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A Systematic Literature Review of Recent Blockchain Platforms

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Abstract: Blockchain is an emerging technology based on the digital ledger in the distributed system. The decentralized trust is one of its prominent features that ensures better transparency. Blockchain-based systems also enhance data integrity, confidentiality, and anonymity by eliminating third-party involvement in completing the transactions. Many SLRs have been published related to blockchain recently, but no comprehensive and systematic study on blockchain platforms has been conducted. So, there is a need for an organized and systematic review of blockchain platforms. This paper has reported a systematic literature review on existing blockchain platforms. We have formulated two research questions to determine the major frameworks used to implement blockchain-based systems and how they differ in implementation and operation. We have identified eighty-five blockchain platforms. To provide comprehensive insights on blockchain platforms, we identified related technologies and provided a map for further research development on blockchain technology.

Keywords: blockchain; platforms; distributed ledger; privacy and security; data management; systematic literature review

مراجعة أدبية منهجية لمنصات سلسلة الكتل الحديثة

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المستخلص: تقنية سلسلة الكتل هي تقنية ناشئة اشتقت فكرتها من دفتر الاستاذ الرقمي في الانظمة الموزعة . وتعد الثقة اللامركزية إحدى ميزاتها البارزة التي تضمن شفافية البيانات والمعاملات بشكل أفضل. وتعمل الانظمة المستندة الى تقنية سلسلة الكتل لى تعزيز سلامة البيانات والسرية وعدم الكشف عن هوية البيانات من خلال القضاء على مشاركة الطرف الثالث في إكمال المعاملات. مؤخراً تم نشر العديد من الدراسات المنهجية التي تتناول هذه التقنية ولكن لم يتم إجراء أي دراسة شاملة ومنهجية حول المنصات المستخدمة في تقنية سلسلة الكتل والتي يتم من خلالها عمل التطبيقات والبرمجيات في هذه السلسلة ومن هنا برزت الحاجة لمراجعة منظمة ومنهجية لمنصات تقنية سلسلة الكتل (البلوكتشين) . تقدم هذه الورقة مراجعة منهجية للأدبيات حول منصات البلوكتشين الحالية. من خلال الاجابة على سؤالين بحثيين لتحديد الأطر الرئيسية المستخدمة لتنفيذ الأنظمة القائمة على البلوكتشين وكيفية اختلافها في التنفيذ والتشغيل. ولقد خلصت الدراسة الى تحديد خمسة وثمانين منصة بلوكتشين مستخدمة في هذه الانظمة وتوزيعها وفقا لخصائصها المميزة تبعا لاختلافاتها في التشغيل والتطبيق وخلاف ذلك ز.وتهدف الدراسة في مجملها لتقديم رؤى شاملة حول منصات البلوكتشين ، وتحديد التقنيات ذات الصلة ومما يجعلنا نوفر خارطة الطريق لمزيد من تطوير الأبحاث حول تكنولوجيا البلوكتشين .

الكلمات المفتاحية: سلسلة الكتل. منصات؛ دفتر الأستاذ الموزع ؛الخصوصية والأمن؛ إدارة البيانات؛ مراجعة الأدبيات المنهجية.

1. Introduction

Blockchain technology is quite popular nowadays in various domains where security is a concern. Around fourteen countries are now developing their official cryptocurrencies, and more than 300 companies are working with the Hyperledger blockchain [2]. More than two billion dollars were spent globally on developing blockchain-based infrastructures in 2018. The number of blockchain-related jobs posted on the LinkedIn site tripled over the last few years. It is expected that the global blockchain market value will be 39.7 billion dollars by the year 2025 [3], [4].

However, an in-depth study on recent blockchain platforms of various domains and their comparisons on a larger scale is absent in the present litereure. In this study, we have identified various blockchain platforms and related tools through a systematic literature review. We have found different types of blockchain platforms and their work approach with consensus algorithms and hash functions. Our study provides a broad guideline for future research and investment in the blockchain domain. The main contributions can be listed as:

- A through systematic literature review was carried out and identified contemporary blockchain platforms since no one has conducted such a study at this scale.
- Eighty-five blockchain platforms are identified and cataloged into subgroups.
- This study would help the readers to discover many different types of blockchain platforms, their implementation languages, and other distinctive features.

The article is organized as: a brief overview of blockchain structure, relevant terminology, its applications, and emerging challenges in Section 2. Section 3 describes a detailed research methodology and process statistics for the study. We report the data synthesis results in Section 4, which includes tables to present all the eighty-five blockchain platforms, relevant consensus algorithms, and hash functions. Section 5 includes a discussion of our study and a summary of previous SLRs on blockchain for future reference. We also have a short discussion to compare our study with previous relevant studies. Finally, we conclude with a future plan in Section 7 and precise the new trending in integrated blockchain in section 6.

2. Blockchain Overview

Blockchain technology has enormous potential to be implemented for any transaction system. It provides a decentralized solution for keeping records of all transactions. In contrast, a typical transaction system is centralized, where every data and operation is controlled and managed by an authentic third-party organization. Maintaining proper security is very challenging for such a centralized system [12].

In this section, we briefly discuss the structure of the blockchain. We briefly discussed related technological challenges and the possible use of blockchain in different domains.

2.1. The Structure of Blockchain

Blockchain is a distributed database or system connecting through a decentralized network. It consists of peer-to-peer networks to keep track of all transactions and activities in a linked sequence block. These transactions are broadcasted and shared with participating entities [12]. Each block holds timestamped transaction information that is secured by public-key. Once an element is added to the blockchain, it cannot be altered. Thus, it turned a blockchain into an immutable record of past activity.

Furthermore, the blockchain organizes and preserves the growing data record of participating nodes by maintaining the linked-list data structure in the distributed network. Each node in the linked-list is called a block, which is cryptographically linked with the previous node. The link includes the hash value of its content and crypto signature. So, it becomes impossible to alter a single block without changing the entire blockchain. This data structure is stored in different networks to improve the integrity and security of data. The data in a blockchain is recorded in a public ledger; it hence contains information of every completed transaction.

Miners are special nodes that verify the transactions and add them to a new block. They compute the hashed blocks and broadcast them to other miners, who will re-compute the hash blocks to ensure the data integrity. However, conflicting issues might come in the font when more than one miners will combat to compute and add the same hash code simultaneously. Thus, consensus algorithms need to define the rules and regulations for the miners when more than one of them will be involved in adding, altering, and deleting the same blockchain, as shown in Figure 1 [10].

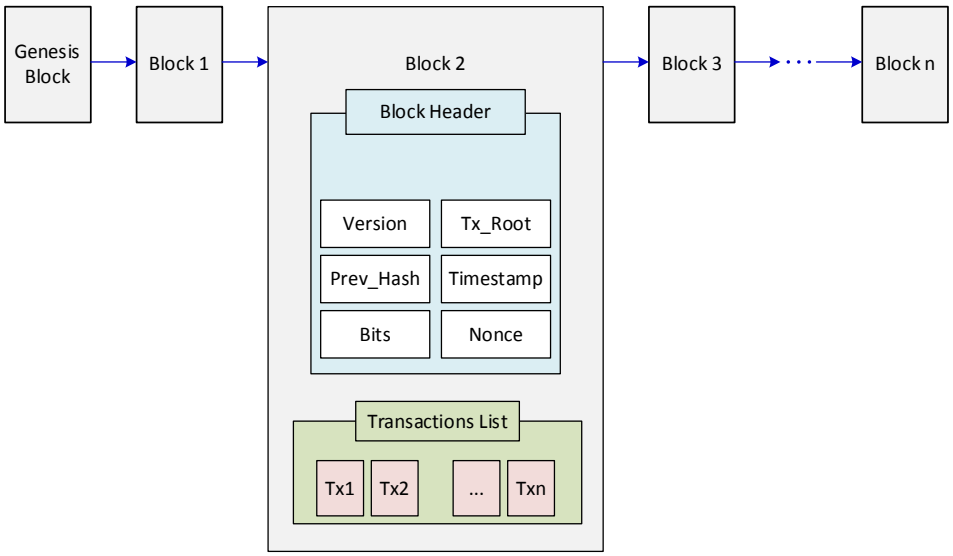

Figure 1. Miners block on Blockchain Technology

Blockchain plays the primary role of registering and authenticating all tasks performed within the system. Sensitive data are produced, stored, and exchanged inside the blockchain systems flawlessly by ensuring their privacy. Each operation of data (i.e., creation, alternative, or deletion) is registered in the blockchain. The blockchain guarantees authenticity and prevents unauthorized access to all blocks.

Since immutability exists, only those who keep the entire ledger can verify and access the transaction data. Blockchain specifications vary on different platforms. So deploying blockchain-based applications in a heterogeneous environment is a bit challenging. It delays mainstream adoptions of any emerging blockchain platforms [13].

2.1. Application of Blockchain

Initially, the blockchain was used as a decentralized, secure financial transaction platform. But its uses spread into other application domains due to transparent and secure data handling mechanisms. Blockchain applications can be grossly categorized into financial vs. non-financial domains [14]. In their study, Ahmed et al. [15] identified many non-financial applications of blockchain - including supply chain, digital media transfer (sale of art), remote services delivery, and distributed credentialing etc. Many research studies suggested that blockchain can handle IoT applications' data more robustly [16], [17]. Liu et al. [18] proposed a blockchain-enabled secure data-sharing scheme for the Mobile-edge computing (MEC) system that facilitates various IoT applications. According to Gao et al. [16] Big Data, Cloud, and Edge computing paradigms are also emerging application domains for blockchain. Medical Informatics is another popular domain for blockchain [19]. Salah et al. promoted the use of blockchain for distributed AI applications [20]. Ohama et al. [21] introduced B-FERL, a blockchain-based information-sharing framework for smart vehicles that is more resilient against malicious attacks.

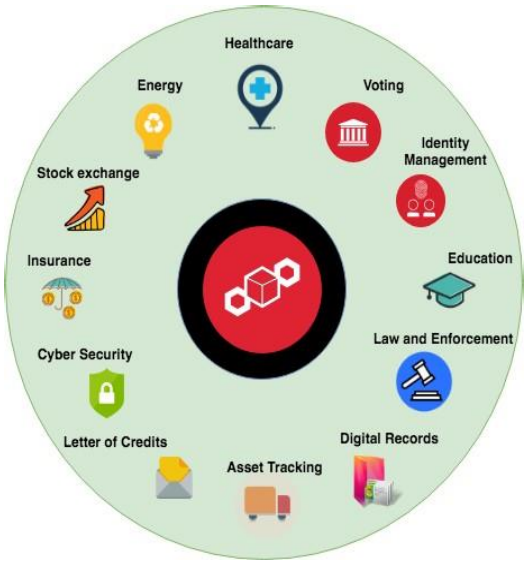

Figure 2. Application domains of Blockchain technology. [15]

2.3. Blockchain Challenges

Several systematic studies have been conducted to identify the challenges related to blockchain technology. We have included some of those studies in Table 5. In this section, we discuss key challenges identified in recent studies -

Data Privacy- Blockchain ensure secure data transaction; however, those data are publically accessible and available for all readers, especially in the public blockchain [20]. . So transaction and data privacy are two serious concerns for many blockchain-based systems [22], [23]. Using private blockchain may mitigate this problem but limits the data accessibility, which is essential for many emerging Big data systems [20].

Security- Gao et al. [16] raised some security issues like- majority attacks, selfish mining, etc., that may encourage abuse of blockchain. Averin & Averin [24] identified nineteen possible types of attacks that can hamper blockchain security. According to Saleh et. al [20], Quantum computing seriously threatens blockchain security. By the year 2027, the underlying security of blockchain may be rendered breakable by quantum computers.

Performance Issues - Scalability and availability are two challenging performance issues for any blockchain system due to the ever-expanding nature of transaction blocks [16]. Sub-optimal performance becomes a norm due to complex permission handling mechanisms that incur high processing time [17]. To accelerate the blockchain performance "Sidechains" mechanism can be used. Sidechains are used to settle transactions between parties in a quick manner outside of the main chain. Main chains are updated only once per day [20].

Incentivizing Stakeholders- Blockchain needs dedicated resources for non-financial applications; coming up with an incentive mechanism to encourage more participants to share their resources is challenging [23].

Other Issues- There are some other challenging issues identified in some recent studies, such as - Real-time analysis and visualization of transaction data, Cost of shared governance [22], Lack of standards, Interoperability, and Regulations [20], etc.

2.4. Previous Blockchain Platform Related Studies

Our literature review found several existing research works that reviewed various blockchain platforms, such as [222], [223], and [224]. We compare them here briefly to justify the contributions of the proposed work.

In [222], Macdonald et al. investigated 5 general-purpose blockchain platforms and compared in-depth their features and limitations. Similarly, Mohammed Jabed et al. performed a comparative analysis of 10 well-established distributed ledger platforms and evaluated them qualitatively and quantitively in [230]. However, [222] and [223] discussed only the widely-used platforms until 2019. Newer blockchain platform discussions are absent, precisely the platforms that are evolved in the last two years. In contrast, the proposed work discussed 85 different platforms, including all the new platforms till to date. Also, the proposed work followed SLR process, whereas [222] and [223] did not.

In [224], Tsung-Ting et al. performed a systematic in-depth literature review, identified 10 popular blockchain platforms for the healthcare and bioinformatics domain, and discussed 21 technical features of those platforms. However, the blockchain platforms of other domains were out of their research scope. In contrast, the current work discussed all blockchain platforms regardless of their domains.

3. Research Methodology

Systematic Literature Review(SLR) is defined as secondary research that identifies, selects, and analyzes various primary research and maps them based on extractable information to answer some research questions [25], [26]. The goal of this study is to answer some informal questions related to blockchain platforms by analyzing relevant research papers.

We have conducted our systematic literature review following guidelines provided by Kitchenham and Charters [27]. In Figure 3 we have shown the process in brief. The following subsections describe in detail the SLR process of our study.

3.1 Identifying Research Questions

This section elaborated on the objectives and goals of this research. To identify the issues and challenges of blockchain platforms, we focused on two research questions, as described below.

RQ1. What are the major platforms and frameworks are used for blockchain-based system implementation?

We have discussed various frameworks, their programming languages, citation origins, and application domains to answer this.

RQ2: How do they differ from each other in terms of implementation and operation?

We answered it from three perspectives: the type of platforms & frameworks, their hash functions, and their security issues.

3.2 Conducting the Search

This is the first step of a SLR. We collected research papers by searching scientific databases using keywords of our research interest, such as **"blockchain", "block chain", "distributed ledger", "blockchain platforms"**, etc. We conducted our searches in the most prominent scientific research databases, like IEEE Xplore, ACM, Springer link, Wiley, and Science Direct, as the novelty and authenticity of published articles in these databases are already verified by the experienced peer reviewers of blockchain fields. It is important to note that in this step, we conducted searches without any restrictions on publication years. Table 1 shows the search results.

3.3 Inclusion and Exclusion Criteria

To select primary study papers, we formulated an exclusion and inclusion strategy. We have discussed the strategy in detail as follows:

- We excluded studies that have no relation to blockchain technology. The words block and chain are used in other domains too, where their combination suggests something else, like the term "polymer block chain" is used in the chemical engineering domain.
- We excluded studies that were written other than in the English language.
- We excluded papers that did not explicitly mention any blockchain platform.
- We excluded studies that are systematic reviews or survey studies from the primary study.
- We included studies that discuss the technical aspects of blockchain platforms.
- We exclude papers that didn't discuss technical details of common platforms (i.e., Ethereum, Hyperledger, Bitcoin, etc.).
- We included studies that discuss any uncommon blockchain platforms.

3.3 Screening for Relevant Papers

In the previous section, we mentioned how we gathered scientific articles that matched our search keywords (See Table 1). We used Zotero [28] to store them and create our paper databases. In the following section, we will discuss the exclusion process we followed to get relevant papers for the study.

I. *Duplicate removal:* After applying Zotero's duplicate removal tool, we got **38918** unique papers.

II. *Reading title, abstract and quick scanning*: We read the title and abstract of all the **38918** papers to remove non-relevant studies. In this way, we are able to identify all non-domain articles. On the other hand, platform information was not readily available in the abstract. To have effective filtering, we did some full-text keyword searches (using PDF search tool) to check the frequency of the words like platforms, frameworks, etc. For the high-frequency papers, we accepted them for the next steps; for the low-frequency (i.e., keywords mentioned four times or less), we checked relevant sentences and then decided its merit to include or not. We ended with 7164 articles after this step.

III. *Removing non-research articles:* We removed all the book chapters, magazine articles, and non-English articles from the database. We ended up with 4900 papers.

IV. *Full-text skimming:* We skimmed through all the 4900 papers. The shallow reading process started with reading sections such as the introduction and conclusion. If we were still undecided, then we applied keyword search on the whole document to identify all the relevant texts. Finally, we examined relevant texts and sections to make a decision. We ended up with 723 studies.

V. *Full text reading:* We extensively studied these 723 papers and applied inclusion-exclusion criteria mentioned in section 3.3. We noticed several articles merely mention the blockchain platform's names, but no detailed technical discussion exists. After filtering them out, the total number of papers got down to 212. We completed our study based on these papers.

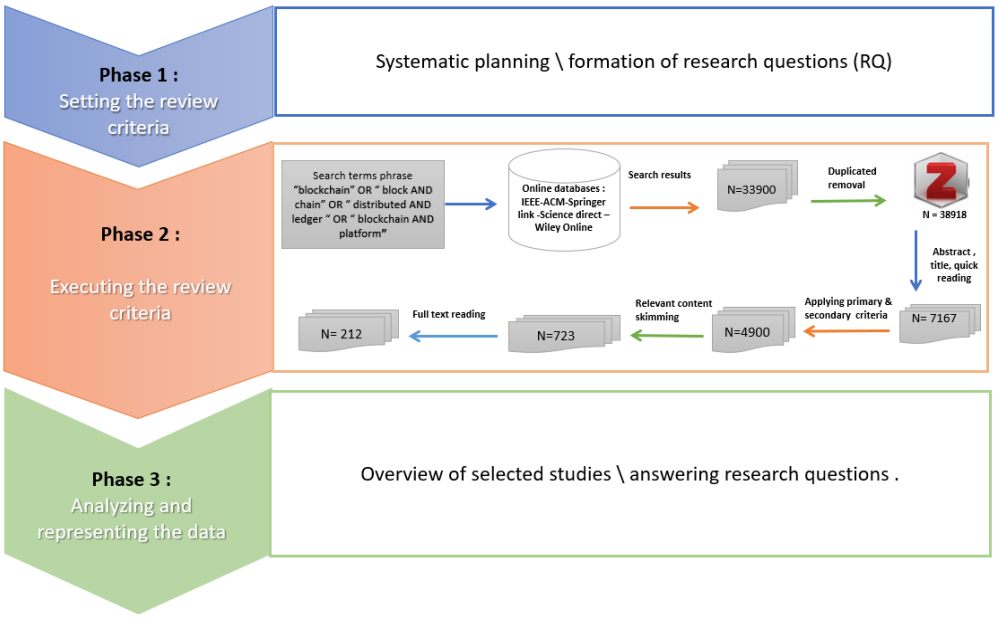

Figure 3. SLR Process

Table 1. Paper Search Results

Research database	Search Keywords	Number of papers
ACM digital library	blockchain	2438
	block chain	944
	distributed ledger	1121
	blockchain platform	425
IEEE Xplore	blockchain	6089
	block chain	247
	distributed ledger	785
	blockchain platform	154
Science Direct	blockchain	3385
	block chain	2185
	distributed ledger	1132
	blockchain platform	1062
Springer Link	blockchain	2156
	block chain	4077
	distributed ledger	3512
	blockchain platform	1094
Wiley Online Library	blockchain	1775
	block chain	760
	distributed ledger	469
	blockchain platform	90
Total number of papers		33900
Total number of papers considered for the study		212

3.5 Quality Assessment of Our Study

We did not use any pre-designed quality instrument to assess the quality of the proposed studies due to our intention of being as inclusive as possible to report any available blockchain platform. Besides that, study quality assessment is regarded as valuable for finding the strength of inferences which was not our aim.

3.6 Data Extraction and Mapping Process

To address the research questions, we have analyzed the relevant papers by extracting information in a structured way. Some information was extracted without in-depth reading, like determining the origins. On the other hand, pulling out some information needed a closer look, like understanding the security and other technical issues. We used an Excel sheet to save the findings of each of the papers. Later, we used this file for data analysis.

To answer the first research question, we collected the platforms' names, platform derivation, the system's origin, platform version, the language used to develop the framework, time of development, and the application domain.

We followed the same process for the second research question. We studied different aspects to differentiate the frameworks, such as their installation procedure, response-time/performance, security features, privacy features, maintenance features, implementation hardware, etc. Later, we added a few more differentiation features, such as their security issues, types of hash functions, types of blockchains, consensus algorithms used, etc.

4. Data Synthesis

The 212 relevant papers identified in the previous section were further analyzed to get the answer of our research questions. The findings are summarized in the following subsections.

4.1 Distribution Based on Platforms

During our study, we found 98 platforms. In Table 2, we present all platforms and their references. Many papers mentioned more than one platform. Figure 4 shows different blockchain platforms and their share in total references. Some articles suggested that they implemented primary platforms, whereas others mentioned they implemented secondary platforms derived from the primary. In our study, we didn't distinguish between primary and secondary platforms. As shown, among all the articles, 32% used Ethereum, 13% used Bitcoin, 22% used different versions of Hyperledger (e.g., Fabric, Sawtooth, Indy, Barrow, etc.), 3% used Corda, 2% MultiChain, etc. The remaining 28% goes to the 75 relatively less popular platforms.

Table 2. Blockchain papers are organized based on their platforms.

Platforms	Number of Papers	References
Bitcoin	32	[5], [10], [14], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40] , [24] , [41], [42], [43], [44], [45] , [46], [47], [48], [49] , [50], [51], [52], [53], [54], [55], [56], [57]
Ethereum	82	[5], [8], [10], [31], [34], [35], [36], [38], [39], [41], [42], [45], [46], [47], [49], [53], [57], [58] , [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [22], [17], [92], [93], [94], [95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107], [108], [109], [110], [111], [112], [113], [114], [115], [116], [117], [118], [119]
Hyperledger	54	[5], [10], [34], [33], [36], [38], [35], [39], [46], [49], [61], [67], [17], [22], [94], [111], [113], [114], [120], [121], [122], [123], [124], [125], [126], [127], [128], [129], [130], [131] [132], [133] [134], [135], [136], [137], [138], [139], [140], [141], [142], [143], [144], [145], [146], [147], [148], [149], [150] [151], [152], [153]
Corda	8	[34], [36], [46], [10], [49], [22], [17], [108]

Platforms	Number of Papers	References
MultiChain	5	[154], [155], [10], [22], [37]
Cosmos	4	[37] , [46], [88], [156]
IBM Blockchain	3	[10] , [46], [157]
Stellar	4	[5] , [22] , [158], [159]
Quorum	3	[81] , [36], [10]
Ripple	2	[14], [108]
BigchainDB	2	[10] , [160]
Exonum	2	[161] , [36]
Qtum	2	[75] , [162]
NEO	2	[75] , [94]
ARK	2	[163] , [75]
IOTA	4	[10], [164] [165], [166]
Ethermint	2	[17], [22]
Nebulas	2	[167] , [109]
Polkadot	2	[168], [46]
EOS/ EOS.IO	4	[169], [159], [75] , [94]
FISCO BCOS	6	[170], [171], [172], [173], [174], [175]
Cardano	2	[168], [159]
Other Platforms(1)	76	Azure, Chain, Chaincore, Open Zeppelin, Rubix ,Openchain, Monax [10], Symbiont, Kadena, HydraChain, Swirld, [36], Interactive Multiple Blockchain Architecture (IMBA) [37], Master-Slave Blockchain Scheme (MSBS) [39], Redes Chain [41], Cocos, IOST, Nervos, Ultrain, ChainIDE [70], Parity [22], Autonity, Symbiont , Ontology [17], AURA [93], VeChain [108], Blockbench [113], Permissioned Blockchain Framework (PBF) [120], Libra [135], BlocHIE [176], BlockCloud [23] , Distributed Blockchain-based Data Protection Framework (DBDPF) [178], Energy blockchain [179], Ekiden [180], OmniPHR [181], SEBDB [182], Orthus [183], Integrated Decision Making Platform (IDMP) [184], CUREX [185], Mchain [186], Hybrid EV Charging Framework (HEVCF) [187], DyMonDS [188], FAR-EDGE [189], Steemit [190], Zcash [191], Blockchain Game Platform (BGP) [192], Nebulas [167] , AVALANCHE [193], originChain [194], RepChain [195], NEM [196], BCIoT-CAF [197], BOSSA [198] DNA [172], SigChain [199], Hyperchain [200] Ganache [201], PriFL-Chain [202], Social-Chain, Algorand [203], NeuChain, ResilientDB , PoE, Monoxide, ByShard, SharPer, Rivet, Basil, BIDL [204], SlimChain [205], Qanaat [206], CITA [207], Medi-Block chain [208], BNB chain [209], Litecoin [210], BF-RANs [211], PHEV chain [213]

(1) Our original search covered published papers until 2020. To include recently reported platforms, we separately searched papers published until march 2023. Please check the discussion section for details

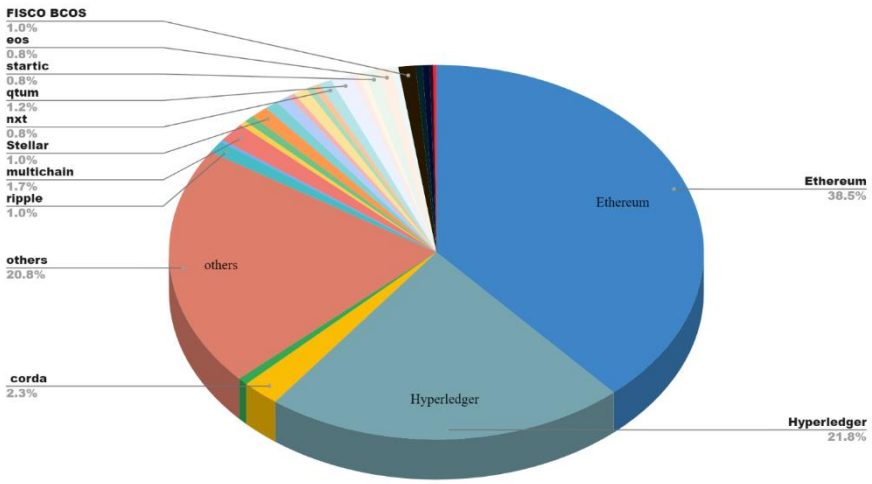

Figure 4. Platform distribution

4.2 Distribution Based on Types

Blockchains can be categorized broadly into three types: Public[(2)], Private[(3)], and Consortium[(4)] [29]. Based on the need and nature, any application can fit with one of them. Figure 5 illustrates paper distribution based on these three types. Public blockchain technology is represented by 75 papers out of all studies, as shown in Figure 5. Private blockchains are in the second place, mentioned in 61 papers. After analysis, we found 23 papers that use consortium blockchain. Interestingly, we can classify the Hyperledger Fabric blockchains into both private and consortium type.

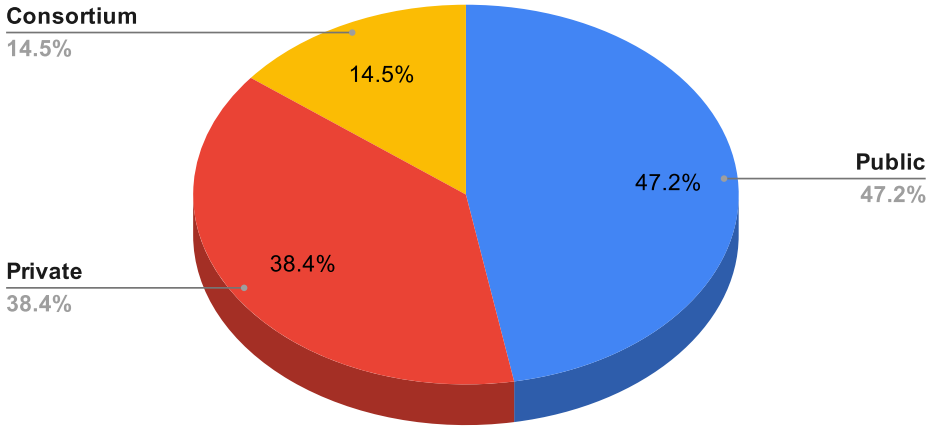

Figure 5. Paper distribution based on Blockchain types

4.3 Distribution Based on Region

We analyzed paper distribution across the globe. Figure 6 shows the result. China is at the top with a total of 37 papers and USA holds 2nd place with 26 papers. The next place is for India and the United Kingdom with respectively 7 and 6 papers. Russia and Japan placed after that with 5 papers for each. The rest of the papers were spread over other parts of Asia and Europe, as shown in Figure 6. We noticed that most regions interested in this technology have some common characteristics, such as large population, strong economy, etc.

(2) Public blockchains are open to the public, and each peer nodes have permissions to participate, create, send, copy, and store transactions. The prominent examples of public blockchains are Bitcoin and Ethereum [73].

(3) The main difference between private and public blockchain is the permission level of the authorized users. Private blockchains are more secure, as only the certified user can access them [239] .

(4) Consortium blockchain authorizes some users to participate in the network. It is similar to the private one, but the latter has only single user access [22]. The Consortium blockchain can also serve multiple organizations in a decentral blockchain [73].

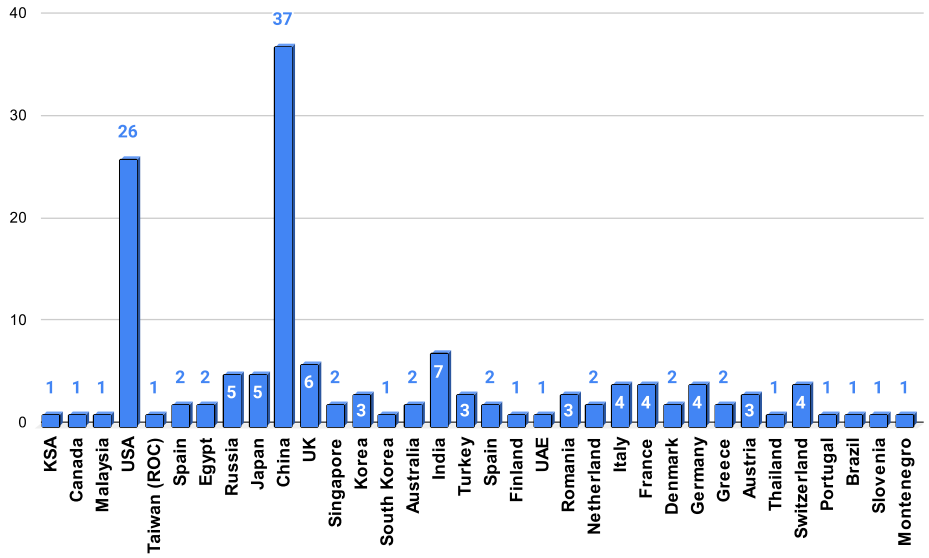

Figure 6. Paper distribution based on origins

4.4 Distribution Based on Application Domains

Figure 7 shows the distribution of relevant papers based on application domains. Blockchain platforms, such as Bitcoin, Ethereum, Ripple, etc., were initially developed for the financial domain only as digital cryptocurrency. Later, blockchain became popular gradually in other domains due to the decentralized security feature [6].

We can see from Figure 6 that 29.9% of our study papers focused on core blockchain technology issues. Banking and finance is the next popular domain where blockchain becomes an important transformative technology, as reported by 11.4% of papers. The Internet of Things (IoT) and intelligent systems is another emerging domain for blockchain, 9.6 % of the study papers came from this domain. Blockchain supports data storage for various forms of multimedia applications like web & social media apps, 9.0% of the articles we have studied came from this domain. 9.0% of the papers discussed blockchain implementation for energy, manufacturing, and other industries.

Healthcare seems a popular domain for blockchain researchers. In our study, 7.3% of the papers discuss the management of healthcare data. 4.0% of the articles discussed the implementation of smart and secured voting applications using blockchain. Another popular blockchain technology implementation area is the Cloud- 3.4% of the study paper.

Minor domains include- mobile applications, telecommunication, academic research, public transportation & traffic management systems, gambling, agriculture, government sector, etc.

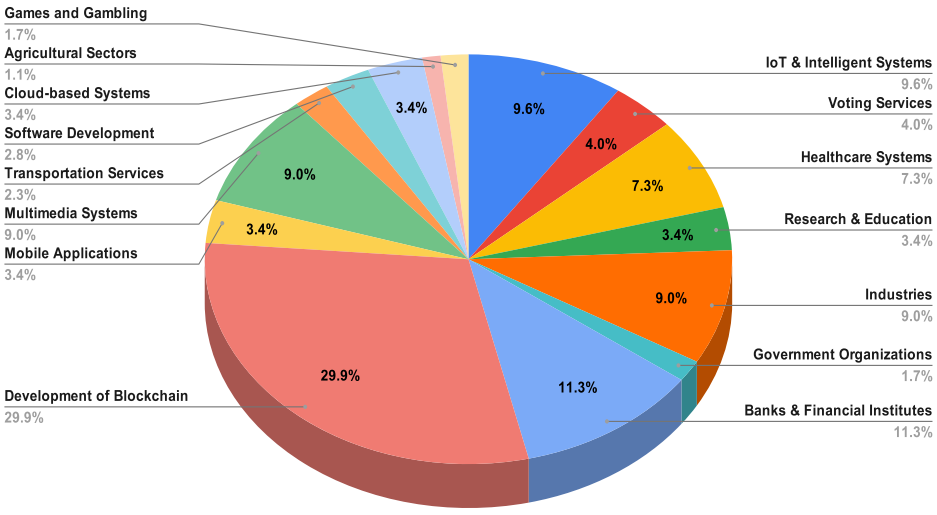

Figure 7. Paper distribution based on domains

4.5 Distribution Based on Programming Languages

This section classified the study papers based on the programming languages mentioned to build applications. For the blockchain-based application, coding can be used for three purposes:

- To program the peer nodes, node algorithm, and libraries.
- To program the smart contract and the consensus algorithm, e.g., using JavaScript.
- To build the blockchain platform itself, e.g., using Solidity.

Only a few papers precisely mentioned this information, whereas others described the programming languages in general terms.

As shown in Figure 8, "Solidity" is the most widely used language to build blockchain platforms, representing 20.3 % of the articles in our study. "Go" is the next popular programming language, representing 17.0% of the study papers. JavaScript is the following popular language, as 16.3% of the articles mentioned them. Subsequently, python is the next widespread language in the ranking- mentioned in 13.6% of the study papers. Traditional languages like Java and C++ also reported in 8.5% and 7.8% papers respectively. 1.3% of the articles mentioned that they used PHP for blockchain platform building. Besides these languages, 2.0% of the article suggested other programming languages, such as C, RUBY, SQL, JSON, node.js, and rust.

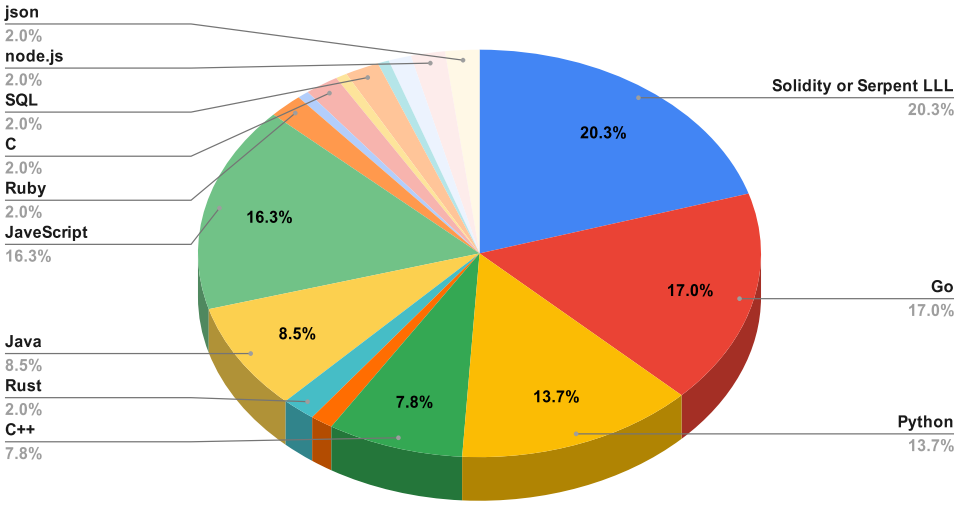

Figure 8. Paper distribution based on Languages

4.6 Security Issues of Blockchain Platforms

In this section, we report the security and vulnerability issues of the blockchain platforms based on our study papers. Figure 9 illustrates the major security issues of blockchain technology, as appeared in the study papers.

As shown in Figure 9, 18.3% of the articles reported that blockchain technology is very prone to DDoS attacks due to the distributed networking environment. Cyber tampering and hacking is the next biggest threat, as reported by 11.7% of the study papers. Weak transaction security is a crucial vulnerable issue reported by 10% of the articles. 8.3% of the study papers mentioned malicious code is a serious threat. Network attack was identified as a threat in 6.7% of the articles.

Data access & block attacks, Byzantine nodes attacks, Double spending attacks, and Services attacks were mentioned individually by 5.0% of the articles. Other significant attacks were identified as Sybil attacks (3.3%) and PoW attacks (3.3%).

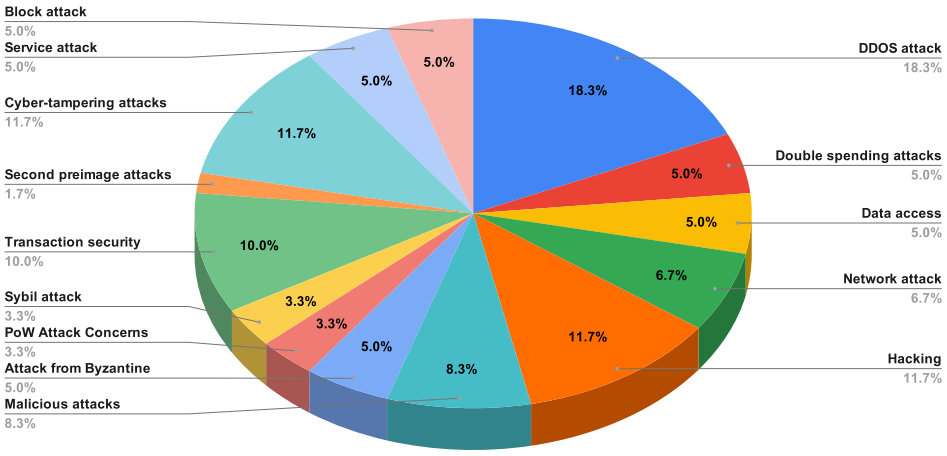

Figure 9. Paper distribution based on security threat

Some of the papers suggested solutions for the above attacks, but we are not reporting it here as it is out of the study.

5. Discussion and Handling Threats of Validity

In this study, we conducted a systematic mapping study to identify recent blockchain platforms in the current research. However, the rapid expansion of blockchain-related literature in the last decades made it challenging. The results of this mapping study are presented below:

5.1 Key Findings

We have formulated two research questions to identify the issues and challenges of blockchain platforms. The first question was - What are the major platforms and frameworks used for blockchain-based system implementation? We have answered this question in Section 4 by providing an extensive list of blockchain platforms. **We found eighty-five such platforms**[(5)].

We also collected related information like their origins, application domains, etc. The second question was how they differed from each other in terms of implementation and operation. We have answered it by analyzing their types, consensus algorithms & hash functions they use, and their approach towards security issues. **According to our study, only 20% of the reported platforms have been analyzed and reported in detail.**

5.2 Threats to Validity

To tackle validity threats, we followed well-known SLR guidelines [27]. After going through a rigorous process, we amassed a large set of primary study papers. We did not use any explicitly defined instrument to assess the quality of the proposed studies. In Section 3.5, we argue in favor of this decision. Multiple authors cross-checked all the relevant studies. In section 3, we already discuss the process in detail.

6. Artificial intelligent and Blockchain:

Both blockchain and artificial intelligence technology (AI) have the potential to revolutionize the digital world. Blockchain is a sophisticated technology involving vast amounts of data and transactions distributed across multiple nodes to ensure privacy, security, and accuracy. However, it is a complex technology that requires substantial hardware capabilities and expert skills and has some limitations. Blockchain integration with other technologies, particularly AI, has been proposed to overcome these limitations. The blockchain provides a secure and transparent database for storing immutable and verifiable transactions, while AI models can simulate

(5) To update the list, we have conducted a separate search for 2021. We followed the same approach and used the same keywords mentioned in Section 3 (except "Block Chain" which brought lots of irrelevant papers). In total, we found 7632 new publications, out of these publications we only found five new platforms that we have added in Table 2. We also found three new SLRs that we have added in Table 5.

human problem-solving abilities, learn from data, and make predictions. Together, these technologies can create synergies and enhance various aspects of our digital world. When integrated, blockchain enhances the trustworthiness of data resources that AI models rely on and provides a robust platform for secure communication among the users in the network system [261].

AI technology has brought new opportunities for blockchain development, such as continuous learning improves the speed of data queries and the efficiency of blockchain applications [262]. The combination of these technologies is complementary, where Blockchain affords a trustworthy platform for artificial intelligence, and artificial intelligence affords the landing conditions for blockchain [262].

Many technologies provide the concept of AI_blockchain and discuss various SMART blockchain-based technologies, including NFTs, DAOs, DeFi, and the Metaverse, which can be the foundation for the next generation of businesses [263]

As described in the recent literature, the integration of Blockchain and AI has countless benefits across various industries, such as:

AI and blockchain combination can lead to improved medical data security, robust treatments, secure healthcare systems, and proactive measures against diverse cyber threats for the healthcare industries [264].

For supply chain traceability, Blockchain ensures transparency and traceability, while AI can analyze this data to optimize food traceability, resulting in safer and more efficient supply chains [265].

Moreover, integrating Blockchain and AI can provide real-time market predictions for real estate or stocks, aiding investors and businesses. Companies such as CertiK, Core Scientific, and Token Metrics use AI to analyze cryptocurrency trends for investment decisions [266].

Although these examples have limitations and challenges, the fusion of blockchain and AI holds immense potential to revolutionize industries, enhance decision-making processes, and improve data security. However, it is important to consider ethical and legal parameters such as data privacy and security, regulatory compliance, and the ethical implications of AI decisions [266]. By considering these factors, we can manage the production cycle and development of the SMART blockchain field.

7. Conclusion and Future Works

Analyzing previous studies is a crucial part of meta-research. Reviewing previous studies helps the researcher to understand an emerging research area. Blockchain promotes various forms of data transactions without an intermediary third party. So it is also extensively applied in many fields, including healthcare, finance, energy, supply chain management, IoT, insurance, transportation, business, and resources management.

Due to increasing popularity and future opportunities, many new blockchain platforms emerged in the last few years. A systematic literature review has assessed this technological expansion to identify contemporary blockchain platforms. In this paper, we have identified eighty such blockchain platforms reported by the relevant research community. We have mapped those platforms based on various criteria. According to our observation, there is a lack of research on most emerging blockchain platforms.

Some other blockchain platforms are used in the industry but have not yet been reported by the researcher. There is a need for multiple technical studies on emerging blockchain platforms. In the future, we will conduct a separate study in this regard.

Our study found that public-centric application domains like donations, car sharing, etc., also incorporate blockchain technology that has far-fetching implications. In the future, we will study and analyze such applications to improve and identify new opportunities in this domain.

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