Interaction Between Blockchain Technology and Conventional Databases: a Systematic Literature Review

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***Abstract*—Day by day, the popularity of blockchain technology is rising in the business sector. Companies that want to benefit from some of the features of blockchain like security, immutability, decentralization, and elimination of central authority, try to integrate this technology to their existing business use cases. During the integration process, companies must go over a decision process and decide whether the blockchain technology should replace the current system or the two systems should be combined. In order to successfully make the decision, developers or researchers must be aware of the blockchain's features and analyze the improvements that a change between databases and blockchain technology would bring to the existing system. In this paper, in order to provide an outline of differences between blockchain and databases and also ease the decision process that researchers or developers must undergo, we conduct a systematic literature review on the differences between blockchain and databases and possible features they would provide in a system.**

Keywords— Blockchain vs Database, Blockchain Database, Systematic Literature Review

I. INTRODUCTION

Blockchain technology has gained significant attention in recent years due to its potential to disrupt a wide range of industries and sectors. Blockchain can be identified as the driving technology behind cryptocurrencies like Bitcoin, Ethereum etc. Although blockchain technology is popular by its usage in cryptocurrencies, overall it can be considered as a database technology that provides a data store of transactions between the participants of the network in a decentralized way. The benefits of using blockchain are as follows:

- Security: Blockchain is decentralized and distributed, it is not controlled by any single entity. This makes it less vulnerable to attacks and ensures that the data stored on the blockchain is secure.
- Transparency: Blockchain technology allows for transparent and immutable record-keeping. All transactions on a blockchain are recorded and can be viewed by anyone with access to the network.
- Efficiency: Blockchain technology has the potential to streamline processes and reduce the need for intermediaries.
- Decentralization: Because a blockchain is decentralized, it is not controlled by any single entity. This can help to reduce the risk of censorship and ensure that all parties have equal access to the network.

The participants of the blockchain network can share data with each other without establishing trust between them. This process is made available through a mechanism called consensus which will be explained in detail in the upcoming sections of the paper.

We can certainly think of blockchain technology as a database solution with unique capabilities compared to conventional database technologies. It provides decentralized data storage among all the participants of the blockchain network. Also, eliminates the need for a central authority to govern the data storage process through consensus mechanisms between the participants of the blockchain network. It allows participants that don't trust each other to share data in a secure way via the usage of cryptographic protocols. Moreover, ensures the integrity and immutability of the data by the usage of hash chain technologies like Merkle Trees.

Blockchain technology is considered a candidate database solution for existing business use cases due to the unique capabilities it possesses. Some of these use cases can be listed as follows:

- Finance: Due to the ability of blockchain to eliminate trusted third parties from the system, blockchains can be considered as a replacement for existing data storage systems in the finance sector.
- IoT: Blockchains are decentralized by nature and this property can be integrated to the existing IoT systems to enhance the scalability of the IoT system.
- Healthcare: Blockchain could be used in healthcare to digitalize medical data and store it on the chain. In this way, we can achieve a decentralized medical system that any medical-related company can access.
- Supply Chain: Data is stored as transactions in the blockchain and the data is immutable. This property could be used in supply chains where we could track a product's lifecycle via the blockchain.
- Identity Verification: Digital credentials can be stored on the blockchain. In this way, blockchain

users can authenticate the digital identity of a person or physical object in a distributed manner.

Although all the mentioned use cases above are currently being managed by existing database technologies like SQL, NoSQL, Distributed DBs, etc. many researchers in the area of blockchain think that in the future, these technologies can be enhanced or replaced by blockchain databases.

Our Contribution: In our work, in order to help researchers, decide whether a blockchain database solution suits their needs or should they replace their existing database solution with blockchain, we have conducted a systematic literature review on the subject "interaction between blockchain and databases". By doing so, we expect to outline the main differences between blockchain databases and conventional databases and explain how these technologies can complement each other's shortcomings.

The rest of this article is organized as follows. In Section II, we gave a brief background about existing blockchain technologies and database solutions. In Section III, we explained the research methodology we follow while conducting our systematic literature review process and then we analyzed our results in Section IV. Finally, we concluded our research in Section V.

II. BACKGROUND

A. An overview of Modern Database Systems

The term "Data" can be described as a collection of facts, figures, measurements and signals. It is the first step on the road to "Knowledge". Adding context to data leads us to information. And meaning plus information equal knowledge. That is exactly the step where we are utilizing the data to help to understand situations and make decisions.

As said above, data is a collection, so, like every collection, it needs to be kept in somewhere safe, accessible, and unmanipulated. That is the reason why databases are needed.

It can be said that modern databases were born in the 1970s, that is the year the relational database model came through. Most of the databases that we use today are still relational database systems. Relational databases can be described as collections of data items that have pre-defined relationships between them. The items are in the form of rows and columns. Oracle, IBM DB2, MySQL, and Google Bigquery are some examples of it.

Today, we also use non-relational databases which have commonly known as "NoSQL" since the late 2000s. In these databases, the items are not tabular. They store data in different ways from relational databases. The types are mainly document, key-value, column, and graph. MongoDB, CouchDB, CouchBase, Cassandra, HBase, Redis, Riak, and Neo4J are some examples of NoSQL databases.

B. An overview of Blockchain Technology

The Blockchain is a system that records information, generally transaction information, as a form of linked blocks. It is a decentralized system, which means that the records are kept and maintained on a peer-to-peer network without any geographical limit.

When a new record is added, the transaction record needs to be authenticated by the peers of the network. After that, it will be verified and added to the chain by linking the previous record with a uniquely encoded key.

This structure makes information manipulation impossible. Also, it cannot be controlled by a single authority due to the decentralized architecture. It can be said that centralized systems are open to manipulation and attacks, blockchain eliminates these risks.

The architecture of blockchain consists of three layers. These layers are Applications, Decentralized Ledger and Peer-to-Peer Networks. Applications developed on top of the blockchain architecture, the Application Layer, which allows users to keep track of their transactions and processes, usually through an interface. The decentralized Ledger is the middle layer and it can be considered as the main layer. All the key processes like recording, authentication, encoding, linkage occur at this layer. Finally, peer-to-peer networks are present at the bottom layer. It keeps the node types for the Decentralized layer for different processes.

C. A comparison of Database and Blockchain

A blockchain is a decentralized and distributed digital ledger that records transactions on multiple computers, making it virtually tamper-proof. This makes it an ideal solution for a variety of applications, including financial transactions, supply chain management, and identity verification. Blockchain is more decentralized, more secure due to its distributed structure, and naturally more transparent as all transactions are visible.

On the other hand, database systems have been in use for decades and are a key component of many modern systems. These systems are centralized, meaning that they are controlled by a single entity, and they use structured data storage methods to store and manage data. traditional database systems are faster, more effective and scalable systems compared to blockchain. This is because the blockchain requests verification by multiple users for each transaction.

III. RESEARCH METHODOLOGY

We have used the guidelines given in [1] to conduct our Systematic Literature Review (SLR) process. The complete flow of our process can be seen in Fig. 1. Our flow contains two phases: Source selection, Systematic Literature Review which we will discuss in the following sections.

A. Systematic Literature Review

Systematic Literature Review (SLR) is a methodical and systematic approach to reviewing research on a particular topic. It involves identifying and analyzing relevant research in a systematic and transparent manner, in order to provide a comprehensive overview of the current state of knowledge on the topic. The steps followed to create SLR are as follows:

- Define the research question.
- Identify relevant sources.
- Search and select studies.
- Assess study quality.
- Extract and synthesize data.
- Analyze and interpret the data.

Overall, conducting a SLR requires a systematic and transparent approach to reviewing the research on a particular topic.

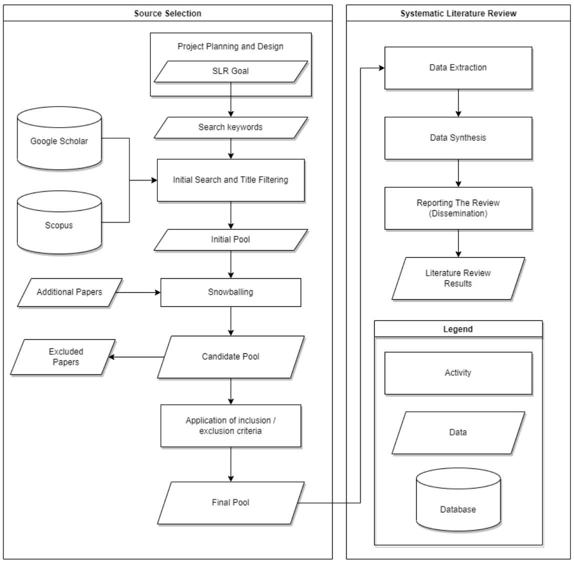

Fig. 1. Overview of our Research Process

B. *Goal of our SLR*

Our purpose in this study is to understand, review and analyze the effects of blockchain technology on the development of modern database systems and explain the relationship between databases and blockchains and thus provide a summary for the researchers in this area.

C. *Research Questions*

According to the methodology we follow in our research, specifying the research questions (RQs) is the most important part of any systematic review as these questions drive the entire systematic review process:

- Primary studies that address the research questions must be found during the search phase.
- The data extraction method must provide the necessary data to provide answers for the research questions.
- The data analysis method must synthesize the data generated from the data extraction process in order to answer the research questions.

Based on the goal of our SLR we have defined our RQs as follows:

- **RQ1 - What are the top differences between blockchain-based databases and conventional databases in terms of database functionality**? : Main differences between Blockchain-Based Database Systems and Conventional Databases.
- **RQ2 - When to use Blockchain-Based Database Storage? :** When should we use blockchain technology as a database? Develop a decision tree for the question.
- **RQ3 - Business use cases which commonly use Blockchains instead of Databases :** Which technologies like the Internet of Things (IoT), Supply Chain, and Auditing Systems use blockchain-based database systems?
- **RQ4 - For which criteria Blockchain-Based Database Systems are preferred over Conventional Databases? :** Which feature of the blockchains (immutability, decentralized technology, etc.) make them preferable over conventional databases?

D. *Research Paper Pool*

We have used two popular digital databases, Google Scholar and Scopus in our research process to form our initial review paper pool. Although the coverage of Google Scholar is much higher compared to Scopus, we have used Scopus to reduce the bias in the paper selection process as much as possible. We have finalized our initial research paper pool at 45 papers.

The search strings we have used in Google Scholar and Scopus platforms are given in Table 1. For our paper selection process, we have used abstract and title-based selection.

TABLE I. EARCH RESULTS FOR GOOGLE SCHOLAR AND SCOPUS

Search String	Number of Papers
Blockchain versus database	92
Blockchain and database	155
Blockchain database	2900

E. *Exclusion and Inclusion Criteria*

We have defined inclusion and exclusion criteria in order to guarantee that the papers that are irrelevant to our study are excluded and the ones that are relevant are included in our paper pool. The exclusion and inclusion criteria we have defined are as follows:

- Can we access the paper in pdf format?
- Is the paper written in Turkish or English?
- Does the paper focus on differences between Blockchain and Conventional Databases? Or can we extract the information ourselves from the paper?

Based on the “Yes” and “No” answers for every criterion for each paper, we have included the papers that had “Yes” for all the criteria and excluded the rest.

F. *Final Pool of Papers*

Our paper pool was finalized at 23 papers after applying exclusion and inclusion criteria. To ease our collaborative work, we have designed an online spreadsheet in which we could put comments for each paper after the review process. The format of the online spreadsheet is given in Fig 2.

Source #	Paper Title	Document Links (Google Drive)	Digital Database	Data extraction	Voting				
					Outcome	Criterion 1	Does the paper focus on differences between blockchain and regular databases? or Can we extract the information ourselves from the paper?		
1	A Blockchain-Based Database Management System	Link	Google Scholar	BO	EXCLUDE	1	1	0	
2	A Brief Review of Database Solutions Used within Blockchain Platforms	Link	Google Scholar	SS	EXCLUDE	1	1	0	
3	A Comparative Testing on Performance of Blockchain and Relational Database	Link	Google Scholar	BO	INCLUDE	1	1	1	
4	A Survey on challenges and progresses in blockchain technologies A performance and security perspective	Link	Google Scholar	SS	INCLUDE	1	1	1	
5	A Ten-Step Decision Path to Determine When to Use Blockchain Technologies	Link	Google Scholar	BO	INCLUDE	1	1	1	
6	A_Prototype_Evaluation_of_a_Tamper-Resistant_High_Performance_Blockchain-Based_Transaction_Log_for_a_Distributed_Database	Link	Google Scholar	SS	EXCLUDE	1	1	0	
7	Analysis of Blockchain technology pros cons and SWOT	Link	Google Scholar	BO	INCLUDE	1	1	1	
8	Analysis_of_Data_Management_in_Blockchain-Based_Systems_From_Architecture_to_Governance	Link	Google Scholar	SS	INCLUDE	1	1	1	

Fig. 2. Our Paper Pool

G. Final Pool of Papers

We divided our final paper pool into two pieces, then every member of our team extracted data from the research papers assigned to him/her. We have defined separate cells in our online spreadsheet for the data extraction process. Each data extractor added his/her comments to these cells and also added the answers to the RQs that he/she extracted from the research paper. Our extracted data has the following format:

- Name of the Data Extractor
- Date of Data Extraction
- Title, Authors, Journal, Publication Details
- Type of the Paper (Contribution Facet)
- Answers to the RQs
- Space for additional notes

Fig. 3 indicates an image of our data extraction process for the RQ1 on a paper from our paper pool. In the image, one of our team members has extracted a relevant text from the article as an answer to RQ1. This process is repeated for all of the RQs and papers in the paper pool.

Source #	Paper Title	Research Questions					
		RQ1 What are the main differences	RQ2 When should we use	RQ3 Which business use cases (IoT,	RQ4 For which criteria Blockchain Based Database Systems	RQ5 Which blockchains are studied in	RQ6 Which databases are studied
1	A Blockchain-Based Database Management System						
2	A Brief Review of Database Solutions Used within Blockchain Platforms						
3	A Comparative Testing on Performance of Blockchain and Relational Database	Differences in capabilities of reading and writing data: Blockchain tends to be slower compared to databases. Databases handle large volume data better compared to blockchains.					
4	A Survey on challenges and progresses in blockchain technologies A performance and security perspective						
5	A Ten-Step Decision Path to Determine When to Use Blockchain Technologies						
6	A_Prototype_Evaluation_of_a_Tamper-Resistant_High_Performance_Blockchain-Based_Transaction_Log_for_a_Distributed_Database						

Fig. 3. Our Data Extraction Process

IV. Research Results

In this section, we report the results of our data extraction process and provide answers to the RQs we have defined.

A. Main differences between Blockchains and Databases

In the first RQ, we have examined the main differences between Blockchains and Conventional Database Management Systems.

One of the key differences is the performance issue. Blockchain tends to be slower than conventional DBs in terms of reading and writing the data. It means, while working with high-volume data, DB handles this better. The average latency of transactions is higher on Blockchain than on conventional DBs. (See Papers; [2], [3], [4], [5], [6], [7], [8], [9])

Another one is centralization. Blockchain is decentralized while conventional DBs are mostly centralized. In centralized type, DB presents one place and multiple users can access it. However, in a decentralized structure, data is split and distributed through several locations within the network. The decentralized structure's main advantage is fault tolerance - robustness. Also, since it has not had a single point of failure, better able to cope with malicious attacks. Moreover, we do not need to trust a central entity to provide the correctness of the state, it is publicly verifiable.

Another difference about centralization is, transactions are accepted to the blockchain via a consensus mechanism rather than a controlling central party. (See papers; [10], [11], [4], [5], [12], [13], [14], [9])

Blockchain is transparent and immutable whereas conventional DBs are not, which means transactions on the blockchain cannot be deleted or altered by some centralized entity. These processes can be executed on conventional DBs, DBs have transaction logs for these. (See papers; [10], [11], [15], [16], [9])

Blockchain allows access to it without any central administration. There is no administrator on the blockchain whereas DB has administrators and super users. It makes accessibility easier and in a more democratized way on Blockchain compared to conventional DBs. Everyone who has a computer can join the network on Blockchain. Access is unlimited and uncontrolled, unlike DBs. This can be questioned in terms of the confidentiality of the data. For security issues, blockchain uses cryptography (chained hashes) rather than traditional access control like DBs. Authentication is assured through complex mathematics. (See papers; [10], [11], [3], [4], [13])

One of the most important concepts about databases is data analysis. For this, data querying is a key concept. Querying conventional DBs are easy with some specialized query languages like SQL. Even though querying NoSQL DBs also harder than SQL, on Blockchain, querying data is harder than conventional DBs whether it is SQL or NoSQL. Information retrieval takes extra programming efforts on Blockchain, unlike DBMS. (See papers; [16], [17], [9])

Another point is redundancy. In blockchain systems, redundancy is inherently provided through replication across the writers. In conventional DBs, redundancy is generally achieved through replication on different physical servers and through backups. Also, on the blockchain, every node is the last copy of itself whereas, on conventional DBs, the central authority has the copies. (See papers; [4], [13])

Energy consumption is massively larger on Blockchain than on conventional DBs. (See paper; [3])

B. When do we need Blockchain?

As discussed in the first question, the main advantage of blockchain over traditional DBMS is granting trust between parties. We need blockchain when the interaction between different parties lacks trust. When security and trust concerns come up between parties, we can use blockchain over traditional DBMS to eliminate the concerns. Transactions are completely transparent on blockchain due to its decentralized structure. Also, the immutability feature provides the guarantee that no transaction can be manipulated by some central authority. (See papers; [2], [10], [11] [3], [18], [13], [19])

Another thing is the performance issue. Again, as discussed at the first question, blockchain's performance is worse than conventional DBs. If we do not need huge performance, if the performance requirements fit the blockchain structure, it can be needed over traditional DBs. There is a trade-off in this area, between advantages like decentralization, granting trust between parties, and security vs. performance. If this trade-off balanced well for the case, then blockchain might be a good solution for database management. (See papers; [2], [4], [5], [13], [19])

Blockchain is needed when fault tolerance is needed for large software systems. Because of the distributed nature, it is the best choice for the robustness of the database. Also, due to the uniqueness of the information and complete synchronization of the processes, data integrity can be granted in any case on the blockchain. (See papers; [15], [4], [7], [20])

We need blockchain when decentralization is the key issue. If we do not want a central authority to grant access, manipulate data, etc., we should use blockchain to everyone has control over transactions. (See paper; [18])

C. Business use cases that use Blockchain over Databases

During our data extraction process, we have tried to answer the question; which business use cases use blockchain technology as a database technology? The answer to our question can be seen in Table II.

TABLE II. BUSINESS USE-CASES

Business	Papers
IoT	[2], [11], [13], [21], [22], [25], [28], [29]
Finance and Banking	[3], [4], [8], [11], [13], [15], [19], [20], [23], [27]
Supply Chain	[4], [8], [13], [18], [19], [23], [24]
Healthcare	[4], [8], [11], [18], [19], [21], [24]
5G	[21], [22], [31]
Digital Identity & E-voting	[11], [13], [18], [19], [24], [26]

D. Why do we prefer Blockchain over Conventional Database?

The first criterion to prefer Blockchain over Conventional DB is its decentralized architecture. There is no central authority on Blockchain. So, it is better in the context of transparency and no need to trust a third party. The data cannot be manipulated by an authority. Transactions are recorded with consensus mechanisms. Also, decentralization grants a more robust and fault-tolerant system compared to conventional DBs due to its distributed nature. The data restoration process is much easier than conventional DBMS. (See papers; [2], [10], [11], [15], [21], [3], [22], [4], [18], [13], [19], [8], [20], [24], [9], [30])

Another criterion is integrity and data security. Due to the consensus mechanism and immutability feature, we can always be sure that data on the blockchain has not been changed and manipulated. This also brings security with cryptographic features in it. The immutability nature brings trust to the data processed on blockchain whereas cryptography secures the data completely. Therefore, with these two, we can say that blockchain is much more secure than traditional DBs. (See papers; [10], [11], [15], [5], [19], [8], [9])

The last thing is anonymity. It is due to blockchain's open-source technological background. Everyone who has a computer can join the network without any authorization. This brings the availability and universal access to the blockchain structure. Another advantage of this is reducing transaction costs. Blockchain allows everyone on the network to conduct transactions. (See papers; [11], [15], [18], [20])

V. CONCLUSION

Although blockchain technology is still in its infancy, the technology is being actively developed and improved by many professionals around the world, and its likely that due its nature, it will provide some unique capabilities to the system where it is used. In the context of analyzing the interaction between blockchains and databases, we have conducted a systematic literature review where we outlined the main differences between blockchains and databases, identified the business use cases that can benefit from blockchains, and listed the advantages of blockchain systems over databases. We also tried to answer the question “When do we need a blockchain?”.

During our study, in order to ease our research process and improve our work as a team, we used a well-known systematic literature review guideline for software engineering [1]which sped up our research process.

We believe that our research will benefit the sector professionals or the researchers in deciding if the system at hand can benefit from a blockchain or a database solution should be enough and also provide a guideline when examining blockchain capabilities over databases.

REFERENCES

[1] S. Keele et al., “Guidelines for performing systematic literature reviews in software engineering,” Technical report, Ver. 2.3 EBSE Technical Report. EBSE, Tech. Rep., 2007.

[2] S. Chen, J. Zhang, R. Shi, J. Yan, and Q. Ke, “A comparative testing on performance of blockchain and relational database: Foundation for applying smart technology into current business systems,” in International Conference on Distributed, Ambient, and Pervasive Interactions. Springer, 2018, pp. 21–34.

[3] P. J. McAliney and B. Ang, “Blockchain: business’ next new “it” technology—a comparison of blockchain, relational databases, and google sheets,” International Journal of Disclosure and Governance, vol. 16, no. 4, pp. 163–173, 2019.

[4] M. J. M. Chowdhury, A. Colman, M. A. Kabir, J. Han, and P. Sarda, “Blockchain versus database: a critical analysis,” in 2018 17th IEEE International Conference On Trust, Security And Privacy In Computing And Communications/12th IEEE International Conference On Big Data Science And Engineering (TrustCom/BigDataSE). IEEE, 2018, pp. 1348–1353.

[5] P. Ruan, T. T. A. Dinh, D. Loghin, M. Zhang, G. Chen, Q. Lin, and B. C. Ooi, “Blockchains vs. distributed databases: Dichotomy and fusion,” in Proceedings of the 2021 International Conference on Management of Data, 2021, pp. 1504–1517.

[6] A. Sharma, F. M. Schuhknecht, D. Agrawal, and J. Dittrich, “Blurring the lines between blockchains and database systems: the case of hyperledger fabric,” in Proceedings of the 2019 International Conference on Management of Data, 2019, pp. 105–122.

[7] S. Bergman, M. Asplund, and S. Nadjm-Tehrani, “Permissioned blockchains and distributed databases: A performance study,” Concurrency and Computation: Practice and Experience, vol. 32, no. 12, p. e5227, 2020.

[8] E. Safak, A. F. Mendi, and T. Erol, “Hybrid database design combination of blockchain and central database,” in 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT). IEEE, 2019, pp. 1–5.

[9] M. Raikwar, D. Gligoroski, and G. Velinov, “Trends in development of databases and blockchain,” in 2020 Seventh International Conference on Software Defined Systems (SDS). IEEE, 2020, pp. 177–182.

[10] X. Zheng, Y. Zhu, and X. Si, “A survey on challenges and progresses in blockchain technologies: A performance and security perspective,” Applied Sciences, vol. 9, no. 22, p. 4731, 2019.

[11] M. Niranjanamurthy, B. Nithya, and S. Jagannatha, “Analysis of blockchain technology: pros, cons and swot,” Cluster Computing, vol. 22, no. 6, pp. 14 743–14 757, 2019.

[12] S. Cohen and A. Zohar, “Database perspectives on blockchains,” arXiv preprint arXiv:1803.06015, 2018.

[13] K. Wüst and A. Gervais, “Do you need a blockchain?” in 2018 Crypto Valley Conference on Blockchain Technology (CVCBT). IEEE, 2018, pp. 45–54.

[14] Z. Ge, D. Loghin, B. C. Ooi, P. Ruan, and T. Wang, “Hybrid blockchain database systems: Design and performance,” VLDB Endowment, vol. 15, no. 5, pp. 1092–1104, 2022.

[15] H.-Y. Paik, X. Xu, H. D. Bandara, S. U. Lee, and S. K. Lo, “Analysis of data management in blockchain-based systems: From architecture to governance,” Ieee Access, vol. 7, pp. 186 091–186 107, 2019.

[16] P. Chitti, J. Murkin, and R. Chitchyan, “Data management: Relational vs blockchain databases,” in International Conference on Advanced Information Systems Engineering. Springer, 2019, pp. 189–200.

[17] S. Helmer, M. Roggia, N. E. Ioini, and C. Pahl, “Ethernitydb integrating database functionality into a blockchain,” in European Conference on Advances in Databases and Information Systems. Springer, 2018, pp. 37–44.

[18] M. E. Peck, “Blockchain world-do you need a blockchain? This chart will tell you if the technology can solve your problem,” IEEE Spectrum, vol. 54, no. 10, pp. 38–60, 2017.

[19] S. K. Lo, X. Xu, Y. K. Chiam, and Q. Lu, “Evaluating suitability of applying blockchain,” in 2017 22nd International Conference on Engineering of Complex Computer Systems (ICECCS). IEEE, 2017, pp. 158–161.

[20] N. A. Popova and N. G. Butakova, “Research of a possibility of using blockchain technology without tokens to protect banking transactions,” in 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus). IEEE, 2019, pp. 1764–1768.

[21] L. Tseng, X. Yao, S. Otoum, M. Aloqaily, and Y. Jararweh, “Blockchain-based database in an iot environment: challenges, opportunities, and analysis,” Cluster Computing, vol. 23, no. 3, pp. 2151–2165, 2020.

[22] A. Chaer, K. Salah, C. Lima, P. P. Ray, and T. Sheltami, “Blockchain for 5g: Opportunities and challenges,” in 2019 IEEE Globecom Workshops (GC Wkshps). IEEE, 2019, pp. 1–6.

[23] A. B. Pedersen, M. Risius, and R. Beck, “A ten-step decision path to determine when to use blockchain technologies,” MIS Quarterly Executive, vol. 18, no. 2, pp. 99–115, 2019.

[24] J. Golosova and A. Romanovs, “The advantages and disadvantages of the blockchain technology,” in 2018 IEEE 6th workshop on advances in information, electronic and electrical engineering (AIEEE). IEEE, 2018, pp. 1–6.

[25] O.Novo, Scalable Access Management in IoT Using Blockchain: A Performance Evaluation, 6, 4694-4701, 10.1109/JIOT.2018.2879679, 2019.

[26] M. Pawlak, A. Poniszewska-Marańda, N. Kryvinska, Towards the intelligent agents for blockchain e-voting system, Procedia Computer Science, Volume 141, ISSN 1877-0509, 2018 pp. 239–246.

[27] N. Dhanda, Cryptocurrency and Blockchain: The Future of a Global Banking System In Regulatory Aspects of Artificial Intelligence on Blockchain, 181-204. Hershey, PA: IGI Global, 2022.

[28] K. Christidis, M. Devetsikiotis, Blockchains and Smart Contracts for the Internet of Things. IEEE Access, 4, 2016, pp. 2292-2303.

[29] E. Zeydan, Y. Turk, S. B. Ozturk, H. Mutlu, A. A. Dundar, Post-Quantum Blockchain-Based Data Sharing for IoT Service Providers, IEEE Internet of Things Magazine, vol. 5, no. 2, 2022, pp. 96-101.

[30] Z. Kaspars, S. Renāte, Blockchain Use Cases and Their Feasibility, Applied Computer Systems, vol. 23, 2018, pp. 12-20. 10.2478/acss-2018-0002.

[31] M. Hajar, S. Cherkaoui, L. Khoukhi, An Overview of Blockchain and 5G Networks, Computational Intelligence in Recent Communication Networks. EAI/Springer Innovations in Communication and Computing, 2022 pp. 1-20.