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Proposing New Blockchain Challenges in eHealth

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Abstract

The blockchain technology has reached a great boom in the health sector, due to its importance to overcome interoperability and security challenges of the EHR and EMR systems in eHealth. The main objective of this work is to show a review of the existing research works in the literature, referring to the new blockchain technology applied in ehealth and exposing the possible research lines and trends in which this technology can be focused. The search for blockchain studies in eHealth field was carried out in the following databases: IEEE Xplore, Google Scholar, Science Direct, PubMed, Web of Science and ResearchGate from 2010 to the present. Different search criteria were established such as: "Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine") selecting the papers considered of most interest. A total of 84 publications on blockchain in eHealth were found, of which 18 have been identified as relevant works, 5.56% correspond to the year 2016, 22.22% to 2017 and 72.22% to 2018. Many of the publications found show how this technology is being developed and applied in the health sector and the benefits it provides. The new blockchain technology applied in eHealth identifies new ways to share the distributed view of health data and promotes the advancement of precision medicine, improving health and preventing diseases.

Keywords Blockchain · Challenges · eHealth · Electronic health records (EHRs)

Introduction

eHealth is a technology that is becoming increasingly important over time, from remote access to medical records, such as Electronic Health Records (EHR) or Electronic Medical Records (EMR), to the exchange of real-time data from different body sensors in patients [1]. The importance of eHealth

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is its ability to provide patients, worldwide, access to their medical data and real-time monitoring of their health with the evolution of IoT and connected objects. Improved communication between patients and health professionals, therefore, effectiveness in treatments and health monitoring, greater access to medical care and less pressure on public health budgets [2].

EHR is a standardized information model, which allows integration among multiple health care providers, and this integration is considered its main advantage [3]. EHR has several benefits, ranging from supporting medical prescriptions, improving the management of disease and contributing to the reduction of serious medication errors. However, EHR has limitations with respect to interoperability, with the security of data exchanged between health organizations, or with the non-incorporation of data on patient welfare [4]. Hence, in the context of eHealth, blockchain emerges as a highly secure and decentralized network platform of several computers called nodes; changing the way medical information is stored and shared. It facilitates the work, monitors the security and accuracy of data and also reduces the maintenance cost [5].

The main advantage of blockchain technology in healthcare organizations is the management of patients EMRs. Nowadays, patient information is stored safely in

many places, dispersed among many institutions, hospitals and insurance providers, without full access to a shared patient database [6]. Health records stored in blockchain could allow patients to make their structured data available to researchers. All these factors have the potential to reduce storage costs and increase efficiency, possibly even by integrating automatic systems of insurance payment through the use of intelligent contracts (automatic execution contracts with terms of agreement between the parties written directly on code lines) built as a layer on blockchain [7].

Blockchain technology has gained great popularity in recent years in different sectors, one of these fields being health. This popularity is due to its unique characteristics such as: absence of centralized control, a high degree of anonymity and a consensus distributed over decentralized networks. Hence, in this work we present a review of the state of the art regarding blockchain technology in eHealth, in order to obtain an overview of topic and expose the possible research lines and trends in which this technology can be focused.

There are similar studies that demonstrate the viability of our research, such as: in [8] the authors determine the current challenges of EMR systems and potential solutions in order to show the interoperability and security challenges of the different EMR systems that they use blockchain technology, [9] the authors present the potential applications of technology and highlight the blockchain challenges in medical care and [10] the authors investigate different blockchains structures in the administration and exchange of EHR and EMR to allow patients, hospitals, clinics and other medical stakeholders to share data with each other and increase interoperability.

The methodology used in this review is described below. Afterwards, the results obtained the discussion of them and the final conclusions of this research work will be finalized.

Methodology

In this paper was developed a review of the existing research works in literature regarding the use of blockchain in eHealth, with publication dates from 2010 to the present. Different scientific databases were used to carry out the review, such as: IEEE Xplore, Google Scholar, PubMed, Science Direct, Web of Science and ResearchGate. Table 1 shows the different search criteria used for the review. The databases used cover the largest amount of research in fields such as eHealth.

Certain requirements for the inclusion of a document were taken into account, such as: 1) The document must be written in English. 2) Blockchain studies applied to eHealth. 3) Those studies focused on how blockchain is applied in other non-ehealth sectors are eliminated. The

selection process of the articles was carried out by reading titles and abstract of results obtained by one of authors, and the articles were classified by reading their abstracts and the full article when necessary. Fig. 1 show the search strategy used in the review.

Of the 84 publications found 53 were duplicated or with irrelevant title for this research, the remaining 31 studies were read and analyzed their abstracts to determine which were of interest, obtaining as a result 18 documents which gave rise to relevant contributions. In the following section shows the most relevant papers found.

Results

Blockchain technology has gained considerable progress in recent years in fields such as health. The medical data contains personal and sensitive information that must be preserved. In the early stages of design and development, several organizations have designed novel technologies that have the latency to maximize medical data, such as heterogeneous transparency and operational capabilities [5]. Blockchain offers a new and promising distributed framework to amplify and support the integration of health care information in a variety of uses and stakeholders [11].

By reviewing the literature we found a total of 18 relevant papers related to the blockchain technology applied in eHealth. Of which 5.56% correspond to the year 2016, 22.22% to 2017 and 72.22% to 2018 demonstrating the novelty of the Blockchain technology applied to eHealth. Fig. 2 shows the statistics of the relevant paper found from 2010 to the present and Fig. 3 shows the percentages of each topic in which results of this review are divided.

Below is show a summary of results obtained in the literature review (See Table 2).

In [6] propose a novel protocol to achieve the preservation of patient privacy, called Pseudonym Based Encryption with Different Authorities (PBE-DA) applying the Blockchain concept in health communication entities in an eHealth platform, with the objective to comply with the requirement of structure distributed in eHealth records system. The results showed the development of the protocol and its validation.

In [16] the authors propose a secure and scalable access control system for confidential information. Employed secure cryptographic techniques (encryption and digital signatures) to ensure efficient access control to confidential shared datasets using an authorized blockchain for enhanced security and a closely monitored system. They designed a blockchain-based data exchange scheme that allows users/data owners to access EHR from a shared repository after their identities and cryptographic keys have been verified. The results show that

Table 1   Searches conducted on the different academic databases

Databases	Search criteria	Search fields
IEEE Xplore	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"abstract"
Google Scholar	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"title"
PubMed	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"title/abstract"
Science Direct	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"abstract, title, keywords"
Web of Science	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"title" AND "topic"
ResearchGate	"Blockchain" AND ("eHealth" OR "EHR" OR "electronic health records" OR "medicine")	"title/abstract"

the system succeeds where traditional methods of passwords access control, firewalls and intrusion detection systems fail.

In [19] the authors present an approach to solve the problem of managing access control in eHealth. Access control is a special complex task in electronic health, since resources and data are distributed among different installation and institutions. To overcome this complexity, they propose an approach that takes advantage use of blockchain to store transactional information about eHealth records and access control policies. The results in general show that approach is viable, which offers several advantages when compared with existing systems.

In [22] the authors propose a DABS scheme for Blockchain in healthcare, which provides an efficient verification of EHR data authenticity and identity of the signer. They also describe a holistic on-chain and off-chain collaborative storage system for efficient storage and verification of EHR data. This blockchain-based storage system ensures that stored and shared EHR data is not constrained cannot be verified, and combination of on-chain and off-chain storage effectively realizes the secure sharing of large-scale distributed EHR data. The experimental results show that the proposed protocol is effective and practical.

In [25] propose a secure EHR system based on attributes and blockchain technology. In the system, they used attribute-based encryption (ABE) and identity-based encryption (IBE) to encrypt medical data, using the identity-based signature (IBS) to implement digital signatures. This greatly facilitates the management of the system and does not need to introduce different cryptographic systems for different security requirements. In addition blockchain techniques guarantee the integrity and traceability of medical data.

In [26] the authors propose a blockchain-based secure and privacy-preserving personal health information (PHI) sharing (BSPP) scheme for diagnosis improvements in e-Health systems. In this case, the private blockchain and consortium blockchain are used. The private blockchain is responsible for storing the PHI, while the consortium blockchain keeps records of the PHI safe indexes. Block generators must provide a conformance test to add new blocks to blockchain, which guarantees the availability of the system. The results show that the proposed protocol can meet the security objectives.

Discussion

One of the blockchain main advantages compared to other models of distributed databases is the integration of data

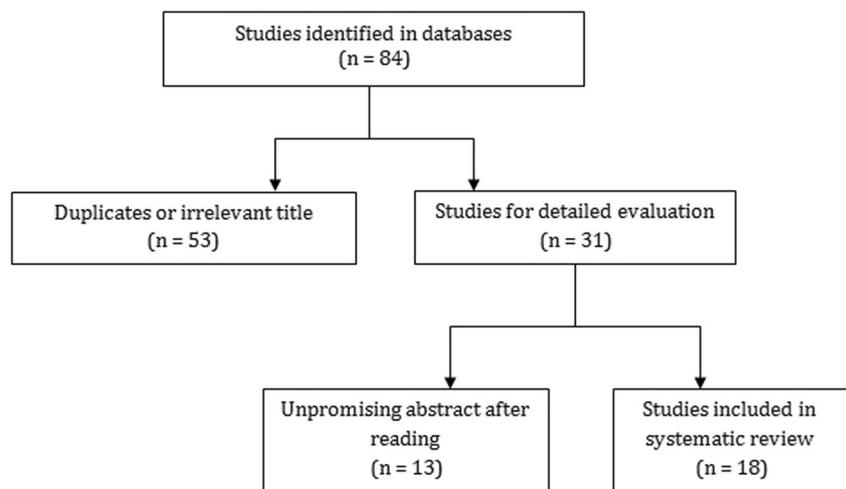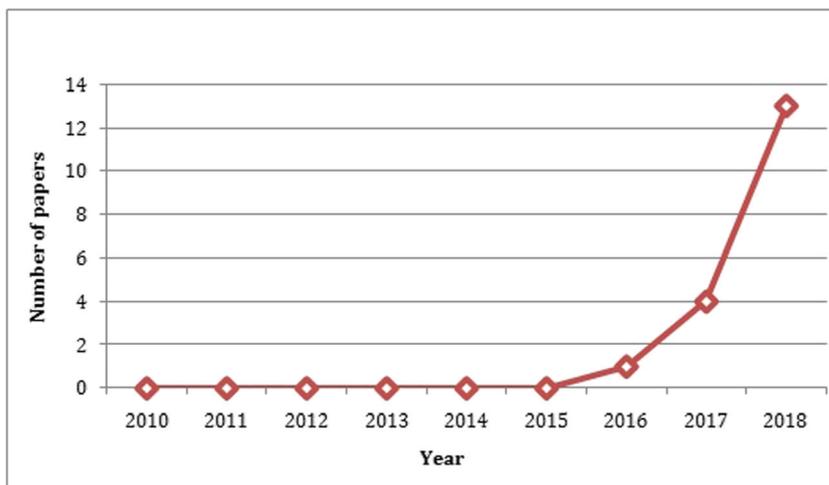**Fig. 1** Flow Diagram

Fig. 2 Relevant papers found in the last 10 years

processing, which guarantees correction and security in a single protocol, is implemented algorithmically and minimizes the human factor [21]. The ability to verify the authenticity of EHR data and signer identity for EHR data is fundamental for the practical deployment of blockchain in medical care [22]. Identify new ways to share the distributed view of health data and promote advancement of precision medicine, health improvement and disease prevention [28]. Below we show the main challenges that are discussed in this review.

Challenges

The Blockchain technology offers a platform that could be used for many potential applications in medical care. It has the potential to improve security in remote patient monitoring systems and automate the delivery of health-related notifications in a manner compatible with HIPAA [29]. You can solve current problems with poorly managed patient data by adding clean and formatted data to EHR and EMR, which allows

healthcare to use big data with more reliable information, leading to more meaningful results.

Blockchain is a technology based on public key cryptography and hashing mechanisms as a means to track historical transactions related to distributed patient records while preserving the data confidentiality, integrity and availability. Ensuring that records are not lost or modified falsified or accessed incorrectly.

There are important obstacles to overcome in order for blockchain to reach its maximum potential and be applied in medical care, the most important problems are technology scalability and data access controls [7]. Some of greatest advantages that application of this technology could provide in health care are: access to a large quantity of anonymous health data that could be used for medicines personalized development, rationalization of medical insurance costs and health, as well as the improvement of public health policies. Along with data availability on health care providers, this type of patient participation could generate a new era in medical care.

The blockchain technology could also help with other aspects of medical care, such as improving the insurance claim or other administrative processes within the healthcare networks and making available to biomedical researchers, population data related to health [30].
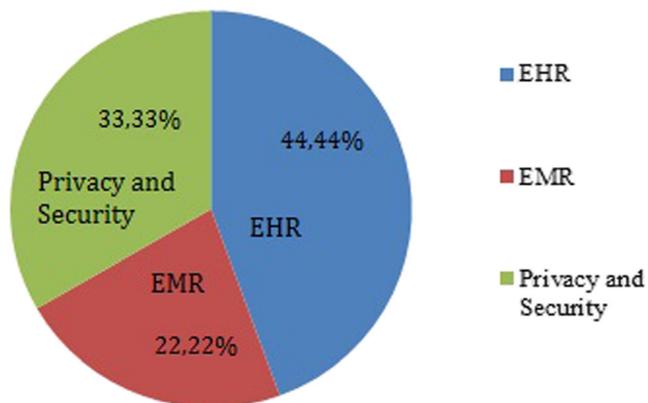

Fig. 3 Percentages of topics found in the review, related with blockchain in eHealth

Conclusion and future work

The purpose of this review was to provide an overview of the state of art in research on blockchain in eHealth and expose the research lines and trends of this new technology in this field. The results obtained show us a very innovative technology from which we obtained relevant papers with publication date from 2016.

Table 2   Studies of the bibliographic review related to Blockchain in eHealth

Authors	Year of publication	Objective of the Study	Results
Azaria et al. [12]	2016	They propose a novel decentralized registry management system called MedRec to manage EMRs, using blockchain technology. The system provides patients with a complete and immutable record and easy access to their medical information through providers and treatment centers.	- The results demonstrated an innovative approach to the management of medical records, providing interoperability and accessibility through a complete registry. MedRec allows the exchange of patient data and incentives for medical researchers to maintain the system.
Cunningham &Ainsworth [13]	2017	They present a system that allows personalized control of the access of third parties to EHR of patients, which allows people to specify when and how their records are accessed for research purposes.	- The results show that the use of Ethereum blockchain technology based on intelligent contract to implement this system, allows it to operate in a verifiable, reliable and openly auditable environment, crucial features for the advancement of health information systems.
Dubovitskaya et al. [14]	2017	The authors propose a framework on the management and exchange of EMR data for care of cancer patients based on blockchain. They implement the framework in a prototype that guarantees privacy, security, availability and detailed access control over EMR data.	- The results show that the proposed study can significantly reduce the response time to share EMR, improve decision making for medical care and reduce the overall cost.
Magyar [15]	2017	They present a study of how blockchain technology can help solve the problem of secure data storage and guarantee its availability at the same time in an EHR system.	- The new technology solves an essential problem of access to data without endangering personal privacy. - It opens new opportunities for automatic personal monitoring devices and takes a step towards the participation of new service providers.
Xia et al. (16)	2017	The authors propose a secure and scalable access control system for confidential information using blockchain.	- The results show that the system succeeds where traditional methods of passwords access control, firewalls and intrusion detection systems fail.
Badr, Gomaa, & Abd-Elrahman [6]	2018	They propose a novel protocol to achieve the preservation of patient privacy, called PBE-DA applying the Blockchain concept in an eHealth platform.	- The results showed the protocol development and its validation.
Dagher et al. [17]	2018	They propose a framework based on blockchain for secure, interoperable and efficient access to EHR by patients, suppliers and third parties, while preserving the privacy of patients' confidential information. The framework, called Ancile, uses smart contracts in blockchain based on Ethereum for greater control of data access, and uses advanced cryptographic techniques for greater security.	- The results show a blockchain system that achieves a high level of decentralization while recognizing that some nodes must be of a higher authority. - It offers an important preservation of the data privacy and integrity.
Da Conceição et al. [18]	2018	The authors analyze blockchain technology and smart contracts in scenarios related to access, administration and interoperability of data for domain of specific medical attention. They propose the implementation of large-scale information architecture to access EHR based on intelligent contracts as mediators of information.	- His main contribution is the framing of data privacy and accessibility problems in medical care as well as proposal of an integrated architecture based on blockchain.
Dias et al. [19]	2018	The authors present an approach to solve the problem of managing access control in eHealth.	- The results in general show that the approach is viable, which offers several advantages when compared with existing systems.
Kaur et al. [5]	2018	The authors propose a platform based on Blockchain that can be used to store and manage EMR in a cloud environment.	-This study offers a summary of the framework, the internal work and protocols for management of heterogeneous health data.
Mikula & Jacobsen [20]	2018	The authors propose a system for the identities and accesses management using blockchain. They propose a prototype based on an open source blockchain framework called Hyperledger Fabric to demonstrate the viability of the system.	- The results confirm that identity and access management can be achieved in a decentralized, efficient and secure manner. - The proposed concept was applied and discussed in a case of use with EHR of health sector.
Novikov et al. [21]	2018	They present a model of health system decentralized infrastructure, a scheme of the distributed data registry for creation of patient electronic medical card. An algorithm has been developed for use of smart contracts in the health system using blockchain.	- The results of research demonstrate the effectiveness of blockchain technology for storing patient EHR.

Table 2 (continued)

Authors	Year of publication	Objective of the Study	Results
Sun et al. [22]	2018	The authors propose a Decentralized Attribute-based Signature (DABS) scheme for Blockchain in healthcare.	-Experimental results show that proposed protocol is effective and practical.
Tamazirt, Alilat, & Agoulmine [23]	2018	The authors propose to use the Blockchain technology as a tool to provide a new model for the exchange of health care information. Describe the tools and methodologies adopted for development of EHR blockchain system illustrating the operating principle of this system.	- The results show that proposed EHR blockchain system has the potential to support the health sector by providing better support to management of health data for physicians and patients.
Uddin et al. [24]	2018	They present an architecture that involves Patient Agent (PA), coordinates the insertion of continuous data flows in Blockchains to form an EHR. The PA will classify the health data of transmission and determine the security level and availability based on the sensitivity and need for health data in a short time.	- The results show that Blockchain can be adopted for EHR that include RPM whenever PA (running on a personal computer or local server of the patient) determines the required storage level of the data before inserting them into blockchain quickly.
Wang & Song [25]	2018	They propose a secure EHR system based on attributes and blockchain technology.	- The results show that blockchain techniques guarantee the integrity and traceability of medical data.
Zhang & Lin [26]	2018	The authors propose a blockchain-based secure and privacy-preserving personal health information (PHI) sharing (BSPP) scheme for diagnosis improvements in eHealth systems.	- The results show that the proposed protocol can meet the security objectives.
Zhang & Poslad [27]	2018	The authors propose an architecture called GAA-FQ (Granular Access Authorization supporting Flexible Queries) for blockchain-based EMR comprising an access model and authorization scheme.	- As a result, an EMR based on Blockchain can respond to an applicant without losing unauthorized private data efficiently, especially for a device with limited resources in an eHealth system.

Challenges such as the scalability, security and profitability of blockchain technology will require more research before large-scale production implementations. The future of this technology in health and other industries needs more research and development. However, a distributed system that eliminates intermediaries has a substantial potential to interrupt many current processes in medical care and research.

Blockchain offers an opportunity to make possible the efficient exchange of information between the interested parties and the protection of the patient's privacy, as well as to guarantee the integrity of the data. Unresolved problems such as acceptance, regulation and ethics should be considered for the use of blockchain technology.

As the health industry moves towards models focused mainly on patients, the use of blockchain technology emerges as a viable solution, since it allows storing and managing electronic health records in an efficient and safe way.

Blockchain's potential for health care depends to a large extent on the acceptance of new technology within the health care ecosystem to create technical infrastructure. Leveraging this technology has potential of connect fragmented systems to generate ideas and better assess the care value. In the long term, a national blockchain network for EMR can improve efficiency and support better health outcomes for patients.

Hence, we propose as future work design and implement a platform using blockchain to share EHRs among various medical and health institutions in a region of Spain, taking into account the security and privacy protocols for the handling of patient data. Facilitating that in a future blockchain can be seen as component of a system in which patients act as administrators of their own data.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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