Reviewing the Integration of Blockchain in Electronic Medical Records within the Pharmaceutical Supply Chain

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Abstract

This paper delves into the application of blockchain technology within the healthcare sector, with a specific emphasis on its integration into the management of Electronic Medical Records (EMRs) as a crucial component of the pharmaceutical supply chain. Identifying the pressing need for a secure and interoperable system to handle medical data, this study confronts challenges such as security, scalability, reliability, interoperability, and data breaches in EMR systems. Through a selective literature review focusing on pertinent articles, particularly those concerning blockchain for EMRs, the aim was to identify suitable blockchain architectures for medical records. Addressing the research gap, the paper proposes an in-depth and comparative evaluation of various blockchain architectures suggested in prior studies to comprehensively assess their implementation in healthcare systems. Preliminary results indicate the potential of blockchain technology to enhance the security, confidentiality, and efficiency of EMRs management. However, the limitation of lacking validation of proposed blockchain architectures by case studies through constrains the effectiveness of proposed solutions, thus urging the future direction towards the development of more efficient and secure blockchain solutions tailored specifically for the pharmaceutical supply chain.

Keywords: Blockchain, Electronic Medical Record, Pharmaceutical Supply Chain

Introduction

In the healthcare domain, the need to provide a high quality of care has become a worldwide preoccupation, particularly during health crises such as the coronavirus pandemic[1]. The development of a pharmaceutical supply chain is one of the main elements in the quality of healthcare[2]. To realize this, it is essential to ensure the availability of patient data, while guaranteeing its safety and efficiency. Therefore, it

is necessary to collect and exchange patient health data between healthcare professionals, while taking into account the protection of patients' data and avoiding any modification. Hence the need for a shared and secure electronic medical record (EMR) makes the integration of blockchain technology for medical records a major issue. In fact, EMRs are digital representations of patients' paper charts that encompass comprehensive information regarding their medical history, diagnoses, treatments, medications, laboratory results, and other health-related data [30]. EMRs are predominantly utilized by healthcare providers to monitor and manage patient care within a single practice or healthcare facility. Given blockchain's ability to guarantee the interoperability, efficiency and security of medical data[3].

This paper aims to identify and compare various blockchain architectures proposed for EMRs in terms of performance criteria, including security, confidentiality, efficiency, interoperability, scalability, reliability, and storage. We conducted a systematic literature review to identify studies that propose blockchain architecture models for EMRs.

The remainder of this paper is organized as follows: Section 2 introduces the theoretical background of blockchain. Section 3 describes the methodology used to conduct this study. Section 4 presents the results. Section 5 develops the discussion and identifies research gaps. Section 6 offers proposals for future investigations and concludes the paper.

1 Theoretical Background

The blockchain is a decentralized, secure, and transparent database used to store information. It first appeared in 2008 with the publication of Bitcoin by Satoshi Nakamoto[4]. Since its creation, it has evolved considerably, and now has five versions ranging from Blockchain 1.0 to Blockchain 5.0 (Fig.1). Initially, Blockchain 1.0 is a basic version that tracks transactions and stores data across multiple machines, with information limited to values of items undergoing ownership changes over time. Blockchain 2.0 marks the emergence of Ethereum, an advanced iteration of cryptocurrency technology. Blockchain 3.0 broadens the application of decentralized systems, making them applicable to fields like healthcare, cybersecurity, supply chain management, and manufacturing. Blockchain 4.0 focuses on enhancing user experience in various sectors, aligning with the goals of Industry 4.0 and Healthcare 4.0. Blockchain 5.0 is the latest version of the blockchain and the future of this technology, it aims to reduce blockchain's traditional drawbacks and security issues[5, 6].

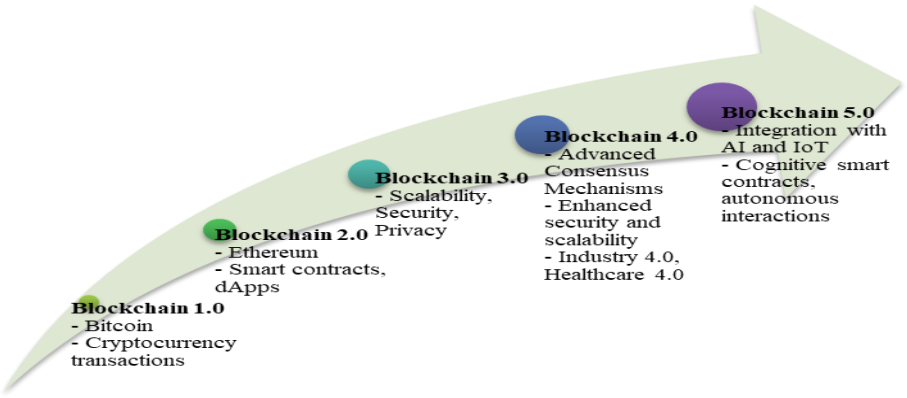

Fig.1. Evolution of Blockchain Technology[5, 6]

2 Research methodology

This paper evaluates the advancements and proposed solutions for integrating blockchain technology in EMRs. Our comparison criteria include security, interoperability, efficiency, scalability, confidentiality, reliability, and storage, which are the general performance criteria of blockchain in EMRs[7, 8]. These criteria were chosen because they represent the main challenges in ensuring successful and functional integration of blockchain in EMRs[9, 10]. Our methodology involves several steps: identifying and selecting relevant articles, analyzing and filtering those that propose blockchain architectures for EMRs, comparing the proposed architectures, and finally, presenting and synthesizing the results (Fig. 2).

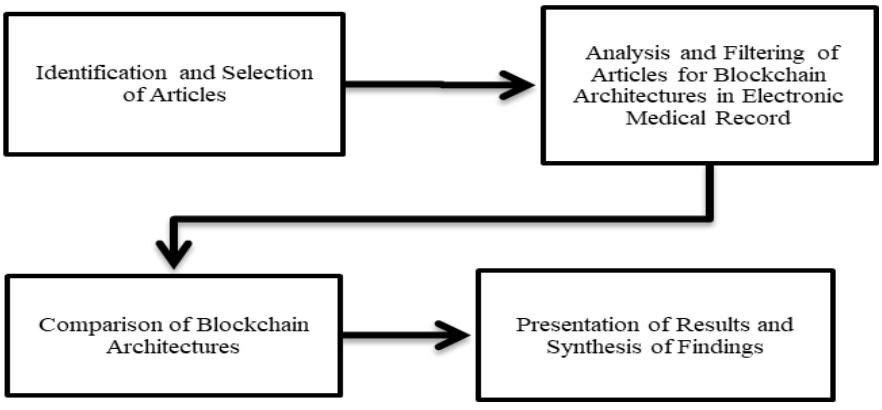

Fig.2. Research methodology

This study adopts a systematic approach to identify and analyze relevant literature on the application of blockchain technology in healthcare, with a specific focus on EMRs[11]. The Science Direct and Web of Science databases were chosen as the primary sources to ensure comprehensive coverage. In the first stage, carefully selected keywords such as "blockchain," "blockchain and healthcare," and "blockchain and electronic medical record" were utilized to include recent and relevant studies. The search was restricted to articles published between 2014 and 2024. This period witnessed a significant increase and widespread adoption of blockchain technology across various industries[12]. Additionally, the search was refined to include only review articles and original research articles written in English and available as open access. In the subsequent stage of our literature review, articles were chosen based on their specific focus on blockchain technology in EMRs. During this phase, full texts were examined to verify that authors proposed blockchain architecture models for EMRs in their publications (Table 1).

Table1. Inclusion criteria

Inclusion Criteria for the First Phase	-Keywords: “blockchain” “blockchain” and “healthcare” “blockchain” and “electronic medical record” -Publication between 2014 and 2024. -Written in English. -Review articles and original research articles -Available as open-access.
Inclusion Criteria for the Second Phase	The article proposed blockchain architecture for EMRs

3 Results

3.1 Annual Scientific Publications

The results of our initial literature review using the ScienceDirect and Web of Science databases with the following keywords: "blockchain," "blockchain and healthcare," and "blockchain and electronic medical record," show that there has been a continuous increase in publications on blockchain technology from 2014 to2024, particularly in the last six years (Fig. 3 and Fig. 4).

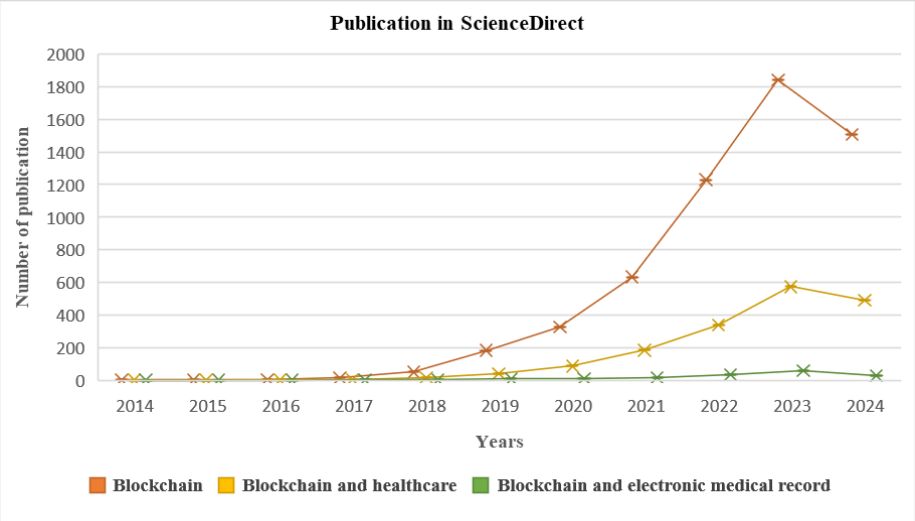

Fig.3. Annual Publications by Keywords in ScienceDirect

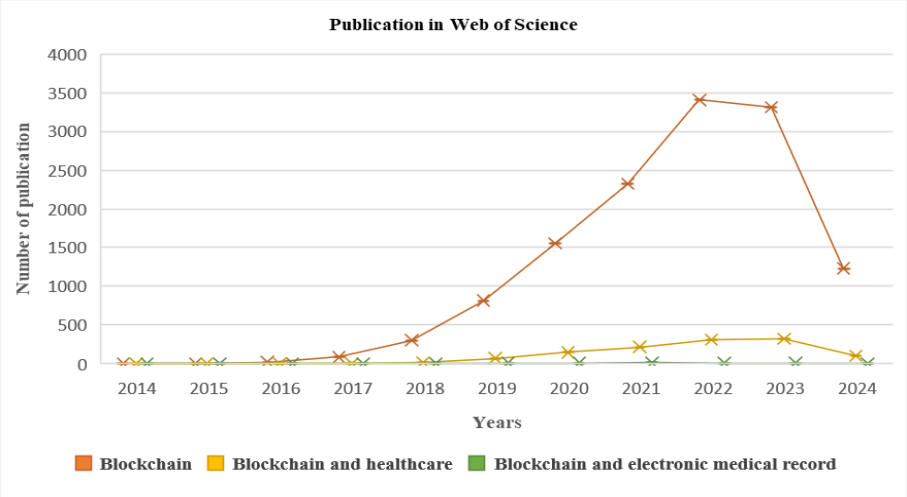

Fig.4. Annual Publications by Keywords in Web of Science

However, when we focus on the use of blockchain for EMRs, we notice that despite the increasing number of publications in this field, the number of studies still remains insufficient (Fig.5) This indicates a significant opportunity for further research and development to address the specific challenges and requirements of integrating blockchain technology into EMRs.

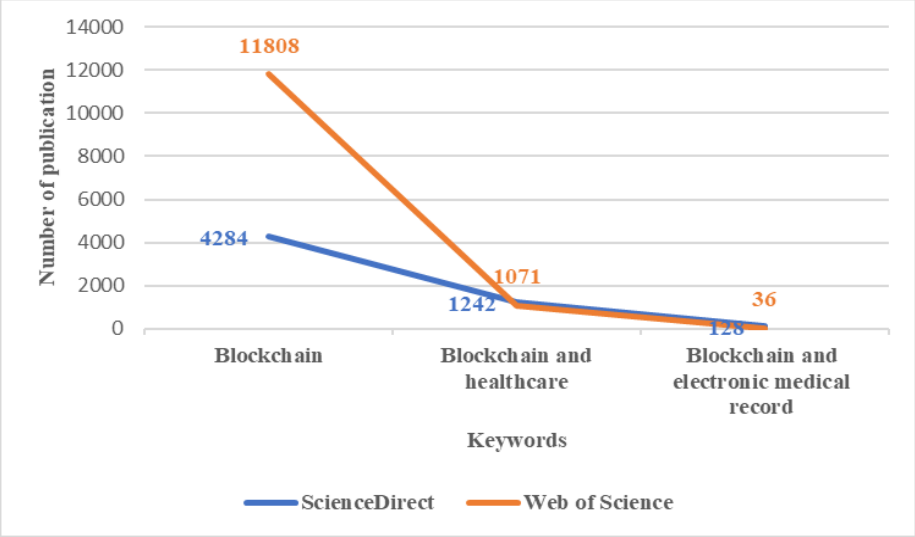

Fig.5. Total Publications in ScienceDirect and Web of Science by Keywords

3.2 Publications Proposing Blockchain Architectures for Electronic Medical Records

After conducting thorough initial research and a rigorous selection process involving verification of full-text articles (Fig.6), we selected 46 articles that specifically propose blockchain architectures for EMRs[13]. These articles were chosen from a total of 194 articles discussing blockchain and EMRs. Subsequently, we analyzed the selected articles based on our predefined performance criteria to effectively compare and contrast the proposed solutions. The results of this analysis are presented below.

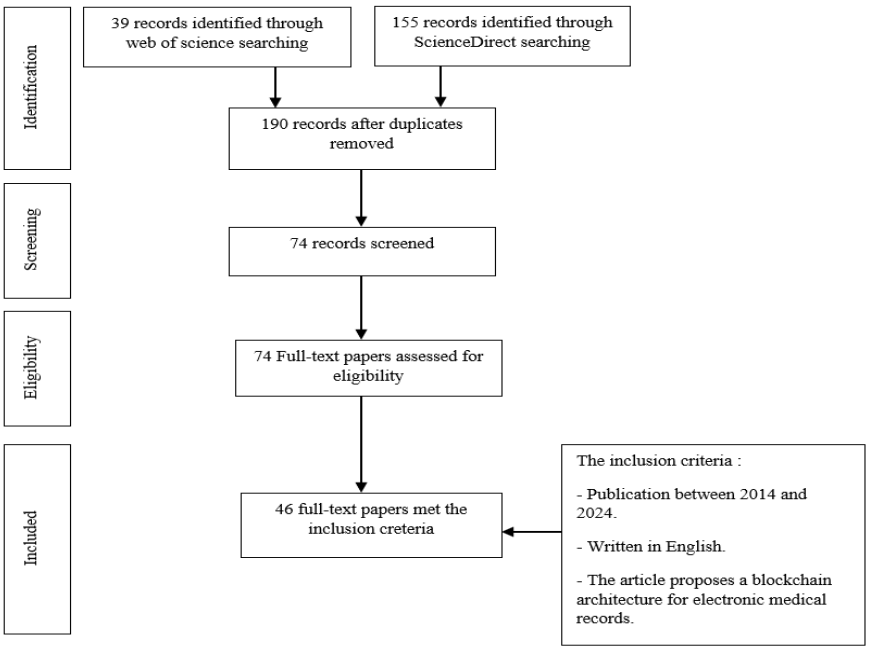

Fig.6. Steps of the Data Extraction and Filtration Process for Articles Proposing Blockchain Architectures for EMRs

3.3 Comparison Results of Proposed Blockchain Architectures for EMRs

Blockchain is a foundational technology recognized for its robust data integrity and decentralized nature, making it essential for ensuring secure, transparent, and reliable record keeping in healthcare applications, particularly EMRs[6]. After conducting an in-depth analysis of 46 articles from our systematic literature review, we extracted information corresponding to each blockchain architecture proposed for EMRs in the literature.

We identified the blockchain-based models utilized, extracted their descriptions and characteristics, documented the problems they addressed, and outlined their results, benefits, and limitations.

This comprehensive analysis aims to provide an in-depth understanding of the solutions that meet the predefined performance criteria for EMRs in this study. The results of this comparison are presented in Fig.7 and Fig.8, highlighting the number of architectures that meet the essential criteria of security, interoperability, efficiency, scalability, confidentiality, reliability, and storage for successful integration of blockchain into EMRs.

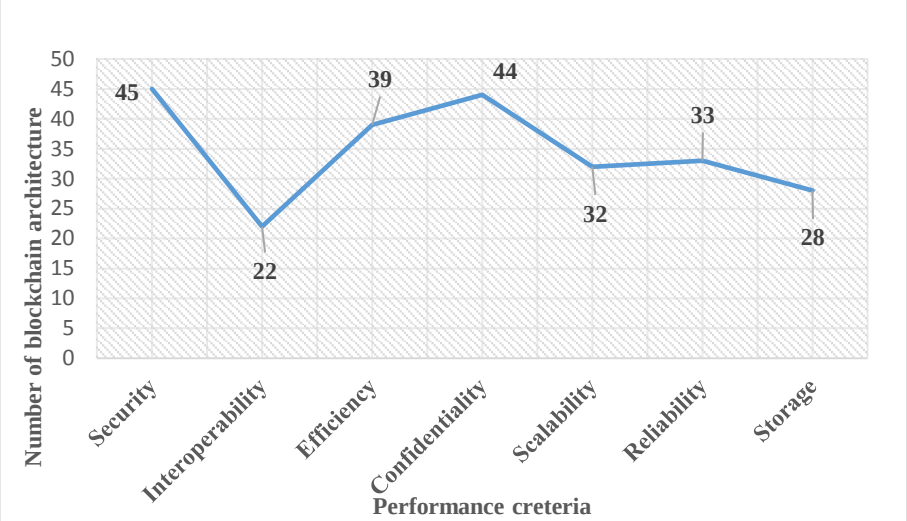

Fig.7. Blockchain architectures that satisfy each performance criteria for EMRs

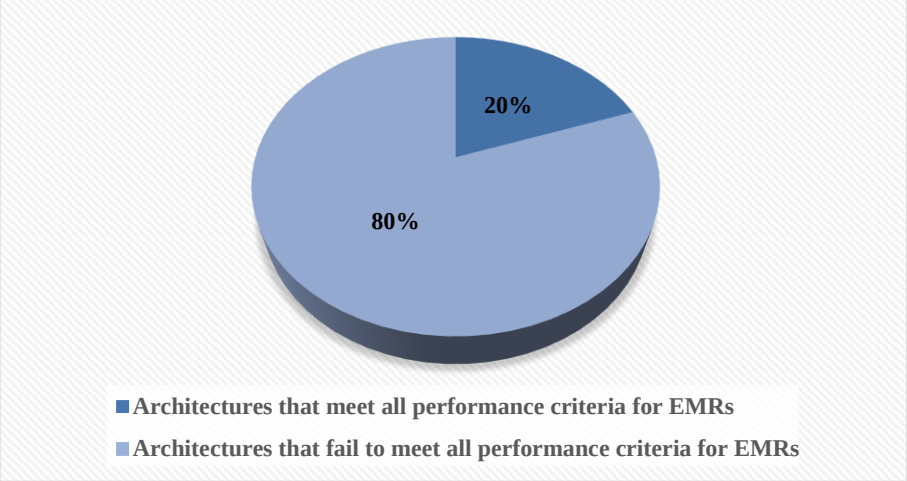

Fig.8. Evaluation of Blockchain Architectures: Meeting vs Failing Performance Criteria for EMRs

Analyzing Fig.7 and Fig.8, we observe that 80% of the proposed blockchain architecture models for EMRs do not meet all the predefined performance criteria, while only 20% meet all of them. The main gaps lie in interoperability, scalability, and storage. Therefore, additional studies are necessary to develop models that fully satisfy these criteria. This highlights the need for further research to address these remaining challenges and achieve comprehensive solutions for integrating blockchain into EMRs.

4 Discussion and Research Gaps

During our research, we discovered that variety of blockchain architecture models for EMRs have been created to improve security, interoperability, efficiency, scalability, reliability and confidentiality of EMRs. To accomplish this, multiple algorithms and techniques have been used. In particular, the system's security is ensured by integrating blockchain technology, Advanced Encryption Standard(AES), and smart contracts[14–16].Interoperability can be achieved by integrating traditional relational databases, using open electronic health record(open HER) interoperability standards, and sharing medical data securely between systems[17, 15, 18]. A responsive infrastructure, efficient data management in decentralized systems, and optimization techniques such as caching and partitioning Maintain high efficiency[19, 20, 15]. The key to scalability is designed scalability, tiered architecture, and distributed storage optimized for big data[20–22]. Protocols such as Searchable Symmetric Encryption (SSE), Attribute-Based Encryption (ABE), and Hyperledger Fabric (HLF) ensure confidentiality[23–25]. The reliability of blockchain-based records management is achieved using measures such as decentralized storage, attack resistance, and blockchain-based records management[26–28]. To address storage limitations, Interplanetary File System(IPFS) in combination with blockchain is used to fragment data and enhance security[21, 29, 26]. According to our analysis of blockchain performance criteria for EMRs across different architectures, only a few of these architectures meet all performance criteria, while the majority have limitations in terms of interoperability, scaling, and data storage with existing systems. Additionally, these models must be validated in real-world environments in order to demonstrate their practical effectiveness and reliability. Closing these gaps is essential to ensure that blockchain technology can meet the rigorous requirements of the healthcare sector and advance its implementation in EMRs.

5 Conclusion

The purpose of this study was to identify suitable blockchain architectures for EMRs. In order to achieve this objective, a systematic literature review was conducted using two digital databases. Based on the results obtained, different blockchain architectures for EMRs were examined and compared to determine which ones met the predefined performance criteria.

As a result of this analysis, gaps and trends in the proposed models have been identified, providing a foundation for future research aimed at improving these architectures and finding the optimal model for EMRs. This approach aims to ensure that patient information can be stored and shared securely and confidentially, thereby improving the pharmaceutical supply chain and subsequent quality of care.

The results of this study present an opportunity for future research aimed at optimizing the integration of blockchain with EMRs. Through this optimization, EMRs can be made more secure, interoperable, efficient, scalable, confidential, reliable, and capable of handling larger data volumes.

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