the cross-border area, taking into consideration the problems of creating the PHR for patients from two national healthcare systems where the patient is a data owner.

The proposed architecture is cloud-based and distributed, in order to support data collection from different types of sources and collected in a different way such as patient' healthcare data, medical practitioner data, sometimes collected from biomedical devices, sensors for measuring vital signs of life, many times collected from remote patients, collected from the disabled population, children and elderly people. The central point of the system is a Cross4all application server, as a part of an integrated e-health cloud system, connected with a central Authentication/Authorization server with many security levels [16]. The authentication layer is designed using the keycloack server. When authentication and authorization are completed, the user will receive an authenticated token. It can be used to access the API endpoints and then the PHR data. The PHR data is stored in a graph database [19]. Data protection and encryption are described in [20]. The cloud-based e-prescription and e-referral systems are part of the main Cross4all system.

The patient's data from the two countries are split according to the patient's country of living. This concept is used because of the different patient data protection laws in two Cross4all participant countries as well as different ownership concepts of the patient data system.

Medical devices such as oximeter, glucometer, spirometer, blood pressure meter, stethoscope, ACG, thermometer and weigh scale are available for doctors. Also, blood pressure meter, thermometer, oximeter and glucometer are available to patients who need them. All medical devices are equipped with Bluetooth which allows machine-to-machine communication. The IoMT infrastructure, combines all these medical devices and software applications which communicate with PHR and other health systems in both cross-border countries and manage the patient's treatment in a substantially improved manner. The patient's quality-of-life could increase with minimized doctor's office time or could receive appropriate health treatment in a cross-border country when he allows permission to his PHR to the doctor in the cross-border country.

The applications have a particular focus on serving the needs of the elderly and people with disabilities [18] and socially/geographically isolated individuals. The applications include multi-language support.

Paired with mobile applications, collected data such as blood pressure, temperature, oxygen saturation, concentration of glucose in the blood, the volume of air inspired and expired by the lungs and weight or mass, are uploaded in real time in the patient's PHR. The collected data with the consent of the patient is shared with the patient's doctors in order to better surveil diseases and track and prevent chronic illnesses. The capabilities of data collected from medical devices are to improve the patient's health service, more accurate diagnoses, fewer mistakes and lower costs of care.

The prerequisites for the project implementation include increasing the participants' e-health and healthcare digital competences. For this reasons, educational material for this purpose was created and posted on an e-learning platform for increasing the population healthcare digital and e-health literacy, taking into consideration the needs of disabled peoples, the elderly population and children.

It is a free platform accessible for everywhere on disposal to the population with many video materials, presentations and brochures that have to support the project aim of increasing the population e-health and digital health literacy [21].

## 4 Cloud-Based PHR implementation challenges

The Cross4all project ecosystem consisted of the four integrated and interconnected components: a Web portal and connected mobile application for citizens; an eLearning module for citizens, which is aimed to improve their health and digital health literacy; PHR and connected mobile app for citizens; and interfaces for connecting external third-party systems to the project's PHR, such as national e-prescription and e-referral systems, or private telecare systems or EHRs, enabled the data recorded in the systems be automatically (i.e., easily and free of error) imported to the PHR owners.

The implemented PHR solution is different from past efforts to integrate existing eHealth systems and sources of patient data in two key aspects. First, the users' data, held and shared, is not restricted only to medical or disease-related data created in the health institution to which the user is connected. It may well include information beyond their medical history, such as information related to maintaining a healthy life, such as lifestyle and living conditions, altogether forming a more holistic representation of the person's health lifecycle, covering all kinds of physical, psychological, and social aspects, as shown in Fig. 1. Secondly, in this PHR-based approach, the records stored are intended to be fully owned and controlled by the user (patient) himself. In this way, it lies upon the user alone to decide who, when and for how long, will be granted access to what information and in which form or level of detail, as shown in Fig. 2.


**Fig. 1.** PHR solution.

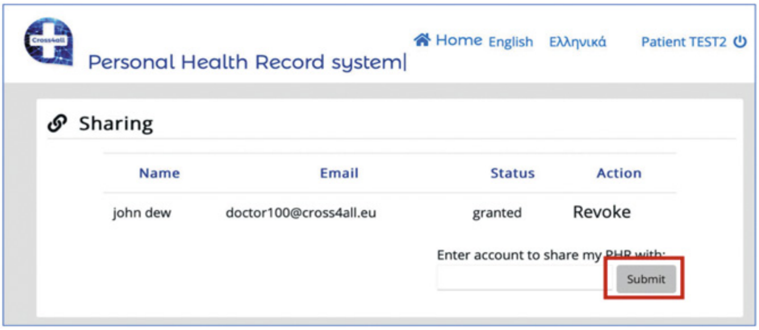


**Fig. 2.** Fully patients' ownership and control on the electronic records.

The data and records of an individual in the project's model, being manually entered (Fig. 3) or automatically imported from a series of connected, authorized by the user, health providers and systems, are completely independent of third-party entities and are not meant to replace, under any circumstances, the official records of other source providers.

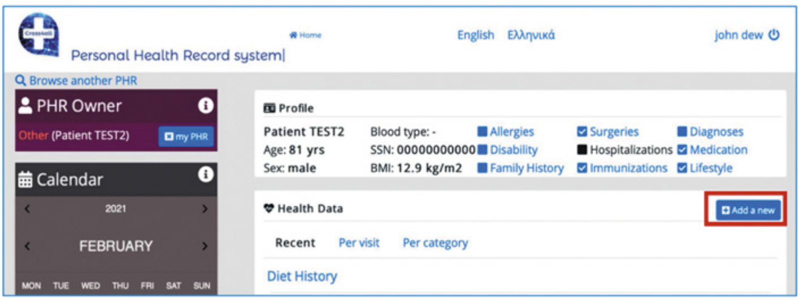


**Fig. 3.** Manually entering data in PHR.

Despite the opportunities and benefits, there were many challenges during the pilot project. The implementation of such a system requires users to have a higher level of e-health and digital healthcare literacy. Some of the patients, especially the elderly ones, usually have a low level of digital literacy and have to be educated for this purpose. There is a lack of awareness and confidence in e-health solutions among patients. Also, some of the medical staff is not open to the idea of technological implementation. Because the EHR system is not fit at all into the existing workflow, physicians find it difficult to adapt to it and it needs time to overcome these obstacles. Moreover, healthcare professionals are supposed to provide help to a big number of patients in a given time frame, which is problematic when they have to use new solutions which they are not familiar with. From a technical side, interoperability is one of the challenges. It is also important for the system to enable the transfer of information among multiple providers, enabling different EHR systems or software to exchange information.

Taking these difficulties into consideration all mobile applications and PHR are developed to be intuitive and easy to use, they are implemented with principles for user interfaces design [22, 23], as shown in Fig. 4. Moreover, during the design and development of PHR and mobile applications, a wide range of opportunities for people with different preferences as well as older people and people with different disabilities are provided.

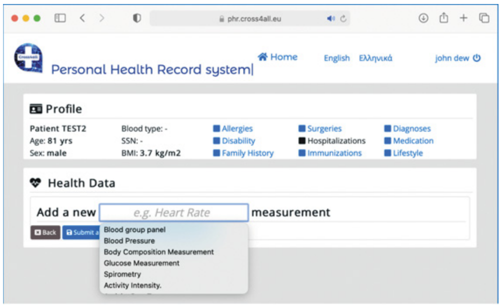

**Fig. 4.** The user interface of the PHR system.

Overcoming the difficulties that medical personnel are faced with was achieved easier with training about the new workflow and mobile applications, using tutorials and providing technical support when needed during the pilot project.

The implementation of these solutions in everyday activity requires additional efforts such as health professionals to be relieved of at least some of their work until they become more familiar with using the system. Additionally, it is necessary to facilitate cross-border data flow to take advantage of cross-border data services. Also, it is important to emphasize the fact that the EHR system has a high level of security of patient data, to increase the patients' confidence.

## 5 Conclusion

Using the patient's centric PHR concept, taking into account the legal regulations of each of the countries for the patients' PHR data, as well protection and standardization of data exchange give a big advantage in existing and new cross-border data services. The increased security implementations result in improved user acceptance of this concept and the full exploitation of their advantages. Implementation of this complex project demands efforts for increasing the participants and population e-health and digital health competences. For this reason, the e-learning platform for increasing digital health literacy as well as e-health literacy was created. The platform was chosen according to WCAG criteria that provide access for all, including disabled, elderly peoples and children.

The implementation of the project includes a cloud web-based PHR system for a patient that has to aggregate all patient's data including data from wearables, biomedical data, medical and healthcare sensors data, patient's e-prescription and e-referral data and data from environmental sources. Also, social media and other natural resources taken as exposome data that influence patient health can be used for health risk assessment as well as all PDF and DICOM data that can be stored by the patient. The whole concept used for the project implementation defines couples of roles in the system that are defined and responsibilities that the owner of data has for their data. The patient as an owner can grant access to their PHR to the medical practitioners' temporary to provide evidence-based healthcare in the era of increasing mobility of the patients. All data are saved in a cloud environment and the patient can have them with him everywhere. The patient and the medical practitioners or specialists can input data in a patient's PHR or acquire from medical sensors according to IoMT concept, providing evidence-based medicine for the patient. The patient also can input their medical and healthcare data, providing scans from HIS data, lab's data or acquiring data from wearables as sensors for monitoring of vital signs of life. Connected with their PHR, the patient and granted medical practitioners can use the exposome data to connect the patient's living place, the influence of environmental factors for patient's living condition adjustment and withdrawing some conclusion about the health condition of living place.

The implementation challenges and obstacles described in this paper can help to clarify some implementation points and demands intended for a wider community when such a project has to be implemented as well as when some other IoMT devices have to be accepted in the implementation. This project has also shown the need for increasing digital health literacy, e-health and m-health literacy in the era of IoMT.

In future work, we have to work on defining od some exposome data for some chronic disease and quantify or assess the risk for this disease from environmental pollutant, location's health factors or other stressors that influence this disease.

## 6 Acknowledgement

Part of the work presented in this paper has been carried out in the framework of the project "Cross-border initiative for integrated health and social services promoting safe ageing, early prevention and independent living for all (Cross4all)", which is implemented in the context of the INTERREG IPA Cross

Border Cooperation Programme CCI 2014 TC 16 I5CB 009 and co-funded by the European Union and national funds of the participating countries.

## References


1. Ristevski, B., & Savoska, S., Healthcare and medical Big Data analytics. *Applications of Big Data in Healthcare: Theory and Practice*, 85, 2021.
2. Ristevski, B., & Chen, M., Big data analytics in medicine and healthcare. *Journal of integrative bioinformatics*, *15*(3), 2018.
3. Shah S. M., Khan R. A., Secondary Use of Electronic Health Record: Opportunities and Challenges, arXiv:2001.09479v1 [cs.CY] 26 Jan 2020.
4. Gamal A., Barakat S., Rezk A., Standardized Electronic Health Record Data Modeling and Persistence: A Comparative Review. Journal of biomedical informatics, 103670, 2020.
5. Bertagnolli M. M, Anderson B., Quina A., Piantadosi S., The electronic health record as a clinical trials tool: Opportunities and challenges, Clinical Trials 1–6, 2020.
6. Serbanati L. D., Health digital state and Smart EHR systems. Informatics in Medicine Unlocked, 21, (2020),100494.
7. Sitapati A., Kim H., Berkovich B, Marmor R., Singh S., El-Kareh R., Clay B, Ohno-Machado L., Integrated Precision Medicine: The Role of Electronic Health Records in Delivering Personalized Treatment, Wiley Interdiscip Rev Syst Biol Med. Author manuscript; available in PMC 2018 May 01.
8. Rubí J. N. S., Gondim P. R. L., IoMT Platform for Pervasive Healthcare Data Aggregation, Processing, and Sharing Based on OneM2M and OpenEHR, Sensors, 19(19), 4283.
9. Koren A., Jurčević M., Huljenić D, "Requirements and Challenges in Integration of Aggregated Personal Health Data for Inclusion into Formal Electronic Health Records (EHR),"2nd International Colloquium on Smart Grid Metrology (SMAGRIMET), Split, Croatia, 2019, pp. 1-5, 201
10. Prados-Suárez B., Molina C., Pena-Yañez, C., Providing an Integrated Access to HER Using Electronic Health RecordsAggregators, Digital Personalized Health and MedicineL.B. Pape-Haugaard et al. (Eds.)© 2020 European Federation for Medical Informatics (EFMI) and IOS Press, doi:10.3233/SHTI200191.
11. Vidal M. E., Endris K. M., Jazashoori S., Sakor, Sakor A., Rivas, A. Transforming Heterogeneous Data into Knowledge for Personalized Treatments—A Use Case. Datenbank-Spektrum, part of Springer Nature 2019 .
12. Saripalle R, Runyan C, Russell M, Using HL7 FHIR to achieve interoperability in patient health record. J Biomed Inform. 2019 Jun;94:103188.
13. Warner J. L., Jain S. K., Levy M.A., Integrating cancer genomic data into electronic health records, Warner et al. Genome Medicine (2016) 8:113.
14. Snezana S, Kilintzis V., Jakimovski B., Jolevski I., Beredimas N., Mourouzis A., Corbev I., Chouvarda I., Maglaveras A., Trajkovik V., Cloud Based Personal Health Records Data Exchange in the Age of IoT: The Cross4all Project. In: Dimitrova V., Dimitrovski I. (eds) ICT Innovations 2020. Machine Learning and Applications. ICT Innovations 2020. Communications in Computer and Information Science, vol 1316. Springer, Cham.
15. Savoska S., Jolevski I., Ristevski B., Blazeska-Tabakovska N., Bocevska A., Jakimovski B., Chorbev I., Kilintzis V., Design of Cross Border Healthcare Integrated System and its Privacy and Security Issues, In Proceedings of Computer and Communications Engineering, Workshop on Information Security, 9th Balkan Conference in Informatics, Volume 13, 2/2019, Pp.58-64
16. Savoska S., Jolevski I., Architectural Model of e-health PHR to Support the Integrated Cross-border Services, In proceedings of ISGT conference 2018, pp. 42-49, Sofia, 2018.

17. Savoska S., Ristevski B., Blazheska-Tabakovska N., Jolevski I. Towards Integration Exposome Data and Personal Health Records in the Age of IoT. In: 11th ICT Innovations Conference 2019, 17-19 October, Ohrid, Republic of Macedonia.pp.237-246, 2019.
18. Barouki R., Audouze K., Coumoul X., Demenais F., Gauguier D., Integration of the human exposome with the human genome to advance medicine. Biochimie, Elsevier,2018, 152, pp.155-158. 10.1016/j.biochi.2018.06.023. hal-02196327
19. V. Kilintzis, I. Chouvarda, N. Beredimas, P. Natsiavas, and N. Maglaveras, "Supporting integrated care with a flexible data management framework built upon Linked Data, HL7 FHIR and ontologies," *J. Biomed. Inform.*, vol. 94, 2019.
20. Savoska S., Jolevski I., Ristevski B., Blazheska-Tabakovska N., Bocevska A., Jakimovski B., Chorbev I., Kilintzis V. Design of Cross Border Healthcare Integrated System and its Privacy and Security Issues. Computer and Communications Engineering, 13 (2). pp. 58-63. ISSN 1314-2291
21. Blazheska-Tabakovska N., Ristevski B., Savoska S. and Bocevska A. Learning Management Systemsas Platforms for Increasing the Digital and Health Literacy, CEBT 2019: Proceedings of the 2019 3rd International Conference on E-Education, E-Business and E-TechnologyAugust 2019 Pages 33–37 https://doi.org/10.1145/3355166.3355176
22. Blazheska-Tabakovska, N., Savoska, S., Ristevski, B., Jolevski, I. and Gruevski, D. Web Content Accessibility for People with Cognitive Disabilities, Proceedings of the IX International Conference on Applied Internet and Information Technologies AIIT 2019. October 2019, Zrenjanin, Serbia
23. Veljanovska, K. Blazeska Tabakovska, N., Ristevski, B. and Savoska, S. User Interface for e-learning Platform for Users with Disability, Proceedings of the ISGT 2020 Information Systems and Grid Technologies, May 29 – 30 Sofia, Bulgaria
24. ATutor Cross4all page: http://atutor.cross4all.uklo.edu.mk/login.php, Accessed 15.3.2021