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Retraction

Retracted: Interoperability Requirements for Blockchain-Enabled Electronic Health Records in Healthcare: A Systematic Review and Open Research Challenges

Security and Communication Networks

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] F. A. Reegu, H. Abas, A. Jabbari et al., "Interoperability Requirements for Blockchain-Enabled Electronic Health Records in Healthcare: A Systematic Review and Open Research Challenges," *Security and Communication Networks*, vol. 2022, Article ID 9227343, 11 pages, 2022.

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Review Article

Interoperability Requirements for Blockchain-Enabled Electronic Health Records in Healthcare: A Systematic Review and Open Research Challenges

Faheem Ahmad Reegu,[1] **Hafiza Abas**,[1] **Abdoh Jabbari**,[2] **Rudzidatul Akmam**,[1] **Mueen Uddin**,[3] **Chih-Ming Wu**,[4] **Chin-Ling Chen**,[5,6,7] **and Osamah Ibrahim Khalaf**[8]

[1]*Razak Faculty of Technology and Informatics, Universiti Teknologi, Johor Bahru 50480, Malaysia*
[2]*College of Computer Science and IT, Jazan University, Jazan 45142, Saudi Arabia*
[3]*College of Computing and Information Technology, University of Doha for Science and Technology, Doha 24449, Qatar*
[4]*School of Civil Engineering and Architecture, Xiamen University of Technology, Xiamen 361024, China*
[5]*School of Information Engineering, Changchun Sci-Tech University, Changchun 130600, China*
[6]*School of Computer and Information Engineering, Xiamen University of Technology, Xiamen 361024, China*
[7]*Department of Computer Science and Information Engineering, Chaoyang University of Technology, Taichung 41349, Taiwan*
[8]*Al-Nahrain University, Al-Nahrain Nanorenewable Energy Research Center, Baghdad, Iraq*

Correspondence should be addressed to Faheem Ahmad Reegu; farfaheem6211@gmail.com

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A distributed ledger system blockchain proves to be worthy in the domain of healthcare due to its enormous applications and benefits. Peer-to-peer devolved transactions in an allocated way make the blockchain an efficient and modern tool to be utilized in healthcare as a solution to problems and challenges. The traditional healthcare system utilizes classical approaches to manage and maintain the EHR and cross-domain implementation. Therefore, a systematic investigation is necessary to find the current research trends, challenges, and solutions to implement blockchain to address the challenges. The motivation of this study is to pave the way for future research to find more problem-specific solutions by implementing blockchain to make the healthcare system more robust. The presented systematic survey provides the visualization and graphical representation of current methodologies, challenges, and future directions. The bibliometric analysis has been performed on the published studies in Scopus from 2017 to 2021. The publication published in the first three months of 2021 in the domain of healthcare using blockchain has also been reviewed to find the latest trends in the blockchain. The study covers multiple challenges in the presented systematic literature review, especially the interoperability of blockchain-based systems in the healthcare domain. The presented study results show the top trending research topics, top-ranked authors, and top institutes focusing on blockchain around the world. The proposed study provides a baseline for future challenges and solutions related to blockchain implementation in healthcare.

1. Introduction

Satoshi Nakamoto introduced blockchain as a cryptocurrency known as bitcoin in the financial sector. The framework of this blockchain was suggested as a peer-to-peer electronic cash system. After that, researchers showed great interest in the decentralized sharing method. The blockchain technology market is still growing [1, 2]. Blockchain development is divided into three stages, including blockchain 1.0, 2.0, and 3.0. The first two stages, blockchain 1.0 and 2.0, deal with economics and trade, respectively. In the finance sector, it focuses on bitcoin and cryptocurrency. At the same time, a transaction includes property transfer, contracts, confirmation, and registration. Blockchain 3.0 includes healthcare, science, government, and education applications [3]. After blockchain 3.0

revolution, researchers attained much hope to deal with current conventional issues in the healthcare sector.

In the early 90s, conventional healthcare organizations have started to adopt the new health information technology (HIT) infrastructure [4]. The continuous evolution of this technology introduced the Industrial Revolution 4.0 (IR 4.0). The IR 4.0 put basis the concept of Health 4.0. The focus of Health 4.0 is to develop trust among stakeholders, establish a sharing procedure, facilitate data management, and protect security issues [5]. The computer-based documentation and recordings are the backbone of HIT infrastructure. These are known as electronic health records (EHRs). EHRs consist of sensitive private information of patients for the recognition and treatment of diseases. This information is the trusted source of healthcare intelligence. EHR is a digital structure of patient data that can store and share among multiple health providers, clinics, and hospitals [6].

In distributed systems, interoperability is a crucial element and defined as the ability of a software or computer system to split, process, and distribute data. According to ISO3, the interoperability of EHR is termed as the effective communication of several domains without compromising the concept of disseminated EHR [7]. Mainly, interoperability is divided into three types semantic, syntactic, and organizational [8]. Semantic interoperability represents the tools and models utilized in designing interoperable platforms. While syntactic operability includes the platform, designing, or developing compatible interfaces according to the concerned field and specific guidelines. Different applications cooperate to exchange and share data utilizing interoperable functions [9]. Organizational interoperability is the working relationship between political, legal, and social entities to exchange information and achieve common interests. Researchers have introduced some generic interoperable systems [10, 11]. These models focused on semantic, syntactic, and organizational interoperability. The interoperable systems have many challenges, but security is the biggest issue [12]. An interoperable system should have the following characteristics: (i) openness, (ii) scalability, (iii) flexibility, and (iv) portability.

Recently, the interoperable systems pushed towards patient-driven interoperability. In these systems, the exchange data is patient-driven and patient-mediated. This patient-driven interoperability trend has the potential to introduce new techniques and models for information sharing in the healthcare system. However, this trend brings new challenges about privacy, security, technology, governance, and incentives [13]. These issues must be resolved for patient-driven information sharing models because most of these issues are still not addressed in traditional interoperability [14]. Blockchain is a new technology that can improve interoperability. This technology emphasizes on encryption, distribution, and sharing of healthcare data. Blockchain can further help in clinical decision-making [15].

The current trends of blockchain in the healthcare industry have been presented in the several SLRs and have cover challenges like data integrity, data security, data privacy, and scalability. The presented SLR has addressed the most challenging trend in the healthcare system using blockchain is interoperability. The interoperability of system in healthcare proved its effectiveness in achieving multiple goals and solution to multiple problems in EHRs as well. Interoperable systems in healthcare will improve data integrity, data security, and cross-platform implementation with robust integration in different ecosystems of healthcare industry.

2. Methodology

Alan Pritchard introduced the idea of bibliometric analysis in 1969 [16]. Bibliometric research and analysis related to the information sciences field implemented quantitative techniques to evaluate the bibliographic content [17]. The growth of information and communication technology accelerated the progress of bibliometric analysis-related studies through quick access to academic articles [18].

A bibliometric survey is a systematic procedure to discover new research trends in the specified field of interest. This investigation is based on academic research studies published in different scientific databases [19, 20]. The focus of a bibliometric study is to identify the challenges and development of a specific phenomenon by understanding the features of academic publications. The analysis incorporates many techniques and methodologies to examine the qualitative and quantitative developments in a specified research field. The above attributes urge the use of bibliometric analysis techniques in different fields [16, 18].

The investigation of a specified research field is not the only aim. This study utilizes different techniques and investigates the systematic approach to analyze the cause and effects of research trends in blockchain-based EHR models and interoperable systems.

2.1. Data Extraction Technique. Elsevier stated that Scopus is the main database of scientific research. It includes multidisciplinary computational methodologies and research studies. The Scopus website includes 69 million research publications in its archive and consists of 34,346 peer-reviewed assessed papers. The acceptance or rejection of these papers is approved by the Content Selection and Advisory Board (CSAB) [19]. Data sourcing took place between June 13 and June 15, 2021. The areas of research of authors are blockchain-based EHR and interoperability. Therefore, the fundamental theme of sourcing is blockchain and healthcare.

The search found a total of 184 documents. The oldest articles are from 2017, and the latest articles are found from 2021. After evaluation, 08 articles are excluded because these are non-English articles identified by their title and abstract. Therefore, after the exclusion of 08 articles, 176 articles were retained for further assessment. The data extraction is shown in Figure 1.

2.2. Maps of Bibliography. The tool used for bibliometric analysis is VOS viewer, software version 1.6.14. The Center for Science and Technology Studies, Leiden University, Netherlands, developed this tool. This study used entities such as countries and author keywords for bibliographic mapping in VOS viewer. This tool collects bibliometric data

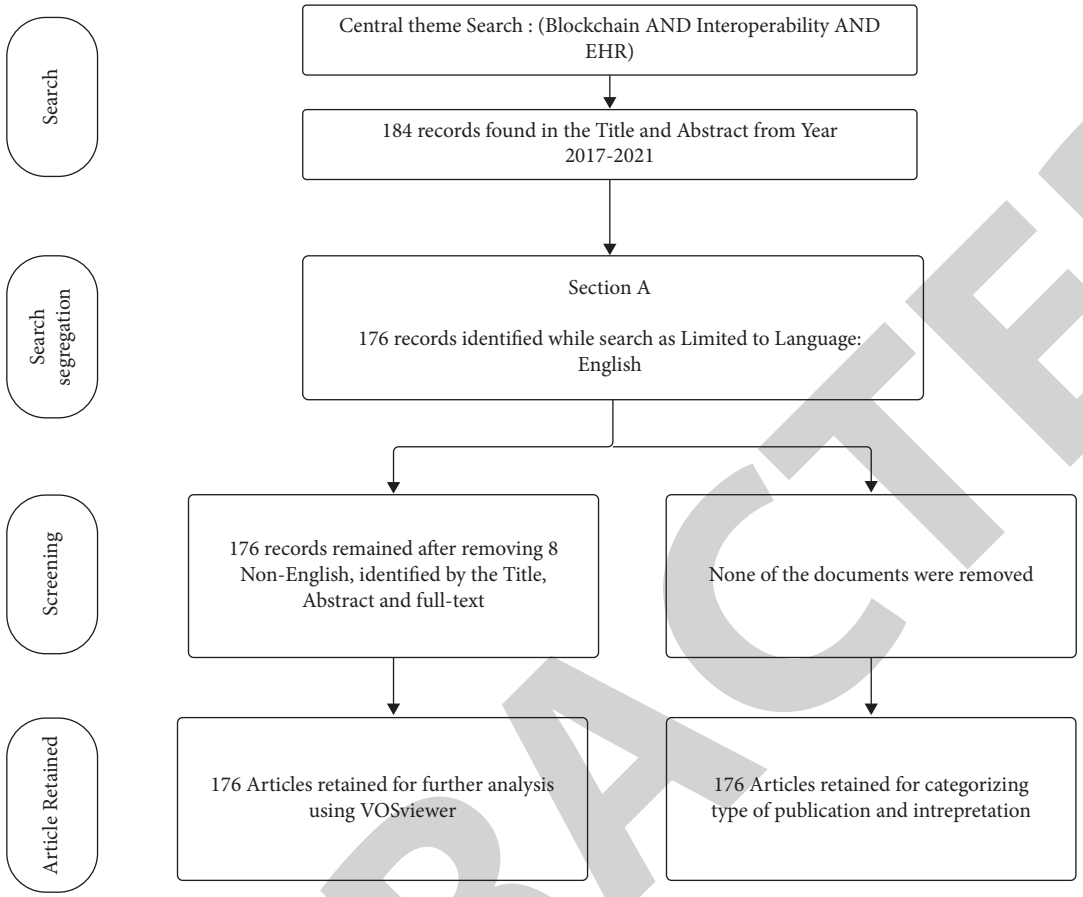

Figure 1: Flowchart illustrating data collection.

generates graphical maps. These maps are based on co-authorship, co-citation, co-occurrence of keywords, and bibliometric coupling. Therefore, bibliometric data, citation details, and author keywords are excluded from the Scopus data to create and visualize the bibliographic maps. For this purpose, the information of 176 articles in the CSV file was given to the VOS viewer. The entities are also known as an item of interest. Any two items that have strength can be interlinked. In VOS viewer, an interlink is represented by a curved line. A positive value indicates the strength of the link. A greater value denotes that the strength of the link is high. The number of journals published by two countries determines the co-authorship with affiliations and co-authors. The link strength determines the overall strength. The co-occurrence link strength is designated as the number of journals having two keywords together.

2.3. Co-Authorship Analysis. Co-authorship estimates the most systematic set of articles with the highest degree of shared publications. In this analysis, the bibliographic network indicates the links among researchers, research institutions, and countries based on the number of journals authored mutually. Figure 2 shows that the bibliographic map of co-authorship has three clusters. The closely related nodes make a cluster. In the network, a node is allocated exactly to one cluster [21, 22]. The resolution parameter determines the number of clusters. To interpret Figure 1, an example is that author Chang H. in cluster 1 has four links with one publication in the year 2018. The link strength is one between the authors. Similarly, author Nayyar A. in cluster 2 has 11 links, two articles with an average year of publication 2019.5 (mid-2019).

Figure 3 shows that from 52 countries, 30 countries have 62 links. The link strength of these 62 links is 73. Therefore, 30 countries were included in this study to analyze the co-authorship. The United States and the United Kingdom have the link strength of 3. High link values have higher link strength.

2.3.1. Analysis of Co-Occurrence of Author Keywords. The repeated keywords are analyzed in the co-occurrence of author keywords. These keywords are present in the same article, usually after keywords and introduction [17]. It is to be noted that we consider author keywords in this study, not index keywords. We analyzed a total of 294 author keywords from 176 articles. These 294 author keywords were recorded in the VOS viewer, and the minimum co-occurrence number of a keyword is set to 05. Only 08 keywords touch the threshold value of 294 keywords. Then, 16 keywords (5%) met the threshold value for co-occurrence number 4, and 29 keywords (9%) for co-occurrence number 3. The author keywords are shown in Figure 4, where the co-occurrence number is set to two and meets the threshold value of 31 words.

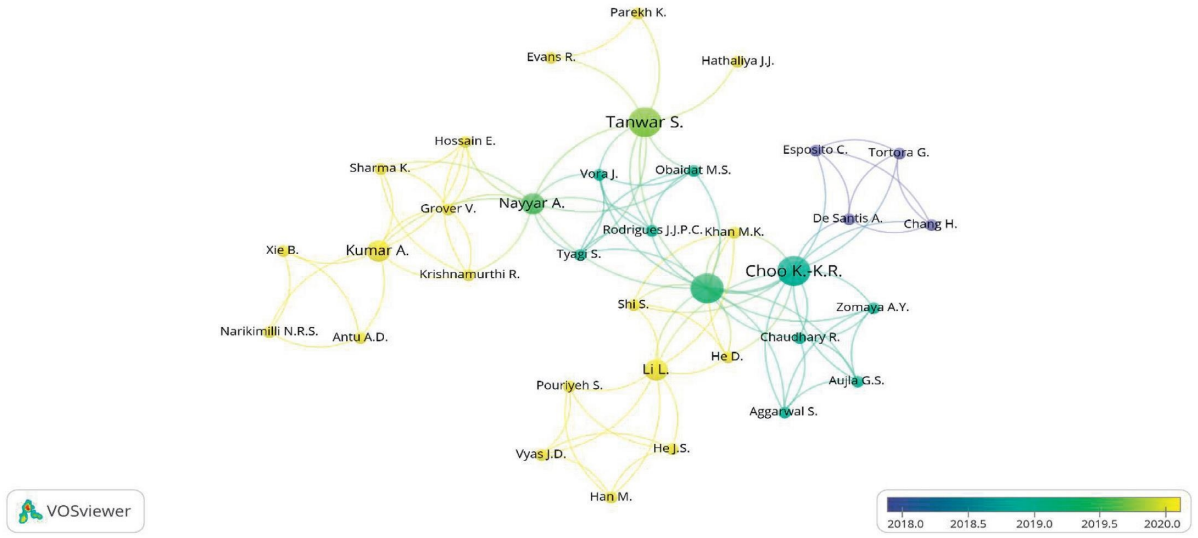

Figure 2: Author's name-based bibliographic map.

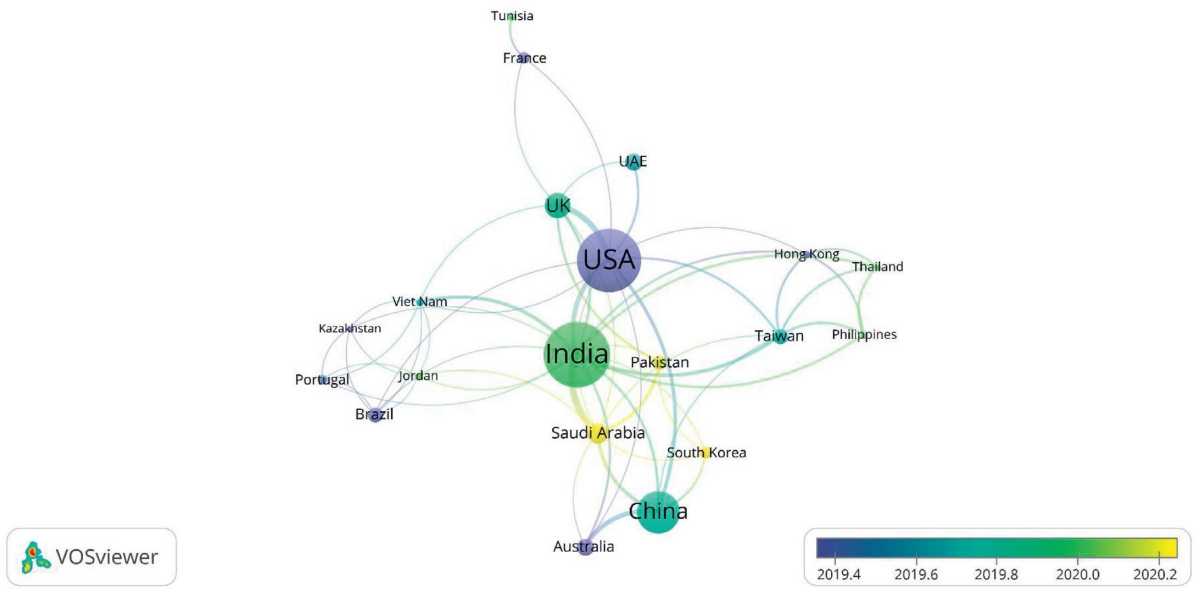

Figure 3: Country-based bibliographic map of researchers.

Some keywords represent the same word. For example, ehr or EHR refers to the electronic health record. Moreover, IoT is the short form of the Internet of Things. Therefore, a few same-meaning keywords were removed. The most often used keywords are e-health (04 times), privacy (7 times), decentralization (7 times), security (9 times), Internet of things (9 times), smart contacts (10 times), healthcare (12 times), and blockchain (65 times).

Researchers in [23] stated that "keywords analysis provides an efficient plan to explore the knowledge structure of research fields. Additionally, it also investigates the recent trends within the research domain after analyzing the recent trends within the research domains." After analyzing the author's keywords, it is concluded that security, privacy, and decentralization are the most significant part of the research in blockchain-based healthcare systems [24, 25].

3. Finding and Analysis

3.1. Sourcing Strategy. Research articles published from 2017 to 2021 expressing the interoperability of blockchain-based systems in healthcare are shown in Figure 5. The concept of blockchain came into existence first in 2008 [26, 27]. Since 2010, researchers are trying to implement blockchain in other domains after its successful implementation in finance management [28]. Research articles published in the top-

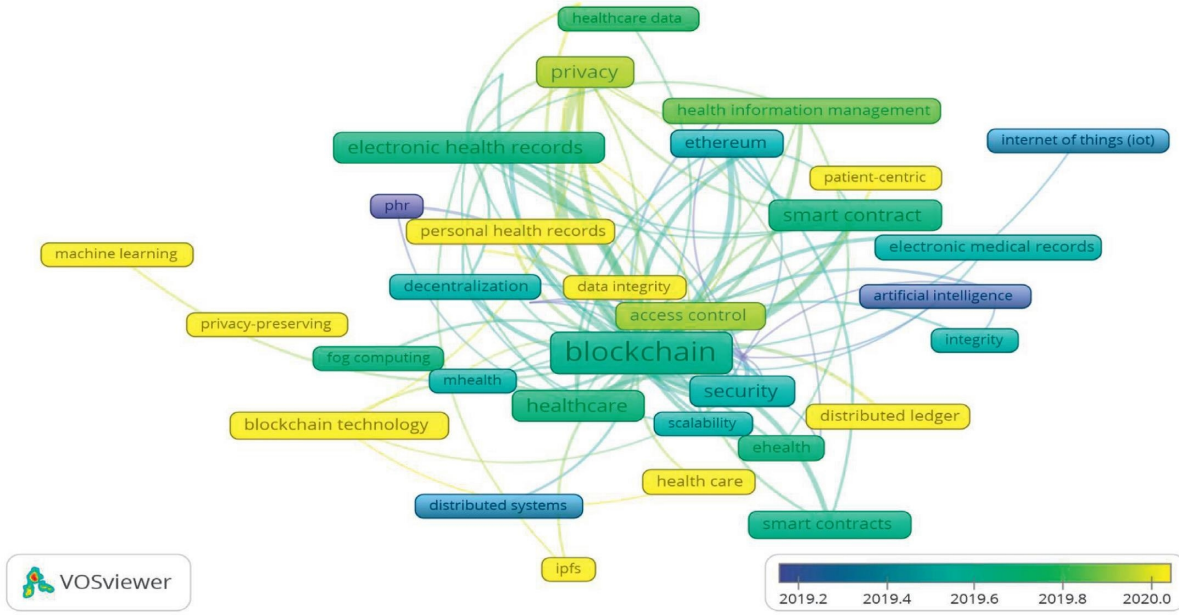

Figure 4: Keywords-based researcher bibliometric map.

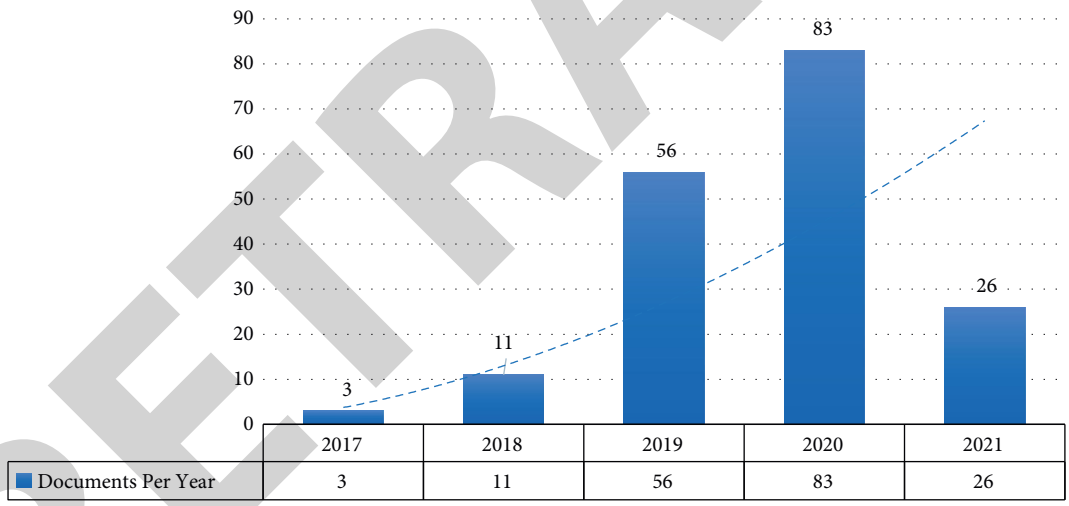

Figure 5: Manuscripts published on Scopus from 2017 to 2021.

ranked world-renowned research journals show the representation of blockchain technology in the healthcare domain. In the early years only, a few publications can be found on the top-ranked journals stating the blockchain implementation in the health care field in terms of interoperability. The year 2018 and onwards shows a significant increase in number of publication on blockchain interoperability in the field of healthcare. The increase in the research publications represents the importance and interoperability of blockchain in healthcare systems as a trending solution to healthcare problems [29].

The published articles mainly focused on the structure of blockchain and system development in a quantitative way. The analysis of current research shows that the research being done in the field of healthcare to implement blockchain does not have compliance to interoperability.

The upcoming blockchain models can become robust and increase their efficiency by following the unique architecture of blockchain. Different projects in the healthcare department are using different prototypes of blockchain to address and manage the challenges in the healthcare system. The quantitative and qualitative research shows that the implementation of blockchain in healthcare can reduce cost [26, 30], improve scalability and interoperability [31, 32], and data security challenges [33, 34].

The studied articles show that the focus of the researchers is to develop architecture and prototypes to improve the performance of blockchain models. Several

architectures of blockchain have been presented in healthcare to utilize the robustness of blockchain technology. The humane interaction with the blockchain-based system is very important; according to the researchers, they are implanting novel methods and models to make the interoperability of blockchain-based models efficient for end-users. Researchers are improving the existing models and introducing a novel blockchain-based healthcare system efficient and user-welcoming.

Researchers [35] revealed that the end-user is unwilling to accept new technology, which is the main hurdle in successfully implementing blockchain technology in the healthcare system. The research finding presents an overview of the user adaption of blockchain technology. The quantitative research can provide an assessment [35] of end-user adoption of blockchain technology in the healthcare system [36, 37].

3.2. Journals and Publisher. An analysis of research journals has been presented in the manuscript to show the analysis of blockchain technology implementation and interoperability in healthcare. The publication of the blockchain research in the journals shows the motivation of journals. The most prominent journal that publishes blockchain technology research in the healthcare system is given in Table 1. The results show that the IEEE Access journals have published 15 publications on blockchain interoperability in the domain of healthcare, followed by the Journal of Medical Internet Research with ten publications.

3.3. Institutions and Territories. The top 10 organizations offering blockchain technology implementation in the healthcare system in terms of interoperability are shown in Figure 6. The results show that the United Arab Emirates University leads all of them presented in the figure with the publication of 06 articles in the blockchain technology in healthcare, followed by Universidad do Vale do Rio dos Sinos and King Saud University with publication of 05 manuscripts. Deakin University published 5 articles and King Abdulaziz University published 4 articles. Five other institutions published 3 articles. The publication affiliation method varies from institution to institution, so the number of publications can be changed.

Different institutes spend a huge amount on developing and publishing novel works and projects. Several journals have affiliations with institutes, who provide financial aid for human development and novel research. The financial aid makes the researcher focus on real-world problems, and at the end, they come up with novel research due to the incentive program of institutions.

The number of publications by the top ten countries is shown in Figure 6. India leads the table by publishing the 36 journals on the use of blockchain technology in healthcare. The United States published 39 journals, followed by China with 25 research publications. The publications by other countries to use blockchain technology implementation in the domain of healthcare are as follows: The United Kingdom (13 publications), Saudi Arabia (10 publications), Australia and United Arab Emirates (8 publications), Brazil and Taiwan (7 publications), and Canada (6 publications).

India published the most articles in the domain of healthcare using blockchain technology, but India is a developing country. China and the United States are developed countries, and most of the top-ranked journal has their origin from China and the United States.

3.4. Leading Researchers. The top-ranked researchers in the domain of healthcare using blockchain to overcome the challenges of interoperability and blockchain are from India followed by the United Arab Emirates. The authors belonging countries are as follows: India (07 authors), United Arab Emirates (2 authors), The United States, Brazil, France, Qatar, and Saudi Arabia (1 author from each country). The researchers Choo and K.K.R leads the table with the greatest number of 825 publications with 15603 citations and h-index of 65. The author ranked second from India is Kumar with 571 publications having 12376 citations and h-index of 60. This author has affiliation with Thapar Institute of Engineering and Technology, India. The researcher Tanwar who ranked 3rd is from India with 182 publications having 2552 citations and h-index of 32. The top 15 ranked authors are given in Table 2.

3.5. Blockchain in the Domain of Healthcare. The presented survey only includes the research comprising blockchain technology in the domain of healthcare by taking interoperability into consideration. In Figure 7, blockchain implementation in the different domains has been presented. Most of the publications in blockchain are from the engineering domain like engineering, computer science, material sciences, physics, and astronomy, which covers almost 70%. Research articles from other domains like medicine, environmental science, social science, decision science, energy, and mathematics cover 21%. The publications selected are according to the human development factor and acceptance of publications.

3.6. Interoperable Blockchain Research Trends. In Figure 8, manuscript published on Scopus from January to March 2021. The articles, book chapters, conference papers published on Scopus from January to March 2021 are illustrated. A total number of 86 articles were published, followed by 68 conference papers. The review articles are 20 followed by eight books chapters published during the abovementioned shorter span of time, which shows that the blockchain technology in the domain of healthcare due to interoperability is a hot and trending research area. The researchers have investigated the research articles that consider the blockchain interoperability, scalability, and data security challenges and comprehensive solutions and research gasps.

The study shows that the cross-domain implementation of EHR in the healthcare industry lacks interoperability which can be addressed using blockchain in the healthcare industry. The implantation of blockchain in the healthcare industry gets the privacy and scalability as well. The

Table 1: Top fiver publishers, journals, and number of publications from 2017 to 2021.

Sr. #	Source title	Publisher	Number of publications	Cite score (2019)
1	IEEE Access	IEEE	15	3.9
2	Journal of Medical Internet Research	JMIR Publications Inc.	10	3.9
3	Journal of Network and Computer Applications	Academic Press	4	13.8
4	Applied Sciences (Switzerland)	MDPI AG	3	2.4
5	International Journal of Medical Informatics	Elsevier Ireland Ltd	3	5.8

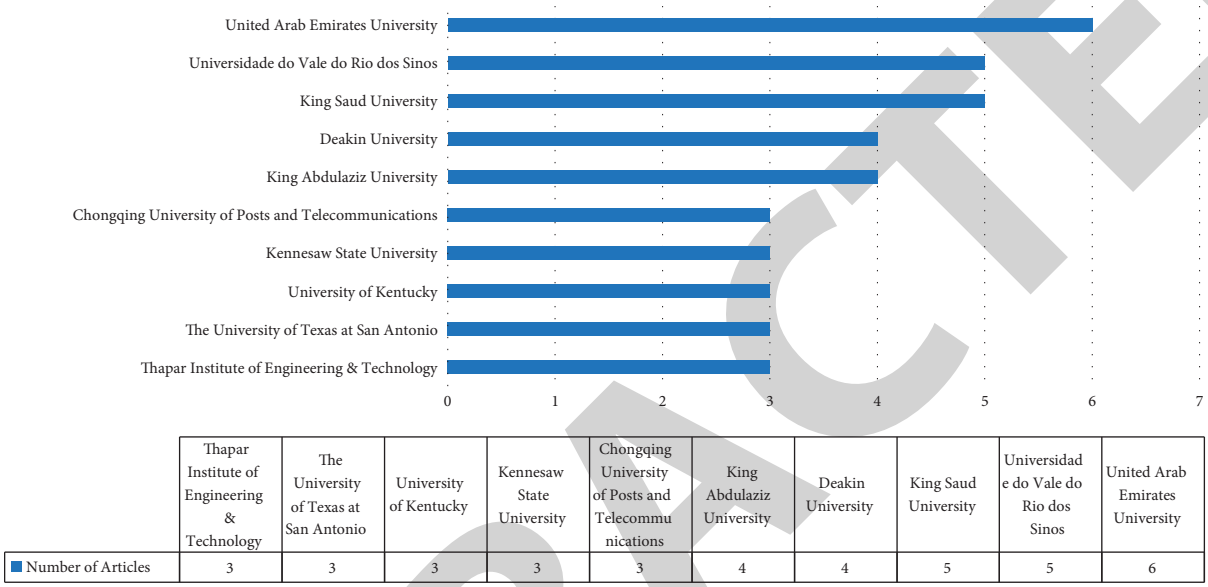

Figure 6: Articles published by the world top ten countries.

Table 2: Top 15 authors discussed in the study.

S. no.	Author name	Scopus ID	Author's 1st journal	Total publication	h-index	Total citations	Current affiliation	Country
1	Ismail L.	25926460300	1997	45	11	299	United Arab Emirates University	United Arab Emirates
2	Materwala H.	57203418499	2018	16	3	66	United Arab Emirates University	United Arab Emirates
3	Roehrs A.	55419909200	2012	11	4	268	Universidade do Vale do Rio dos Sinos	Brazil
4	Agrawal A.	26632917100	2009	64	13	417	Babasaheb Bhimrao Ambedkar University	India
5	Choo K.K.R.	57208540261	2004	825	65	15603	The University of Texas at San Antonio	United States
6	Fetais N.	55395468600	2008	33	5	72	Qatar University	Qatar
7	Khan R.A.	25724398200	2008	107	13	535	Babasaheb Bhimrao Ambedkar University	India
8	Kumar N.	57206866080	1994	571	60	12376	Thapar Institute of Engineering and Technology	India
9	Kumar R.	55492126400	2016	48	13	403	Babasaheb Bhimrao Ambedkar University	India
10	Tanwar S.	56576145100	2013	182	32	2552	Nirma University	India
11	da Costa C.A.	34976368800	2004	136	16	1088	Universidade do Vale do Rio dos Sinos	Brazil
12	Alenezi M.	55854089000	2013	79	13	468	Prince Sultan University	Saudi Arabia
13	Andola N.	57203193682	2018	11	2	27	VIT Bhopal University	India
14	Ansari M.T.J.	57202821054	2018	10	4	52	Integral University	India
15	Barkaoui K.	6602514483	1988	204	19	1721	CNAM Laboratoire Cédric	France

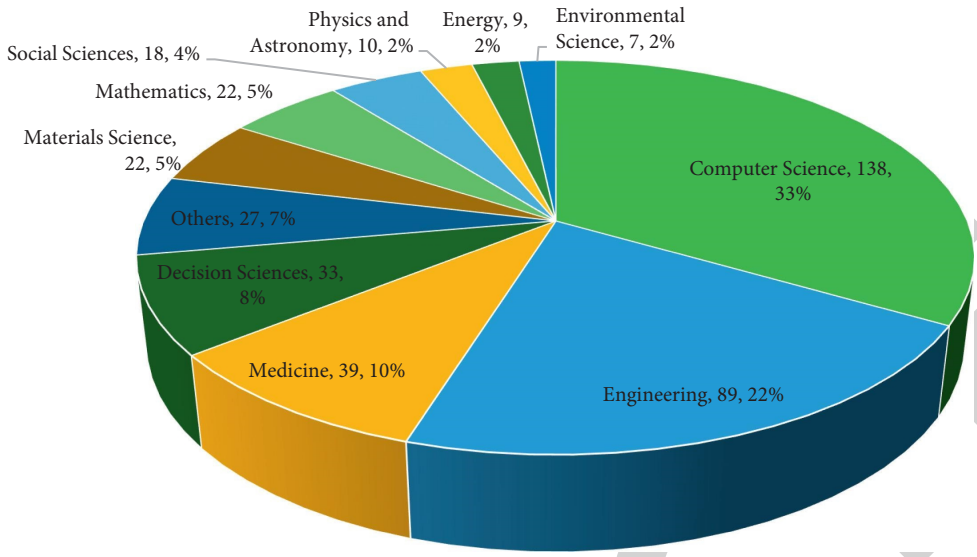

Figure 7: Diverse nature of blockchain research subject areas under the blockchain domain.

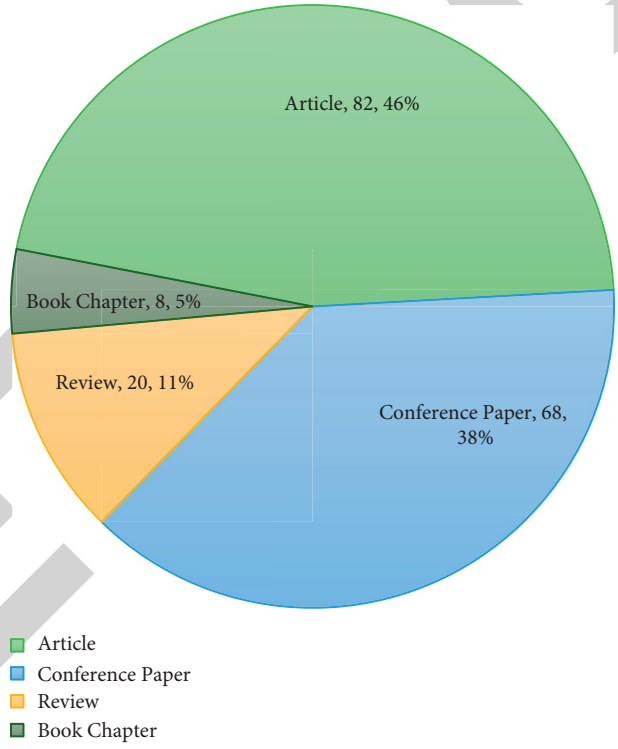

Figure 8: Manuscript published on Scopus from January to March 2021.

blockchain utilization in the healthcare system proved to be robust while maintaining patient records and diseases database as well. The blockchain privacy and authentication model increases the privacy and data security of patients as well as cross-domain implementation of healthcare application with data integrity.

The countries with the highest number of publications in the domain of EHR in the healthcare domain are given in Table 3. The results show that India leads the list with 43 publications followed by the United States with 39 publications. China, the United Kingdom, and Saudi Arabia have published 25, 13, and 10 articles, respectively. Australia and United Arab Emirates have published 8 publications each, Brazil and Taiwan have published 7 publications each, and Canada has published 6 articles in the domain of healthcare implementation of EHR in system management.

3.7. Open Issues and Challenges. This section describes some issues and challenges in EHR systems based on this

Table 3: Top 10 countries with the highest number of publications.

Rank	Country	Number of publication
1	India	43
2	The United States	39
3	China	25
4	The United Kingdom	13
5	Saudi Arabia	10
6	Australia	8
7	United Arab Emirates	8
8	Brazil	7
9	Taiwan	7
10	Canada	6

systematic literature review. Following issues have been observed, including:

(i) The healthcare facility must provide a minimum of one node to the blockchain to convert the servers into blockchain adapters. Another issue observed in the study is the scalability limitations of the blockchain protocol.

(ii) If the system is not deployed correctly, then it has a high risk of system failure. A healthcare provider cannot update the permission and grant access; therefore, when an unconscious patient reaches a medical center, the healthcare provider cannot access the patient's EHR information

(iii) The privacy of patients is a significant concern in EHR systems. The goal of data security is to restrict the access of unauthorized users. Data security is also a concern of healthcare providers to safeguard the patient's health information.

The cost is based on the lattice model. The model may contain many Gaussian distribution-based parameters. This model increases the communication cost, which is a major issue.

3.8. Study Limitations. Scopus database has been used in this review to analyze the blockchain technology implementation in the domain of health care. The researchers only included the studies that focused on blockchain in healthcare and discarded all the other domains presented by blockchain technology. A concise search has been performed from abstracts and titles of research articles by searching the terms "blockchain," "healthcare," and interoperability to narrow the search pyramid to more specific results. Several research articles did not appear in the research because they followed the different phrases and terms.

Phrases and terms: during the data search, the authors were limited. The articles written in the English language are only selected during the data acquisition phase. The article would have maximum global availability if written in English and sent to English journals. Therefore, that is the acceptable logic behind the articles written and published in English. The first author of each article has also been taken into consideration [34, 38]. The biasedness of the English language and first author name is the limitations of this study. The main factor that is the real reason for the limitation is that we only extracted articles from the Scopus database. The occurrence of authors and articles is resulted due to different keywords and phrases [39, 40]. The some of the researchers have published blockchain-based research articles in healthcare, and their data and articles are available only on their website [41, 42]. The authors claimed that such type of projects has been unnoticed. The bibliometric analysis changes rapidly with the addition of more articles. In the future, the survey should include other databases like Web of Science and Scopus to find the more relevant and specific research articles and trends. The in-depth data search strategy to be followed to get the more specific and trending research topics can be found in the domain of healthcare using blockchain interoperability [43, 44].

4. Discussion

In this SLR, we cover the latest trends of blockchain which are used in the healthcare to transform the entire ecosystem of healthcare in terms of interoperability, scalability, and cross-domain implementation. Different publications published to address the issue of interoperability in the healthcare domain using blockchain to maintain EHR have comprehensively and systematically reviewed. Different standards and techniques utilized to main EHR based on the blockchain model have been discussed, and based upon the robustness and effectiveness of the standards, the best standards have been discussed here. We classified the standards based upon interoperability, and the best one has been selected and discussed briefly in the article.

5. Conclusions and Future Work

The presented study explores blockchain interoperability in the domain of healthcare using the Scopus database. VOS viewer tool utilized to find the keyword and authors co-occurrence. The study sheds light and overviewed the research trends from published articles covering the use of blockchain in the healthcare field from 2017 to 2022. The studies showed rapid growth in articles in the domain of healthcare using blockchain. A concise summary has been presented of contributing and collaboration of countries, authors, and research institutes in the mentioned domain. The main contribution of this SLR is interoperability of the healthcare system using the trending technology blockchain. The study shows that the use of blockchain proved its robustness in achieving, data integrity, and the most important interoperability of the system and cross-domain implementation. The capacity and robustness of blockchain technology will make it a trending hot research area in the future.

This study may lead to future studies and research. In this study, we discuss different EHR models and answer the research questions. These answers to research questions may be utilized in the future to develop the EHR models or architectures that address the issues and challenges faced in blockchain-based electronic healthcare frameworks. Additionally, more exploration is required to resolve the current

issues in blockchain-based systems combined with the Internet of things (IoT) and decentralized blockchain combined with AI, cloud computing, and big data. The organizational level implementation should have the flexibility to adapt the cognitive solution by using natural language processing and monitoring contextual facts to increase the interoperability of blockchain-based EHRs [45].

Data Availability

The data used to support this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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